EFFECTS OF SALINITY AND HIGH TEMPERATURE STRESS ON WINTER WHEAT GENOTYPES

by

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AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

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Abstract

Increased ambient temperature and soil salinity seriously affect the productivity of wheat (*Triticum aestivum* L.) which is an important cereal second to rice as the main human food crop. However, wheat plant is most susceptible to high temperatures and salinity at booting and flowering stages. Several studies have documented the effects of individual stress like salinity and high temperature stress on wheat, nonetheless little is known about effects of combined salinity and high temperature at critical growth stages. Therefore, the objectives of this research were (i) to screen winter wheat germplasm for salinity tolerance at the germination stages and to determine seedling growth traits associated with salinity tolerance, (ii) to evaluate the independent and combined effects of high temperature and salinity stress on winter wheat genotypes at the booting stages through growth, physiological, biochemical, and yield traits, and (iii) to evaluate the independent and combined effects of high temperature and salinity stress on winter wheat genotypes at the flowering stages through growth, physiological, biochemical, and yield traits. In the first experiment, 292 winter wheat genotypes (winter wheat germplasm) was screened for salinity stress at germination stage under controlled environments. The seeds were subjected to three levels of salinity, 0, 60, and 120 mM NaCl to quantify the effects of salinity on seed germination and seedling growth. In the second experiment, controlled environment study was conducted to quantity the independent and combined high temperature and salinity stress effects on growth, physiological, biochemical, and yield traits of twelve winter wheat genotypes during booting stage. Plants were grown at 20/15 °C (daytime maximum/nighttime minimum) temperature with 16 h photoperiod. At booting stages, the plants were exposed to optimum (20/15 °C) or high temperature (35/20 °C) and without (0 mM NaCl) and with (60, and 120 mM) NaCl. In the third experiment, plants were exposed to optimum or high temperature and with and without NaCl levels at flowering stages. The temperature regime

and salinity levels were same as experiment II. The duration of stress was 10 d and after the stress period the plants were brought to optimum temperature and irrigated with normal water (0 mM NaCl). The results indicated that, at 120 mM NaCl, the final germination percentage was decreased and the mean daily germination was delayed. Irrespective of the genotype, salinity stress significantly decreased the shoot and root length; seedling dry matter production, and seedling vigor. Based on the seedling vigor index, the genotype GAGE, OK04507, MTS0531, TASCOSA, ENDURANCE and GUYMON, were found to be most tolerant and CO04W320, 2174-05, CARSON, OK1070275, TX02A0252 and TX04M410211 were the most susceptible to salinity at germination stage. Combined stresses of high temperature and salinity decreased photosynthetic rate and grain yields. Based on grain yield, the genotype TASCOSA was found to be most tolerant (64 % decrease) to combined stresses, and AVALANCHE was the most susceptible to combined stresses (75 % decrease) at booting stages. Similarly, at flowering stage, TX04M410211 had greater tolerance to combined stresses (65 % decline) as compared to GAGE (83 % decline). In both experiments, tolerance was associated with higher spikelet number and seed set. In conclusion, there is genetic variability among winter wheat genotypes that can be used in breeding programs to improve winter wheat yield under combined high temperature and salinity stress conditions.

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Table of Contents

List of Figures

List of Tables

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Dedication

This dissertation is dedicated to my mother: Your prayers to god have been answered and to the

memory of my father and sister: You left fingerprints of grace on my life. You won't be forgotten.

Chapter 1 - Literature Review

Importance of the Wheat Crop

Wheat (*Triticum aestivum* L.) is the world's most widely grown cereal crop and is a food staple (Carte, 2002). Wheat is a widely adapted crop and is grown from moderately irrigated to dry and high rainfall areas and from temperate, humid to dry and cold regions (Dubcovsky et al., 2007). The origin of wheat is thought to date back more than 10,000 years ago and has since spread worldwide to become a major crop (Dubcovsky, 2007). There are different species of wheat, however, the most extensively cultivated one is common wheat or *Triticum aestivum* (Cooper, 2015). Global wheat production in 2015 was forecasted to be at about 735 million tones worldwide, and the world trade for wheat in 2015-16 was forecasted to be150 million tones (FAO, 2015). Approximately 95 % of the wheat crop is common wheat, which is used for making bread, cookies, and pastries, and 5 % is durum wheat, used for making pasta and other semolina products (Oleson, 1994; Dubcovsky et al., 2007). Global production in 2016-17 is projected to increase due to increased acreage and production from several countries including Argentina, Australia, Canada, Russia, Serbia, Ukraine, and the United States (FAO, 2015).

With more than 700 million tons produced annually worldwide, wheat provides about 21 % of the calories consumed by humans (Nechaev and Gaponenko, 2013.). Like all grains, wheat has two critical components, which are carbohydrates and proteins, the two important sources of energy for the human body. Wheat has the highest protein content of all the cereal grains (McCance et al., 1945; Cooper, 2015). Wheat starch itself is considered to be an important commercial by-product of wheat, and second in economic value to wheat gluten (Cooper, 2015). Moreover, wheat foods are a good source of vitamins such as thiamine (vitamin B1) and other B vitamins as well as vitamin A. Wheat also contains large amounts of fibers, minerals, fats, and other bioactive

compounds that have been used as drugs for millennia. Wheat is mainly grown for use in human food production; however, it is used as an animal feed including an additive to pet foods (Spragg, 2008). Wheat bran is rich in total antioxidant compounds, which play a big role in the health benefits because of their antioxidant activity (Gao, 2002). Industrial uses of wheat grain include starch for paste, alcohol, oil, and gluten. The straw was used for making newsprint, paperboard, and other products (Spragg, 2008). Wheat is also used for ethanol and bio-fuel production (Hazzledine et al., 2011).

The world population has grown tremendously over the past two thousand years. In 1999, the world population passed six billion (Kirkham, 2005). The latest official current world population estimate, for mid-year 2016, is estimated to be about seven billion (7,432,663,275) (http://www.worldometers.info/world-population). Over the next four decades, the world's population is forecasted to increase by an additional 2-4 billion people, and it will exceed 9 billion people by 2050 (Cohen, 2003). Recent FAO estimates specify that, to meet the expected demand, global agricultural production has to be increased by 60 % from its current level (Barnes and Shields, 1998; FAO, 2013). With wheat, maize, and rice leading the way, the Green Revolution reduced poverty and increased grain availability for consumption. Most of the calories that made that increase possible have come from these three crops. The oldest, most widespread and, until recently, the biggest of the three crops, is wheat (Hafner, 2003).

Global wheat production is projected to be the same as for 2015 about 735 million tons in 2016-17 (FAO, 2013; FAS, 2016). Currently, about 65 % of the wheat crop is used for food, 17 % for animal feed, and 12 % in industrial applications, including biofuels (Oleson, 1994; FAO, 2013). To meet demand, the world's farmers will have to produce 40 % more grain in 2020. Most of the increase in world wheat production has to result from greater yield per hectare (Curtis, 2002). Both

genetically improved cultivars for yield and better cultural methods have contributed to the yield increases in the past (Oleson, 1994). Yield stability has increased substantially across environments largely due to the adoption of management responsive, high yielding, disease resistant semi-dwarf wheat cultivars throughout much of the world, particularly in developing countries. Improved agronomic practices play an equally important role in enhancing the dependability and sustainability of yields (Curtis, 2002).

The important wheat producing countries of the world are the United States, China, and Russia; however, significant production also comes from India, Europe, Canada, Argentina, and Australia. China has the largest land area devoted to wheat production, and then comes the United States, India, and Russia (Curtis, 2002). In developing countries, increments in wheat productivity gain is slowing, because varietal replacement has slowed compared to initial adoption. In addition, environmental factors limit wheat production in developing countries (Heisey, 2002).

Botany of the Wheat Plant

Wheat (*Triticum sp*.) is a cereal and a member of the family Poaceae (formerly called the Gramineae family). This family also includes important cereals such as rice, rye, corn, sorghum, and barley (Peterson, 1965). Wheat is an herbaceous annual plant. The cultivated plant is green when young, turning to golden-yellow as it matures. The plant has two forms of roots, the seminal roots and the nodal roots (adventitious roots), which arise from the lower nodes of the shoot (Kirby, 2002). Wheat has a single main stem (culm) in addition to 2-6 tillers per plant. The stems are vertical and have a structure of cane, which means that they are hollow inside except at the nodes; however, some species have varieties with solid stems (Peterson, 1965). The leaves grow from

each node and include a leaf sheath that wraps around the stem and a leaf blade. Wheat has small auricles and these wraps around the stem at the point where the leaf sheath meets the leaf blade (Peterson, 1965). Flowers are grouped in spikes (also called the ear or the head). A spike forms at the top of the plant, and it usually has 35-50 grains (Kirby, 2002). Each spike consists of a main axis from which some filaments arise terminated by the glumes that enclose the flowers until they begin to mature (Shitsukawa et al., 2009). Wheat flowers do not have petals or sepals. Each female flower consists of an ovary from which two styles emerge, and it has two feathery, sticky stigmas. Male flowers have three stamens that can be gold, green, or violet (Peterson, 1965). Wheat spikes are from two to eight inches (5 to 20 cm) long and bear from 20 to 50 kernels. Each kernel is protected by a pair of scale-like leaves, called glumes (Shitsukawa et al., 2009). A wheat grain typically weighs 30-66 mg (Gooding et al., 1997) depending on the variety and growing conditions. The kernel is made up of several layers of bran, forming a tough outer coat, the aleurone layer, rich in proteins and minerals; it also includes the endosperm that is mostly starch, but also contains proteins, and the embryo (Peterson, 1965).

Types and Classes of Wheat

From the primitive variety of wheat (*Triticum vulgaris*) have developed different species, classes, and varieties that may be classified into many types of wheats. Now they are classified into groups depending on their genetics, growing habit, and grain quality.

From a genetic view, there are three varieties of wheat:

1- **Diploid varieties**: They have two sets of chromosomes in each cell. These varieties include species such as einkorn (Macdonald, 1994).

2- **Tetraploid varieties**: They have four sets of chromosomes in each cell. These varieties include species like *Triticum turgidum* that belong in the durum group (Macdonald, 1994).

3 - **Hexaploid varieties**: They have six sets of chromosomes in each cell. In this group there are species like *Triticum aestivum* or *Triticum spelta* (Macdonald, 1994).

Depending on grain quality, wheat is classified into two groups:

1- **Soft wheat**: It is a group which includes some wheat varieties in which the protein matrix does not adhere to the starch granules tightly. These varieties are destined essentially to make cakes and biscuits. The most abundant species within this group is the common wheat, *Triticum* aestivum. Soft wheat is grown mainly in warm and temperate regions. The grains, when broken open, show a difference in texture between the edge, which is harder, and the center, which is starchier. Their content in starch, fat, iron, phosphorus, and vitamin B is higher than in durum wheat (Oleson, 1994).

2- **Hard wheat:** It is a group which includes some wheat varieties in which the protein matrix adheres tightly to the starch granules and milling causes breakage of the starch granules. It is grown in drier areas. It has hard grains and the appearance of the interior of the grain, when it is broken, is crystalline and uniform. It features a greater proportion of protein (gluten), water, and calcium than soft wheat. Varieties of hard wheat are most widely used for the production of bread (Oleson, 1994).

Based on growing habit or growing conditions wheat can be classified into two groups:

1- **Winter wheat:** They are wheats that are planted in the fall and harvested at the beginning of summer (Macdonald, 1994).

2- **Spring wheat:** They are planted in the spring and harvested in late summer. They are planted in cooler places (Macdonald, 1994).

3- **Facultative wheat:** which can be grown as either winter or spring planted. They typically lack strong winter hardiness and are grown in regions where there are less harsh winters (Braun and Sãulescu, 2002).

Based on grain color wheat can also be classified into two groups:

1 - **Red wheat:** They show a red coloration, due to their tannin content.

2 - **White wheat:** They are amber, because the alleles for grain color do not expressed the reddish tannin pigments. (Oleson, 1994).

Growth and Developmental Stages of Wheat Plant

Wheat plant development is classified into three broad phases: the seed germination and seedling establishment phase; the vegetative phase; and the reproductive and maturity phase (Hossain et al., 2012). There are at least five scales commonly used worldwide to describe the developmental stages of the wheat plant. The most commonly used scales are the Zadoks, Haun, and Feekes. The Feekes scale is the most popular scale used in the U.S.; however, the Zadoks and Haun scales are more descriptive (Miller, 1992).

Zadoks Growth and Developmental Stages Scale:

Zadoks growth scale is a 0-99 scale follows plant development, which based on ten principal cereal growth stages (first digit). Each primary growth stage is divided into 10 secondary stages (second digit), extending the scale from 00 to 99.

1.   **Germination stage (GS 00 – 09):** Adequate temperature and moisture are needed for wheat seeds to germinate. Minimum moisture for germination in wheat is 35 to 45% of kernel dry weight (Evans et al., 1975). At germination the seminal root extends first, followed by the coleoptiles. Adventitious roots are produced in association with the coleoptile node. When the coleoptiles emerge from the soil, their growth stops so the first real leaf pushes through its tip (Kirby, 2002). Under favorable conditions, seedling emergence occurs within seven days. Until the first leaf becomes functional, the seedling depends on energy and nutrients stored in the seed (Evans et al., 1975).

2.   **Seedling stage (GS10 – 19)**: After germination the vegetative shoot apex initiates additional leaf primordia. The seedling stage begins with the appearance of the first leaf and ends with the emergence of the first tiller (Kirby, 2002). Up to six seminal roots and three leaves support the plant at this stage. The crown of the plant usually becomes noticeably distinct after the third leaf has emerged (Kirby, 2002).

3.   **Tillering stage (GS20 – 29):** It begins with the emergence of lateral shoots from the axils of the true leaves at the base of the main stem of the plant. The tillers are formed from the auxiliary buds located at each crown node. Crown formation is soon followed by the appearance of tillers and development of a secondary or crown root system. The crown root system provides the plant with nutrients and water (Evans, 1975). At the base of each tiller is a sheath (small leaf like structure) called the prophyll, from which the tiller leaves emerge. Tillers depend on the main stem

for nutrition during their development. Once a tiller has developed three or more leaves, it becomes nutritionally independent of the main stem and forms its own root system (Evans, 1975).

4.   **Stem elongation stage (GS30 – 39):** At stem elongation, the stem nodes and internodes appear above the soil surface and become visible. During the tillering stage, the nodes from which leaves expand are telescoped at the crown (Miller, 1992). The beginning mark of stem elongation is called jointing. As jointing starts, the internal node region extends, moving the nodes and the growing point upward from the crown to create a long rigid stem that carries the head . This synchronizes the start of the stem elongation stages of the main stem and tillers. The spike at this stage is fully differentiated, containing all potential spikelet and florets or seed forming branches (Miller, 1992).

5.   **Booting stage (GS40 – 49):** Throughout the booting stage, the head of the wheat develops and becomes visible below the sheath on the stalk. At this stage the flag leaf's ligules are visible and the leaf has totally emerged from the spiral. The leaf sheath extends and the head begins to enlarge (Miller, 1992). Also in this stage the head develops and becomes visible in the leaf sheath directly below the flag leaf. Booting stage ends when the tips of the head, called awns, begin to emerge (Miller, 1992).

6.   **Heading stage (GS50 – 59):** As the stem continues to elongate, the head is pushed out of the flag leaf sheath, which is the beginning of the heading stage. The heading stage begins when the tip of the spike or the head can be seen rising from the flag leaf sheath, and emergence goes on until the head completely appears (Miller, 1992).

7.   **Anthesis stage (GS60 – 69):** Just after the wheat head has completely emerged, the anthesis stage (flowering) occurs. Commonly, flowering in wheat begins within three or four days after head emergence (Miller, 1992; Peterson, 1965). Once flowering begins, pollination will be

complete in about four or five days. Wheat is self-pollinating. Most florets are pollinated before anthers are extruded (Miller, 1992). Pollination begins in the head, starting first with the florets in the central spikelet. Within the next few days flowering progresses both up and down the spike (Miller, 1992).

8.   **Grain milk stage (GS70 – 79):** After anthesis, grain filling stages starts, this stage is known as the period during which the kernel matures. Pollination occurs within a few hours, and then the embryo and endosperm begin to form and photosynthetic products are transported to the maturing grain from the leaf. Also, starches, proteins, and all other compounds earlier produced and stored in leaves, stems, and roots are relocated to the maturing grain (Peterson, 1965). In this stage the kernel quickly increases in size; however, it does not gather much dry matter (Miller, 1992). During the milk stage, white milk-like liquid can be squeezed from the kernel. By the end of the milk stage, the embryo is fully formed (Peterson, 1965).

9.   **Grain dough stage (GS80 – 89):** In this stage the kernel rapidly gathers starch and other compounds, and, by the end of this stage, the green color begins to fade. Most of the kernel dry weight has accumulated by this stage. In addition, the kernel becomes solid and hard. This is because the kernel's moisture content decreases. At the end of the dough stage, the kernel reaches its highest dry weight (Peterson, 1965).

10. **Ripening stage (GS90 – 99):** When wheat begins to ripen, the kernel's moisture decreases rapidly. The kernel becomes very hard, and the plant turns to a straw color. Harvest can begin when the grain has reached a suitable moisture level (Peterson, 1965). Grain is best harvested at 14 % moisture content (Miller, 1992).

Importance of Environmental Factors on Wheat Productivity: Temperature and Salinity

Crops are influenced by many climatic and environmental factors, which can be abiotic and biotic factors. They respond directly to changes in temperature, carbon dioxide (CO_2), water, light intensity, the condition of the soil, and so on. Climatic change due to greenhouse gas emissions is predicted to increase the mean global temperature by 1.0 to 2.7 °C in the next 100 years. Some parts of the world are likely to experience higher temperature increases than the global average (IPCC, 2013). The rate of change of global average temperature projected for the 21st century is in the range of 0.15–0.6 °C per decade, which is much larger than any rates of change the climate has experienced for at least the past ten thousand years (Houghton, 2005). Climate change is expected to result in long-term shortages of water and other resources, poor soil conditions, drought and desertification, disease and pest outbreaks on crops, and sea-level rise (Kurukulasuriya, 2003). Recent growth in agricultural production has been uneven. In many regions, climate change has brought irregular weather patterns such as rising temperatures, violent storms, higher atmospheric CO_2 concentrations, increasing water and or soil salinity, and flash flooding. These changes can either increase or decrease plant production (Ludwig and Asseng, 2005; Porter and Semenov, 2005).

Abiotic stresses generally have negative impacts on plant growth and development, and thus decrease plant yield. In the field, crops are normally exposed to a combination of one or two or multiple abiotic stresses. Critical abiotic stresses that crops are commonly exposed to include drought, high temperature, salinity, and lack of nutrients. The most widespread stresses have in common their effect on plant water status. Water availability is a critical factor in determining the impact of climate change in many places (Kurukulasuriya, 2003). Plant species differ in their

sensitivity and response to the decrease in water potential caused by drought, high and low temperature, and high salinity. Water stress may affect plants by limiting their growth and productivity (Bohnert, 1995) . The three variables that have a large impact on plants, in general, are rainfall change, temperature change, and increase of atmospheric CO_2 concentration. The information regarding the combined effects of changes in precipitation, temperature, and atmospheric CO_2 concentration on wheat yield are limited. Studies have shown that drought is the most influential aspect in low rainfall areas (Trethowan and Pfeiffer, 1999).

Climate change factors could strongly affect the wheat crop that accounts for 21 % of food and 200 million hectares of farmland worldwide (Ortiz, 2008). Climate-change induced temperature increases are likely to reduce wheat production in developing countries by 20–30 % (Andersen et al., 1999; Asseng et al., 2015). Some studies found that global warming, as a result of climate change, may negatively affect wheat grain yields potentially increasing food insecurity and poverty; even though the magnitude and direction of climate impacts on crop yields will vary locally (Tubiello, 2000). High temperature has negative impact on change in average grain yield (Nicolas et al., 1984; Wheeler et al., 1996; Modhej et al., 2008; Narayanan et al., 2015). A recent study showed that global wheat production is estimated to fall by 6 % for each degree centigrade of further increase and become more variable in space and time. In other words, projected changes in future temperature and precipitation will negatively influence wheat yields (Tubiello, 2000).

To cope with environmental stresses, plants can develop adaptation strategies. There are two distinct strategies used by plants to deal with different abiotic stresses. The first strategy is stress avoidance, which allows the plant to avoid the exposure of plant systems to the stress factors by excluding those factors or their effects from plant systems. The second strategy is stress

tolerance, which is the ability of the plant to sustain plant function with the presence of stressed conditions (Touchette et al., 2007).

Dehydration avoidance is defined as the plant's capacity to maintain a fairly high leaf water potential under conditions of water stress. Plants have a number of defense mechanisms against water stress. The first plant response to water stress is to avoid low water content and low water potential and keep a balance between water uptake and water loss via transpiration. The way that plants achieve this is by increasing water uptake and reducing water loss via evapotranspiration. This requires stomatal closure, a thick cuticle, and an increase in the root system to reach and absorb more water. When transpiration is reduced, the water potential of the plant will be maintained as long as water in the soil is available for plant uptake. Under low soil water content, water potential of the soil will decrease and so does plant water potential. However, the plant has mechanisms to avoid the lowering of water potential by accumulation of solutes and cell wall hardening. Increasing the concentration of solutes leads to a decrease in water potential in plant cells as compared to the surrounding medium, and this results in water moving from the soil or surrounding medium (high water potential) into plant cells (low water potential). Also, leaf movements, leaf shedding, and leaf orientation are common responses to water stress in plants (Morgan, 1984; Touchette et al., 2007). By leaf movements, plants can decrease the amount of sun radiation that their leaves capture. Leaf movements give plants the ability to decrease the surface area by folding and /or rolling the leaf. The benefit of leaf rolling is to reduce the damage caused by increased leaf temperature, which results from solar radiation incident on leaf surfaces. With leaf rolling, less radiation is intercepted by leaf tissue. Another way that plants may benefit from leaf rolling is the reduction in transpiration rates. As the leaf is rolled up, it has a reduction in the surface area that transpires and, therefore, water loss by transpiration is reduced. In addition, some

plant species respond to water stress by changing leaf anatomy and structure, and these adaptation include reduction in leaf area, decrease in the number of stomata; thickening of leaf cell walls, waxing of leaf surfaces, and increasing root systems. Another mechanism that plants use to avoid dehydration is the production of abscisic acid. Dehydration stress causes loss of water from leaves, and this causes a loss of turgor in guard cells which induces the production of abscisic acid. Abscisic acid also accelerates the loss of stomatal turgor and leads to stomatal closure to reduce water loss. The increased stomatal resistance under stressed conditions helps a plant keep water. Dehydration tolerance strategies, such as osmotic adjustment and cell wall elasticity, are important mechanisms that some plants use to tolerate stressed condition (Touchette et al., 2007).

Dehydration tolerance usually involves the development of low osmotic potentials. Many plants have the ability to withstand dehydration stress by physical changes within the plant body and commonly by creating signals for changing metabolism. Major tolerance mechanisms that plant employ involve changes in membrane lipid composition, ion transporters, proteins, and antioxidants (Srivastava et al., 2012). In addition, accumulation of solutes such as proline, glutathione, glycine betaine, mannitol, fructose, sucrose, raffinose, and polyamines in plants cells results in tolerance to stresses (Krasensky and Jonak, 2012). Maintenance of turgor by osmoregulation is an important tolerance response to dehydration stress (Morgan, 1984). This increase of solutes in plant cells leads to a decrease in the osmotic potential and leads to higher water absorption by plant roots. Studies on some plants, including strawberry and black spruce, reported that plants showed a tolerance mechanism to water stress based on high elasticity of plants tissues (Blake et al., 1991; Save et al., 1993), and they suggested that tissue elasticity was more important for turgor regulation than osmotic adjustment (Blake et al., 1991). Also, abscisic acid

induces the expression of some drought tolerance related genes such as late embryogenesis abundant (*LEA*).

In general, to cope with abiotic stresses, plant responses include changes in morphological, physiological, biochemical, and molecular processes that decrease a plant's stress exposure and/or limit damage and facilitate recovery (Potters et al., 2007). At the morphological and anatomical level, a plant response includes three components: inhibition of cell elongation, localized stimulation of cell division, and alterations in cell differentiation status. Also changes in anatomical characteristics of plant organs such as roots, xylem, and leaves contribute to adaptation of the plant to critical environmental conditions. At the physiological level, phytohormones play significant roles in abiotic stress tolerance. At the biochemical level, biosynthesis and accumulation of osmoprotectants, antioxidant enzyme activation and synthesis of antioxidants, and synthesis of polyamines are the mechanisms of stress tolerance (Rathinasabapathy, 2000) and at the molecular level, many genes are induced by abiotic stress. Products of those genes may function in stress response and tolerance at the cellular level. Natural stress tolerance is a very complex process involving several metabolites and metabolic pathways (Krasensky and Jonak, 2012).

High Temperature Stress

Temperature is an important factor controlling plant growth and development. Temperatures above the optimum are identified as high temperature (heat) stress by all living organisms. Most plants function has relatively narrow range of temperatures window. The extremes of this range may be considered killing frosts at about 0 ºC and death by heat and dehydration at about 40 ºC. In fact, each plant species grows and develops most rapidly at a favorable range of temperatures. This is

called the optimum growth temperature range. For most crops the optimum functional efficiency occurs mostly between 12 and 25 ºC (Went, 1953; Abrami, 1972).

As a cool season crop, wheat grows best when temperatures are in a range of 21 to 25 °C; however, it requires different temperatures at different stages of plant growth and development. In wheat, the optimum temperature for wheat germination is between 12 and 25 °C, but germination will occur between 4 °C and 37 °C. At a temperature below or above the optimum temperature, germination of the seed decreases (Bowden et al., 2008). A temperature between 20-25 °C is the ideal for vegetative and reproductive growth. The optimum temperature for wheat anthesis and grain filling stages ranges from 12 to 22 °C (Farooq et al., 2011). During reproductive development, temperature extremes beyond the optimum range affect development, photosynthesis, and the reproductive parts. High temperature during the reproductive and grain filling stage is one of the main causes of yield loss in wheat (Farooq et al., 2011). Temperatures above 30 °C during floret formation cause complete sterility (Saini and Aspinall, 1982). Table 1 shows the critical temperature for each process and stage of wheat growth and development.

As a result of climate change, global temperature has increased and is predicted to increase in the near future in most of parts of the world. (IPCC, 2013). Scientists expect that an increase in average temperatures worldwide will lead to more frequent and extreme heat events. The change will vary with regions. The projection is that changes will be highest in the high latitudes of the northern hemisphere and that they will be significantly higher over land than over oceans. Increasing global temperatures will impact negatively the whole ecosystem. High temperature stress affects almost 7 million ha of wheat in developing countries, and terminal heat stress is a problem in 40 % of temperate environments, which cover 36 million ha (Reynolds et al., 2001).

Effects on Physiological and Biochemical Processes

Temperature plays an important role on plant growth and physiology. Plant growth and development include several biochemical reactions that are sensitive to temperature. Also, many physiological processes are regulated by temperature such as evapotranspiration and water stress (Ritchie, 1972), cold hardening (Hurry et al., 1995), vernalization (Brooking, 1996), leaf formation and leaf senescence (Miglietta, 1989), and photosynthesis and respiration (Evans and Rawson, 1969; Azcon-Bieto and Osmond, 1983). High temperature stress affects the stability of many proteins, membranes, and RNA species and alters the efficiency of enzymatic reactions in the cell, which affect all major physiological processes, and these changes create metabolic imbalance (Hasanuzzaman et al., 2013). Increased temperature may affect water availability to the plant so that crop water requirements will increase with increased temperature (Simoes-Araujo et al., 2003). This will affect physiological processes of plants. Some researchers tried to find out which developmental stage is the most affected by high temperature stress. They showed that photosynthetic capacity decreases rapidly when temperate species are exposed to high temperature stress during reproductive development, and they concluded that high temperature initially accelerated thylakoid membrane breakdown, an effect similar to normal senescence patterns (Harding et al., 1990; Djanaguiraman et al., 2011; Pradhan et al., 2012a). The effect of high temperature on higher plants is primarily on photosynthetic functions, and thylakoid membrane is highly susceptible to high temperature. A study by Weis and Berry (1988) indicated that CO_2 assimilation may be limited, in part, at high temperature by an imbalance in the regulation of carbon metabolism, which is reflected in a down regulation of ribulose-1, 5-bisphosphate carboxylase/ oxygenase. Also high temperature decreases leaf chlorophyll content and accelerates senescence (Zhao et al., 2007; Pradhan et al., 2012a). A decrease of chlorophyll content is

generally attributed to membrane damage and leaf senescence (Simon, 1974). High temperature stress decreased the photosynthetic rate because of ultrastructural damage to chloroplasts, mainly breakdown of chloroplasts and the plasma membrane coupled with dilation of the thylakoid membrane. Research on the impact of high temperature at the post anthesis period showed that a high temperature in the post anthesis period inhibits biomass production by promoting leaf senescence and reducing radiation use efficiency, and the failure of the assimilate to supply grains plays a dominant role in lowering grain yield in spring wheat subjected to a high temperature (Acevedo et al., 2002; Kobata et al., 2012). In addition, one of the major consequences of high temperature stress is the excess generation of reactive oxygen species (ROS) such as accumulation of singlet oxygen, the superoxide radical, hydrogen peroxide, and the hydroxyl radical, which leads to plant oxidative stress (Hasanuzzaman, 2012; Narayanan et al., 2015).

Effects on Growth and Yield

High temperature stress is one of the major abiotic stresses limiting the growth and development of cool-season plants. High temperature stress is defined as the rise in temperature beyond a threshold level for a period of time sufficient to cause permanent damage to plant growth and development (Wahid et al., 2007). In general, crops usually grow more quickly in higher temperatures, which will create a shorter growing season and less time to produce grains. Because high nighttime temperatures increase the respiration rate, it reduced growth and yields of crops (Narayanan et al., 2015). Many studies found that high temperatures severely limit plant growth and yields (Prasad and Staggenborg, 2008; Prasad et al., 2008; Pradhan et al., 2012b; Hatfield and Prueger, 2014; Narayanan et al., 2015). Also a study of maize showed that a decreasing diurnal temperature amplitude increased leaf night respiration rate, which resulted in decreased carbohydrate content and a decrease in overall biomass accumulation (Sunoj et al., 2016).

The effects of increased temperature on plant growth depend on the location, so that an increasing temperature for crops that grow in cold regions may result in increased yields, which is not the case with crops that grow in warmer regions. That means increasing temperature will lead to decreased yields in those places, whereas change in cropping systems or a change in planting dates and selection of tolerant varieties may be needed to avoid high temperature events. Some studies also have reported that high temperature is a major determinant of wheat development and growth. For instance, one study by Gibson et al. (1999) found that yields decreased by 3 to 5 % per 1 °C increase above 15 °C in plants under controlled conditions. Under high temperatures, wheat plants tend to alter the phenological duration of different stages and the whole life period is reduced. This leads to reduced germination period, days to booting, days to anthesis and maturity and shorter grain filling periods, which negatively affect yield components (Nahar et al., 2010). High temperature affects plant growth and development at all growth stages. The germination stage is very sensitive to high temperature. It may result in reduced germination percentage, low germination rate, reduced plant emergence, abnormal seedlings, decreased seedling vigor, reduced root and shoot growth of germinated seedlings, and reduced dry matter production (Wahid et al., 2007; Kumar et al., 2011; Iloh et al., 2014). Also, high temperature stress during germination to emergence results in seedling mortality and a poor crop stand (Acevedo et al., 2002). However; high temperatures occur frequently during reproductive growth of temperate species and strongly influence many plant processes during the reproductive stages. A recent study found that pollination is one of the most sensitive stages to high temperature across all species and during this developmental stage high temperature will significantly affect fertilization. The same study concluded that the major impact of high temperatures is during the reproductive stages of development, and, in all cases, grain yield is significantly reduced by temperatures that do not fall

within the optimum range 80–90 % of the time (Hatfield and Prueger, 2014). Many studies also found that yield and yield components are highly affected by high temperatures (Ferris et al., 1998; Lobell et al., 2005; Rahman et al., 2009; Kumar et al., 2011; Kobata et al., 2012). The grain filling stage is very sensitive to high temperature, and, when it occurs at this stage, yield reduction is great (Rahman et al., 2009; Kobata et al., 2012). In regard to the most sensitive development stages of wheat, Prasad and Staggenborg (2008) reported that the most sensitive stages of development to high temperature stress are generally during panicle development and during flowering. Another study suggested that, since high temperature periods appear to be more severe around anthesis, they may affect pollination processes (Prasad et al., 2011) and seed-set set are found to be the most sensitive stages (Prasad et al., 2008; Narayanan et al., 2015).

Recent study on wheat to quantify the impacts of short episodes of high temperature stress and to identify the sensitive stages and thresholds for temperature and duration of temperature was conducted. . The results showed that two periods (first at 6 to 8 d before anthesis and second at 0 to 2 d before anthesis) during reproductive stages of development were most sensitive to short episodes (2 or 5 d) of high temperature stress (Prasad and Djanaguiraman, 2014). They also observed that short episodes (5 d) of mean daily temperatures > 24 °C imposed at start of heading quadratically decreased floret fertility, with the values reaching close to zero around mean daily temperature of 35 °C. The floret fertility and individual grain weight decreased linearly with increasing duration (in the range from 2 to 30 d) of high temperature stress when imposed at start of heading or start of grain filling, respectively. The combination of lower floret fertility (leading to decreased grain numbers) and decreased individual grain weight can cause decreases in grain yield under high temperature stress.

Some studies concluded that grain set is reduced by temperatures warmer than 30 °C during the period from the onset of meiosis in the male generative tissue to the completion of anthesis (Smika and Shawcroft, 1980; Ferris et al., 1998). Many researchers found that high temperature accelerates the increase in grain dry weight, but shortens the grain filling period which causing a yield reduction. The acceleration of the increase in grain dry weight cannot compensate for the shortening of the grain filling period, and the reduction in yield is primarily caused by a failure of the sink function (Nicolas et al., 1984; Wheeler et al., 1996; Dupont and Altenbach, 2003; Zahedi and Jenner, 2003; Prasad et al., 2006; Modhej et al., 2008; Pradhan et al., 2012b). Wheat grain yield and flour quality are strongly influenced by the effects of environment during the grain filling period (Labuschagne et al., 2009). Temperature influences the rate and duration of wheat grain development, protein accumulation, and starch deposition in unique ways and by different mechanisms (Nicolas et al., 1984; Dupont and Altenbach, 2003; Zahedi and Jenner, 2003; Labuschagne et al., 2009). Recent studies have been done to address the effect of high temperature on different genotypes of wild wheat (*Aegilops* species), and they showed that high temperature at the late grain filling period decreased yield of wild wheat, and the decrease in yield was mainly due to a decline in individual grain weight. This study revealed that high temperature decreased leaf chlorophyll by 38 % due to electrolytic leakage from thylakoid membranes. The same study found that high temperature decreased grain yield per plant by 70 % (Pradhan et al., 2012a). Other studies have suggested that different genetic traits responded differently to temperature stress (Prasad and Staggenborg, 2008; Rahman et al., 2009; Laghari et al., 2012).

Response to High Temperature Stress

Each plant species has its own optimal temperature for growing, and its distribution is determined to some extent by the temperature range in which it can survive and function. Also, genotypes

may vary in their responses to high temperature stress (Asthir et al., 2012). Wheat is widely grown

cereal in temperate and tropical environments, where it is often grown as the winter season crop

in rotation with a number of other crops (Reynolds et al., 2001). It is grown under a wide range of

environmental conditions where climatic factors such as temperature, drought, and light combined

with cropping practices, such as fertilizer and irrigation practices, have different effects on plant

growth and development. However, plant response to high temperatures varies with variation of

temperatures, duration of exposure, crop growth stages, and the level of crop tolerance. Under field

conditions, it may be possible to regulate some environmental stresses, but air temperature is

impossible to regulate. Hence, breeding for high temperature tolerance is needed. High

temperature tolerance is an essential characteristic for crop production worldwide. Developing

high productivity genotypes that are tolerant to high temperatures will be very important to

improve crop production. However; under field condition, effects of high temperature are often

confused by the effects of drought stress. It is also possible that crops face combined effects of

high temperature and drought at the same time (Pradhan et al., 2012b). Plants have a number of

tolerance and avoidance mechanisms to deal with high temperature stress situations. To cope with

the high temperature stress in many plants, they synthesize some proteins known as heat shock

proteins. These proteins provide protection and repair the cellular damage caused by high

temperatures (Mitra and Bhatia, 2008). Major tolerance mechanisms that plants employ are

changes in membrane lipid composition, ion transporters, proteins, and antioxidants (Srivastava el

al., 2012; Narayanan et al., 2015). In term of morphological and anatomical defense, plants adapt

to high temperature by transpiration cooling, increasing root growth, decreasing leaf area, or even

narrowing the leaf, changing the leaf direction, and developing leaves with thick wax coatings on

the surface (Pandey et al., 2015). In semi-arid regions considerable increases in day temperature

during the period from anthesis to ripening of wheat are common (February to April). However it can also often increase risk of freeze and frost damage in many areas. Therefore, planting dates would be one way to avoid high temperature stress as well as low temperature stress. Other agricultural practice can be used to minimize high temperature stress, and they could be important ways to increase yield in these environments. These practices include planting date, seeding rate, fertilizer application, and water supply.

Salinity Stress

Salinity is a major factor reducing plant growth and productivity throughout the world. The FAO expects that over 800 million ha will be affected by salinity in the near future, and it considers salinity as a major limitation to food production for an increasing population (Rengasamy, 2006; FAO, 2008). The exact extent of salt affected soils is unknown due to absence of updated information. However, based on Pessarakli and Szabolcs, as cited in Behnassi et al. (2013), around 954.8 million ha of land has salt affected soils worldwide. It is important to produce more crops that require effective utilization of salt affected land and saline water resources. Qadir et al. (2008) reported that at least 20 % of the world's irrigated land is salt affected and/or irrigated with saline waters. In addition, about two million ha of cropped land are deteriorating because of salinity every year (Rengasamy, 2006; Tuteja, 2007). As a result of increased salinization of agricultural land, it is projected that about 50 % of cropped land will be lost by the middle of the 21st century (Wang et al., 2007). In arid and semi-arid regions, high temperatures during the summer season cause severe evaporation losses, which leaves behind large amounts of salts. However, the problem exists even in some of the world's sub-humid and humid regions, especially in coastal areas.

The term salinity refers to the presence of the major dissolved inorganic solutes (essentially Na^+, Mg^{2+}, Ca^{2+}, K^+, Cl^-, SO_4^-, HCO_3^-, NO_3^- and CO_3^-) in water and soil (Bernstein 1975; Tanji, 1990; Rhoades et al., 1999). The relationships of these salts to each other as well as other ions are important and may differ greatly at different sites. A salinity problem occurs when salt accumulates in the crop root zone to a concentration that causes a loss in yield (Francois et al., 1999). In irrigated areas, these salts often come from a saline, high water table or from salts in the applied water and they are prevalent with a shallow water table. Irrigation is considered to be an important sources of salinity (Munns et al., 2004; Plaut et al., 2013). This is because irrigation water transports additional salts and releases immobilized salts into the soil through mineral dissolution and weathering. Also water lost through evapotranspiration will concentrate the dissolved salts in the soil solution (Gupta et al., 1990; Plaut et al., 2013; Francois et al., 1999). Naturally founded salty soils also are a major cause for salinity. Salty soils are most found where rainfall is fairly low and in coastal regions where salty water has entered the soil or salt spray has been absorbed by plants and soil (Tanji, 1990). However, even in regions with sufficient rainfall, salt can accumulate in a soil with poor drainage. Another source for soil salinity is substantial use of fertilizers (Plaut et al., 2013). Atmospheric salt deposition, especially in coastal regions, is an important source for salinity in soils (Gupta et al., 1990). The relative impact of each source in contributing soluble salts depends on the natural drainage conditions, soil properties, water quality, soil water content, and cropping systems and management practices used for crop production (Tanji, 1990). When soils have the problem of excessive soil moisture in addition to high levels of soluble salts in the root zone, plant growth is either limited or totally prevented (Gupta et al., 1990). Salinity affects crop plants in three major ways: (1) osmotic stress, decreasing water availability; (2) ionic stress, causing ion homeostasis; and (3) changes in the cellular ionic balance, which in turn leads to

deficiency and/or toxicity of some nutrients (Kirst, 1989; Ahmad et al., 2010; Azooz et al., 2011; Carillo et al., 2011). Saline water has a low osmotic potential that results in decreased availability of water to root cells, which, in turn, exposes the plant to secondary osmotic stress. All the physiological responses that are the result of water deficit stress can also be observed under salinity stress (Qadir et al., 2008).

Effects on Physiological and Biochemical Processes

In general, water is taken up by the fine roots of plants by the process of osmosis, which involves the movement of water from states of low salt concentration to states of high salt concentration. However, when salt concentration in the soil is high, the movement of water from the soil to the root is delayed. When the salt concentrations in the soil are higher than inside the root cells, the soil will pull the water from the root. This is the simple way in which salinity affects plant growth and reproduction (FAO, 2005). High salinity affects plant growth and development in many ways: causing water stress, resulting in ion toxicity, causing nutritional disorders, alteration of metabolic processes, reducing the photosynthetic leaf area, and reducing cell division and expansion (Munns, 2002). Physiologically, salinity may have negative impacts on many processes, but the most important impacts are reduced cell growth and decreased leaf area, biomass, and yield (Shannon, 1998; Acevedo et al., 2002). Plant biomass production depends on the accumulation of carbon products by photosynthesis. In fact, photosynthesis is determined by two main components: the rate of photosynthesis per unit leaf area and the area of leaf surface available for photosynthesis (Terry and Waldron, 1984). Many studies have shown that total dry matter production by cereals is correlated with the amount of photosynthetic active radiation intercepted, which depends on leaf growth and the balance between photosynthesis and respiration (Gallagher and Biscoe, 1979). In

24

addition, reactive oxygen species (ROS) such as the superoxide radical (O_2^-), hydrogen peroxide (H_2O_2), and the hydroxyl radical (OH^-) are also produced during salinity stress and these free radicals cause severe damage to membranes and other essential macromolecules such as chlorophyll pigments, proteins, and fats (Sairam et al., 2005; Krieger-Liszkay et al., 2008; Behairy et al., 2012; Djanaguiraman and Prasad, 2013).

Effects on Growth and Yield

Salinity is one of the major abiotic stresses affecting germination, crop growth, and productivity (Munns and Tester, 2008). Plants that grow in saline soils are affected by high levels of solutes, which result in yield losses. Most plants are glycophytes, including most crop plants. They grow under low soil salinity conditions and do not show salt tolerance. Therefore, they will not grow at a high level of salinity and are severely inhibited or even destroyed by 100-200 mM NaCl (Munns and Termaat, 1986). Francois et al. (1986) reported that salinity above 4.5 dSm^{-1} electrical conductivity of the saturation extract decreases the percentage of plants established per unit area, and, at 8.8 dSm^{-1}, the emergence of wheat plants decreased to 50 percent. Salinity stress symptoms include reduced seed germination, plant growth, and plant yield. Some studies showed that the reduction of leaf area is often the first indication of salinity stress (Bernstein, 1975; Kingsbury et al., 1984; Volkmar et al., 1998; Acevedo et al., 2002; Cicek, 2002). Shoot and root growth also are reduced by salinity, but the shoot is usually more sensitive due to the inhibitory effect of salt on cell division and enlargement in growing point, which, in turn, affects the normal growth of wheat and the viability of tillers and decreases the number of primary and secondary tillers. Many studies have reported that wheat is the most sensitive to salinity during germination and during tiller appearance (Ayers et al., 1952). In wheat, tillering capacity is also reduced with increasing salt concentrations. The number of effective ears per plant is the most seriously affected yield

component in wheat under saline conditions (Maas and Hoffmann, 1977; Munns et al., 2006). In addition, salinity causes reduction in the number of leaves in the main shoot and reduction of the number of spikelets in the main spike, which result in reduction of seed set and grain yield (Maas and Grieve, 1986; Frank et al., 1987).

Responses to Salinity Stress

In an agronomic context, salt tolerance is described as a complex function of yield decline across a range of salt concentrations (Maas and Hoffman, 1977; van Genuchten, 1984; Munns, 2002). The ability of plant species to tolerate salinity is described in relative terms and is generally divided into four categories: sensitive, moderately sensitive, moderately tolerant, and tolerant (Francois and Maas, 1999). Plant salinity tolerance is basically thought of in terms of the inherent ability of the plant species to tolerate the effects of high salts in the root zone or on the plant's surfaces without a significant adverse effect on the plant (Munns and James, 2003). Salinity resistance is another term that is mainly used for this phenomenon, although some have tried to differentiate the two terms (Shannon, 1998). Plant species and genotypes within species show differential responses to salinity stress (Djanaguiraman and Prasad, 2013). The physiological responses of cereals to salinity stress differ at different stages of growth and development and depend on the time of exposure and the severity of the stress. Moreover, the nature of the salts present in the soil may affect the response of plants to salinity stress. However, continued growth of cereal plants under saline conditions is dependent on their ability to control the influx of salts into their shoots through the transpiration stream (Greenway and Munns, 1980; Da-Silva et al., 2008). Salt tolerance in some plants can be developed by identification of new genetic materials through screening for individual and combinations of different adaptation mechanisms. The various traits used for selection was accumulation of osmoprotectants, exclusion of sodium and chloride, tissue tolerance

to accumulated sodium and chloride, and detoxification of ROS (Rathinasabapathy, 2000; Zhang et al., 2001; Munns and Tester, 2008; Ashraf et al., 2010; Djanaguiraman and Prasad, 2013). Plant species vary in regards to salinity tolerance. For example, some crops such as barley, cotton, and sugarbeet, are salt tolerant and they grow well in moderately saline environments (Maas and Grattan, 1999). However, some plant species adapt to saline conditions and become tolerant to salinity. Wheat has a moderate tolerance to salinity (Maas and Hoffman, 1977; Acevedo, 2002). However, some wheat species are more tolerant than others. For example, bread wheat, seem to be more tolerant to salinity than durum wheat (Maas and Grieve, 1986).

To survive under salinity stress, plant species have evolved a number of physiological, biochemical, and molecular mechanisms to tolerate salinity by adjusting their metabolic processes. These mechanisms include ion compartmentalization, ion transport and uptake, biosynthesis of osmoprotectants, antioxidant enzyme activation, synthesis of antioxidants and polyamines, and hormonal adjustment (Rathinasabapathy, 2000; Gupta and Huang, 2014). To deal with high Na^+ and Cl^-, plants have developed a mechanism to keep ion balance within plant cells, and this mechanism is called ion hemostats (Niu Xiaomu et al., 1995). High concentrations of Na^+ and Cl^- in the soil solution reduce nutrient-ion activities and create extreme ratios of Na^+ /Ca^{2+}, Na^+/ K^+, Ca^{2+}/Mg^{2+}, and Cl^-/NO_3^-, which in turn, result in osmotic and specific ion injury (Alam, 1999; Grattana and Grieveb, 1999). However, some plant species have the ability to maintain ion balance within plant tissue. This mechanism mainly regulates Na^+ transport within plant cells. Na^+ ion transport to the cell's vacuole is affected through Na^+/H^+ antiporters. Proteins and enzymes that regulate this process and encode plasma membrane Na^+/H^+ antiporters play an important role. As a result, plants undergo synthesis of such proteins that tend to maintain ion balance within plant cells (Niu Xiaomu et al., 1995; Hasegawa 2013). Another mechanism that regulates ion balance is

the ability of a plant species to increase K^+ uptake and reduce Na^+ uptake its roots. This process also is regulated by some proteins and enzymes (Sairam and Tyagi, 2004). In addition some plants have the ability to exclude salt. Salt tolerance in plants, to some extent, depends on the ability and efficiency of root system (Alam, 1999). One function of plant roots, especially in a drying soil, is to sense water stress. The performance of many crops depends upon the ability of their root systems to obtain water and nutrients. In fact, in saline soils, roots act as highly effective filters and about 95 % of soil salt can be excluded by the root (Gucci and Tattini, 1997). This degree of exclusion occurs in most halophytes and in highly salt tolerant crop species. In some salt-tolerant species roots maintain K^+ uptake despite competitive inhibition by Na^+ due to selectivity of K^+ uptake over Na^+. However, salt contamination of soils can exploit and damage plant roots depending upon the sensitivity of the species and environmental variables (Bernstein and Kafkafi, 2002). Plant species have the ability to exclude Na^+ from leaf blades; however, excluding Na^+ by roots reduces Na^+ toxicity (Munns and Tester, 2008). Moreover; salt treated plants have lower stomatal conductance and relative growth rate. Several studies showed that there is a relationship between salt tolerance and stomatal conductance. Stomatal conductance affects CO_2 assimilation and growth rate (Munns and Tester, 2008). Another pathway to overcome the deleterious effects of Na^+ and Cl^- is by the accumulation in plant cells of solutes such as proline, glutathione, glycine betaine, mannitol, sucrose, and polyamines, and this results in resistance to salinity stress because they contribute to the osmotic pressure (Munns and Tester, 2008). This increase of solutes in plant cells leads to a decrease in the osmotic potential. It is well known that salinity stress induces the production of ROS such as OH^-, O_2^-, and H_2O_2; however tolerant plants have a mechanism that detoxifies ROS by synthesis of protective chemicals including antioxidants such as ascorbic acid and glutathione and enzymes such as peroxidases, catalases, and superoxide dismutase (Gupta and Huang, 2014).

Another mechanism that plants use to tolerate salinity stress is by the production and regulation of some plant hormones such as abscisic acid and salicylic acid. Abscisic acid accelerates the loss of stomatal turgor and leads to stomatal closure to reduce water loss (Popova et al., 1995).

Combination of High Temperature and Salinity Stress

In the field, crops are normally exposed to a combination of different biotic and abiotic stresses. Abiotic stresses such as drought, high and low temperatures, nutrient deficiency, high light intensity, and salinity stress can delay growth and development, decrease productivity, and may cause plant death (Krasensky and Jonak, 2012). Under natural conditions, combinations of two or more stresses, such as drought and salinity, salinity and high temperature, and drought, high temperature, and light are common in many cultivated regions, especially in coastal areas all around the world. Combined stresses become more acute and lethal threats to plant growth and development compared to individual stresses (Rizhsky et al., 2004; Mittler, 2006; Ramegowda and Senthil-Kumar, 2015). The general effect of combined stresses on plants depends mainly on the age of a plant, the inherent stress-resistant or susceptible nature of a plant, and the harshness of the two stresses (Pandey et al., 2015). In many areas, like arid and semi-arid regions, crops encounter a combination of these stresses, such as high temperature stress and salinity stress.

Effect of Combined Stresses on Physiological and Biochemical Processes

The first steps of germination are imbibition and water absorption by seeds. Temperature plays an important role in water absorption so that elevation of temperature, to some extent, accelerates the imbibition process. However, under saline conditions water absorption is decreased due to the low water potential of the saline water. Water absorption by seeds depends on the water potential gradient between the seeds and the soil solution. Under saline conditions, as a result of dissolved salts, there will be a decrease in that gradient, which will decrease water uptake by seeds, and this

will affect germination and seedling growth. Both high temperature and salinity cause a depletion in cellular water content and osmotic potential, thus causing osmotic stress and yield reduction. Saline water has a low water potential; therefore, salinity always results in plant water stress. Also high temperatures in many cases lead to water stress. Therefore, plant grown under high temperature and saline conditions are subjected to water stress and reduced plant water potential.

High temperature stress usually enhances transpiration, and, with combination of salinity stress, this could result in enhanced uptake of salt, which may cause salt toxicity (Keles and Oncel, 2002). Temperature affects the movement of salts in the soil, uptake of salts, overall biochemical processes in a plant, and transpiration (Gale, 1975). Hampson and Simpson (1990) in their study showed that adverse temperature intensified the harmful effects of osmotic stress on germination and early growth stages of wheat. High temperature and salinity stress induce alterations in ion transport and compartmentalization (Munns, 2002). A study on wheat plants showed that both of these stresses reduced net photosynthesis and increased the substomatal CO_2 level, leading to lowered CO_2 assimilation by Rubisco. This study also reported that salinity and high temperature stresses damaged gas exchange properties of the flag leaf, yield, yield components of some varieties of wheat plants (Anjum et al., 2008). Gas exchange and chlorophyll *a* fluorescence transients were studied in leaves of sorghum grown under salt and high temperature stress by Yan et al. (2012). They found that during salt treatment, photosynthetic rate decreased due to stomatal closing. A study on wheat seedlings reported that high temperature inhibited growth and increased the carotenoids and growth regulator activities of seedlings when they were grown under saline conditions (Keles and Oncel, 2002). This study concluded that the effects of temperature stresses on the antioxidative defense system may be altered by salinity stress. Another study on wheat seeding growth showed that heat shock increased the harsh effect of salinity on seed germination

and seedling growth, and it increased soluble carbohydrates and proline (Hamada and Khulaef, 1995).

Effects on Growth and Yield

High temperature and salinity stresses affect plant growth and development at all growth stages of plant development. The germination stage, for example, is affected by the combination of temperature and salinity. Many studies have been done to address the effects of high temperature and salinity on germination of different plants. One of these studies found that in sunflower plants at the optimum temperature for germination seeds were more tolerant to higher salinity levels and lower osmotic potentials than at high temperatures (Maftoun and Sepaskhah, 1979). Also, investigations done with many plants including wheat and barley, have reported that the more the temperature differed from the optimum for germination the more final germination became dependent on the osmotic potential. They also have found that germination rate is affected by temperature and that osmotic potential is dependent on temperature (Tadmor et al., 1969; Sharma, 1976). Ahi and Powers (1938) reported that temperature is a main factor in the germination and growth of plants under saline conditions. They suggested that temperature relations should be considered before recommending certain crops for saline soils. Salinity and high temperature stresses affect not only the germination stages of the plants, but they are highly damaging to plant growth and reduce productivity. The combined stresses affects yield of many plants. A study on bread wheat showed that high temperature and salinity stresses had effects on grain number per spike, which led to decreased grain yield and harvest index (Anjum et al., 2008). This study also suggested that salinity stress was relatively more damaging to grain filling and final yield than high temperature. There is a shortage of information in the literature in regards to the effects of high temperature and salinity on wheat plants. However, the effects of temperature and salinity

have been investigated on barley plants. An investigation found that there is significant interaction of temperature and salinity on the number of tillers and growth of shoots and roots. The study concluded that barley plants produced the highest number of tillers and the highest dry matter under saline conditions when the root temperature was at intermediate levels of 15 to 20 °C. The study suggested that the adverse effects of salinity on the growth of barley could be reduced if the temperature of the rooting media could be kept at about 15 to 20 °C (Mozafar and Oertli, 1992). Another study on barley showed that high temperature may stimulate plant growth and reduce some of the negative effects of salinity stress, and it also showed that high temperature affected the transcription of several stress related genes (Faralli et al., 2015).

Response to Plants to Combined Stresses

Under field conditions, plants are often exposed to several abiotic stresses at the same time, which may result in yield loss. However, plants do not respond equally in their reaction to the combined effect of salt and other climatic factors. Therefore, some crops are reduced equally in relative yield at a given salt concentration regardless of climate condition, whereas most crop yields at the same salt concentration are decreased more in high temperature than in low temperature (Magistad et al., 1943). Many plants have developed several physiological, biochemical, and molecular adaptations to defend themselves under such combined stresses (Rivero et al., 2014; Pandey et al., 2015). Natural stress tolerance is a complex process involving several metabolites and metabolic pathways (Krasensky and Jonak, 2012). Plants' responses to a combination of stresses are distinctive from individual stress responses. Plants also show common responses that are common to individual stresses and stress combinations (Suzuki et al., 2014; Rivero, 2014; Pandey et al., 2015). Under saline conditions, plants tend to maintain a high concentration of K^+ and a low concentration of Na^+ in the cytosol. They have the ability to do that by regulating the expression

and activity of K^+ and Na^+ transporters and of H^+ pumps that generate the driving force for transport (Zhu, 2003). Many plants have to cope with osmotic stress and molecular denaturation caused by salinity and high temperature. They produce and accumulate osmoprotectants such as different sugars, proline, and amino acids. These biochemical compounds stabilize proteins and membranes against the denaturing effects of high temperature and high concentrations of salts (Kuznestov and Shevyakova, 1997; Yancey, 2005). A study on wheat seeding growth showed that heat shock and salinity increased the production of soluble carbohydrates and proline, which may cause resistance to the stresses (Hamada and Khulaef, 1995). Salinity and high temperature stresses have a strong impact on gene expression, because many genes coding for enzymes involved in cellular metabolism are differentially expressed upon stress (Krasensky and Jonak, 2012). Also, plant growth regulators, such as GA and kinetin, are effective in alleviating the inhibitory effects of salinity under high and low salinity conditions (Khan and Rizvi, 1994).

A study on tomato had contrasting results concerning the effects of the combined stresses of high temperature and salinity compared to the studies reviewed above. This study showed a positive effect of combined stresses on plant growth. The study found that the combination of high temperature and salinity offered a level of protection to tomato plants compared to the effects of salinity alone (Rivero et al., 2014). Rivero et al. (2014) detected a specific response of plants to the stress combination that included accumulation of glycine betaine and trehalose. This study concluded that the accumulation of these compounds under the stress combination was linked to the maintenance of a high K^+ concentration and a reduction in the Na^+/K^+ ratio, which resulted in a better performance of the cell water status and photosynthesis as compared with salinity alone.

Nevertheless, even though there have been numerous investigations to study the effect of individual stresses on wheat , little is known about the biochemical and physiological mechanisms

underlying the tolerance of wheat to a combination of two different stresses such as high temperature and salinity. Therefore, this work will give a better understanding of their combined effects on genotypes of winter wheat.

Dissertation Hypotheses

- The genetic variability for salinity tolerance in winter wheat germplasm can be explained by mean daily germination percentage and seedling vigor index under salinity stress.

- The combined effects of salinity and high temperature stress during booting and flowering stages is more detrimental than the individual effects of salinity and high temperature stress in winter wheat genotypes.

- The decreased grain yield under salinity, high temperature and its combined stresses during booting and flowering stages will be associated with spikelet and grain number.

Dissertation Objectives

The objectives of this research were (i) to screen winter wheat genotypes for salinity tolerance at the germination stages and to identify seedling growth traits associated with salinity tolerance, (ii) to evaluate the independent and combined effects of high temperature and salinity stress on winter wheat genotypes at the booting stages through growth, physiological, biochemical, and yield traits, and (iii) to evaluate the independent and combined effects of high temperature and salinity stress on winter wheat genotypes at the flowering stages through growth, physiological, biochemical, and yield traits.

Potential Outputs:

- Expand the knowledge of the biochemical and physiological basis of high temperature and salinity stress tolerance in winter wheat.

- Novel screening tools for identifying high temperature and salinity stress tolerant genotypes under controlled conditions will be known.

- Offer diverse high temperature and/or salinity tolerant genetic materials to breeders for use in their breeding programs.

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Figures and Tables

Table 1-1 Summary of temperature ^{o}C for various processes and growth stages in wheat as reported in Porter and Gawith's diary (cited in Porter and Semenov, 2005).

Process	Minimum Temperature (T_{min})	Optimum Temperature (T_{opt})	Maximum Temperature (T_{max})
Vernalization	-1.3	4.9	15.7
Emergence	3.5	22.0	32.7
Leaf initiation	-1.0	22.0	24.0
Shoot growth	3.0	20.3	> 20.9
Root growth	2.0	< 16.3	> 25.0
Terminal spikelet	1.5	10.6	> 20.0
Anthesis	9.5	21.0	31.0
Grain filling	9.2	20.7	35.4

Chapter 2 - Screening Winter Wheat Germplasm for Salinity Tolerance during Germination Stage

Abstract

Salinity is one of the major abiotic stresses which limits wheat growth, development, and yield. Identification of salinity tolerant genotypes is critical for yield improvement. Therefore, a series of control environment experiments were carried out to evaluate the response of 292 winter wheat cultivars (*Triticum aestivum* L.) to different levels of salinity. The experiments were designed in a randomized complete block design (RCBD) with four replications. Twenty seeds of each germplasm were placed on pre-moistened filter paper in petri dishes, and placed in incubator at 20 °C. The seeds were subjected to three levels of salinity 0, 60, and 120 mM NaCl. Seedlings were harvested after eight d and data on final germination percentage, rate of germination, mean daily germination, shoot and root length, and seedling fresh and dry weight was recorded. The results indicated that the genotypes differed significantly for germination percentages, rate of germination, mean daily germination, shoot and root lengths, and seedling fresh and dry weight. At higher concentration of NaCl the germination rate and mean daily germination was delayed and final germination percentage was decreased in most of the genotypes. The data also showed that increasing salinity level, significantly decreased shoot and root length, seedling dry weight and seedling vigor was recorded. Principal component analysis separated genotypes in to three groups viz., tolerant, moderately tolerant and susceptible to salinity. The genotypes GAGE, OK04507 and MTS0531 and AVALANCHE, NE05496 and ENHANCER were classified as tolerant and moderately tolerant. The genotypes CO04W320, 2174-05, and CARSON were found to be susceptible to salinity.

Introduction

Climate change has brought irregular weather patterns such as rising temperatures, violent storms, higher atmospheric CO_2 concentration, increasing water and soil salinity, and flash flooding (Ludwig and Asseng, 2005). Salinity is a major abiotic factor reducing plant growth and productivity throughout the world. It is estimated that over 800 million ha will be affected by salinity in the near future (Rengasamy, 2006; FAO, 2008). Recent tendency and future demographic projections propose that it is important to produce more crops which require effective utilization of salt affected land and saline water resources. Qadir et al. (2008) found that at least 20 percent of the world's irrigated land is salt affected and/or irrigated with saline water. About two million additional ha of cropping land are affected by salinity every year (Rengasamy, 2006; Tuteja, 2007). As a result of salinization increases of agriculture land, it is projected that about 50 % of crop land will be lost by the middle of the 21st century (Wang et al., 2007). Saline soils are found where rainfall is fairly low and in coastal regions where saline water has entered the soil (Tanji, 1990). However, even in regions with sufficient rainfall, salt can be accumulated in the soil with poor drainage soils. Another source for soil salinity is substantial use of fertilizers (Plaut et al., 2013).

Wheat (*Triticum aestivum* L.) is the world's most widely grown cereal crop for food (Carte, 2002). Wheat is a generally grown in irrigated, dry and high rainfall areas and also from temperate, humid to dry and cold conditions (Dubcovsky et al., 2007). With 620 million tonnes produced annually worldwide, wheat provides about one-fifth of the calories consumed by human (FAO, 2006). Taking into account the importance of wheat on an economic basis, the demand for wheat is expected to increase in the future with the increase in global population (Barnes and Shields, 1998). Global wheat production is projected to be about 735 million tons in 2016-17 (FAO, 2013).

Currently, about 65 % of the wheat crop is used for food, 17 % for animal feed, and 12 % in industrial applications, including biofuels (Oleson, 1994; FAO, 2013). To meet the demand, 40 percent more grain in 2020 is required (Andersen et al., 1999). Increases in cultivated area are expected to contribute only about one-fifth of the global cereal production between 1995 and 2020 (Andersen et al., 1999). Therefore, improvements in crop yields will be required to bring about the necessary production increases.

Germination of seed is an important for seedling establishment for ensuing plant stand. Salinity can affect germination and seedling growth by producing an osmotic pressure that prevents or reduces water uptake. Also, salinity may affect germination due to Na and Cl ions toxicity (Munns, 2006). Wheat has a moderate tolerance to salinity (Maas and Hoffman, 1977; Acevedo, 2002). Francois et al. (1986) found that salinity level of > 4.5 dSm^{-1} electrical conductivity of the saturation extract decreases the percentage of plants establishment per unit area and at 8.8 dSm^{-1} the wheat plants emergence decreased to 50 per cent (Francois et al., 1986). Salinity stress symptoms include, reduced seed germination, plant growth, and plant yield. However, plant species and genotypes within species show differential responses to salinity stress (Djanaguiraman and Prasad, 2013). To our knowledge, screening winter wheat germplasms to salinity stress and understanding the genetic variability for seedling character was not studied in detail. Therefore, the objective of this study is to screen winter wheat genotypes for salinity tolerance at the germination stages and to determine seedling growth traits associated with salinity tolerance.

Material and Methods

Plant Materials

The Hard Winter Wheat Association Mapping Panel (HWWAMP), developed by the Triticeae Coordinated Agricultural Project (TCAP), containing about 300 cultivars and advanced lines (Appendix 1) were used in this study. Germplasm included 193 cultivars and 106 breeding lines, of which 258 were hard red winter wheat and 41 were hard white winter wheat. Nine public breeding programs contributed 270 entries and four private breeding programs contributed 27 entries. The public breeding programs that contributed were Colorado, Kansas, Michigan, Montana, Nebraska, North Dakota, Oklahoma, South Dakota, and Texas. The private breeding programs were AgriPro-Syngenta (APS), WestBred-Monsanto (WES), and a private breeding sources (Hardeman) Grain and Seed. The historic entries included in this panel were the landrace from Turkey; the two ancestral cultivars Cheyenne and Kharkof; and five cultivars released before 1960 (Comanche, Wichita, Kiowa, Bison, and Tascosa) (Awad, 2015; Grogan, 2015).

Experimental and Treatment Conditions

The experiments were conducted in controlled environmental facilities at Crop Physiology Laboratory, Department of Agronomy, Kansas State University. The plant material consisted of about 292 genotypes of winter wheat and three different concentrations of NaCl (0, 60, and 120 mM NaCl with EC value of < 0.7, 7.5 and 14.5 dSm^{-1}) were used as salinity treatments. Salinity solution prepared by dissolving the required amount of NaCl in tap water. Healthy seeds of each genotype were surface sterilized with 5 % sodium hypochlorite solution for five min and washed with distilled water, dried in air and used for the experiment. A set of 20 seeds were placed in a Petridish with moisturized Whatman no. 1 filter paper discs. The filter paper was moisturized daily by adding 5 mL of the appropriate NaCl solution. The filter papers were changed once every 2 d

to prevent salt accumulation. The Petridishes were placed in the dark throughout the germination period at 20 ± 2 °C in an incubator (Low temperature Illuminated incubator, Model 818) USA. Seeds were considered germinated when both shoot and root extended more than 2 mm from the seed. The germination rate and speed of germination, mean daily germination, shoot and root length, seedling fresh and dry weight traits were collected on eight d.

Data Collection

Germination percentage (G %) was expressed according to Nasri et al., 2011. The G % = (Number of seeds germinated at the end of the experiment (8 d after sowing) / (Total number of seed sown) x 100. Germination count was taken after 24 h from sowing to end of experiment (8 d). Germination index (GI %) was calculated according to the equation given by Karim et al. (1992). GI= (Germination % in each treatment)/ (Germination % in the control) x100. Number of seeds germinated on daily basis was counted from first d of germination to 8 d after sowing. From this data the germination rate (GR) was calculated according to the equation given by Rubio-Casal, (2003). GR = (n1t1) + (n2t2) + ……. + (nxtx) / Xn. (Where: n_1 is the number of seed germinated on the first day of germination, t_1 is the days from start to fist germination and Xn is the total number of seeds germinated). Mean daily germination (MDG) was calculated as per Gairola et al. (2011). MDG = Total number of germinated seeds/total number of d to final germination.

Thereafter, 5 seedlings were selected from each replicate and dissected into shoot and root to record the fresh and dry weight. The fresh weight was recorded using a balance (SALTER BRECKNELL, MODEL ESA-600 China) and then the shoot and root were dried in oven maintained at 70 °C for 2 d to record the dry weight and expressed as mg seedling[-1]. The distance from seed to the tip of the leaf blade were recorded and expressed in cm as the shoot length. The distance from the seed to the tip of the root were recorded and expressed in cm as the root length.

The salinity tolerance (ST) index calculated according to the equation given by Tregay et al. (2014). The ST= Seedling dry weight of NaCl treated/seedling dry weight in control x 100. Seedling vigor index (SVI) calculated according to the equation given by Abdoli1 et al. (2013) SVI= seedling length (cm) x germination percentage / 100.

Experiment Design and Data Analysis

The experiment design was a randomized complete block design (RCBD) with four replications. The principal component analysis was done using XLstat program The analysis of variance of the data and the comparison of the means was done using least significant difference (LSD) using SAS 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

Analysis of variance results showed that salinity had significant effect ($P < 0.05$) on germination %, germination index, mean daily germination, germination rate and seedling vigor index. However, genotype and salinity x genotypes interaction had no significant effect on these parameters (Table 2.3). Also the results showed that salinity, genotype and their interaction had significant effect ($P < 0.0001$) on all seedling characteristics studied (Tables 2.3 and 2.4). All mean values of the 292 winter wheat genotypes for germination and seedling characteristics were presented in appendixes B and C, however in the result section only result of twelve genotypes was presented. These twelve genotypes were selected randomly from the 292 genotypes of winter wheat after grouping the 292 genotypes based on the seedling vigor index, such that those with the smallest and largest percent reduction over the control were ranked respectively as the most and

least tolerant genotypes At 120 mM NaCl these genotypes were (1) tolerant to salinity at germination stage (GAGE, MTS0531, TASCOSA, and GUYMON) (2) moderately tolerant to salinity at germination stage (AVALANCHE, OK05108, TX86A5606 and ONAGA) and (3) susceptible to salinity at germination stage (CO04W320, 2174-05, CARSON, and TX04M410211).

Germination Parameters

Germination percentage (G %) of wheat genotypes was significantly ($P < 0.05$) reduced by increasing salinity level. Genotypes GAGE, OK04507, GUYMON and MTS0531 were tolerant to salt stress, whereas, genotypes O04W320, 2174-05, and CARSON were sensitive to salt stress at 120 mM NaCl. Mostly increasing level of salinity stress resulted in the decrease in germination percentage over control. However, in some genotypes, the germination percentage were not affected at 60 mM NaCl, but decreased by 70 % at 120 mM NaCl over the control (0 mM NaCl; Fig. 2.4a).

The results showed that salinity significantly reduced germination index (GI) at all concentrations with the largest decrease at 120 mM NaCl. The results showed a decline by 70 % in germination index in some wheat genotypes 2174-05, CO04W320 and CARSON under high level of salinity 120 mM NaCl. However, under the same level of salinity, genotypes MTS0531 and TASCOSA had about 11 % decline in term of germination index (Fig. 2.4b). In addition, the analysis of variance showed that salinity significantly increased ($P < 0.05$) germination rate (GR) (Tables 2.3 and 2.4). Figure 2.4c showed that increasing salinity concentration resulted in dramatic increase in germination rate. Genotypes 2174-05 and ONAGA showed an increase in germination rate over the control by 77 % and 81 %, respectively at 120 mM NaCl, whereas, genotypes GUYMON, and MTS0531 had percent increase of 23 % at the same level of salinity 120 mM

NaCl over the control. Mean daily germination (MDG) was strongly decreased with salt stress in all genotypes. The result showed that, in some genotypes, moderate salinity decreased mean daily germination by lesser extent and severe stress decreased to a greater extent. Genotypes 2174-05 CO04W320, CARSON and TX04M410211 showed decline over the control by 85, 81, 80 and 81 %, respectively, whereas, genotypes GUYMON, GAGE, MTS0531 and TASCOSA showed decline over the control by 47, 46, 42 and 49 %, respectively (Fig 2.4d).

Seedling Parameters

All seedling parameters decreased with increasing salinity level (Tables 2.3 and 2.4). Under non-saline conditions genotypes showed no significant differences in terms of shoot length. However, under both levels of NaCl condition there were significant differences in response of genotypes to salinity levels (Fig. 2.5a). Under high level of salinity, 120 mM NaCl, the genotypes 2174-05, TX04M410211, ONAGA and TX86A5606 had the greatest decrease in shoot length and genotypes GUYMON and GAGE had the lowest decrease in shoot length. Similarly, there were significant differences among genotypes in terms of root length in response to salinity stress. Increasing NaCl level resulted in a significant decrease in root elongation as compared to the control. Increasing salinity levels inhibited the root length of wheat genotypes. In fact, root length was more affected by salt stress than shoot length. Genotypes 2174-05, TX04M410211 and TX86A5606 showed a percent decline of above 70 % (Fig. 2.5b). In addition, increasing salinity level consistently reduced the growth and biomass production of almost all wheat genotypes used in this study. In comparison with control, maximum reduction in seedling fresh weight was observed in 2174-05, TX04M410211 with a per cent reduction of 42 and 39 %, respectively. Seedling dry weight was also decreased with increasing salt concentrations, (60 to 120 mM NaCl; Fig. 2.5c). The seedling dry weight was decreased to higher level than fresh weight under high level of salinity 120 mM

NaCl the highest decline of fresh weight was by 42 % in 2174-05, whereas the dry weight declined by 78 % in the same line. Results regarding salt tolerance (ST) of different winter wheat genotypes showed that genotypes GUYMON and GAGE were tolerant to salinity stress at germination stage, whereas genotypes TX04M410211 and 2174-05 were sensitive to salinity stress. On the basis of tolerance at germination stage, genotypes were grouped as tolerance, moderate, and sensitive genotypes based on salinity tolerance index. The result showed that genotypes GUYMON, GAGE, and TASCOSA had a per cent reduction of 47, 48, and 49 %, respectively over control. Therefore, these genotypes were more tolerance to salinity stress, while the genotypes 2174-05, CO04W320, and TX04M410211 had a per cent reduction of 77, 72 and 71 %, respectively and therefore these genotypes were sensitive to salt stress at germination stages (Fig. 2.5d). Increasing salinity concentrations from 0 to 120 mM NaCl gradually decreased seedling vigor index. The highest seedling vigor index was observed in control, while salinity at 60 and 120 mM NaCl decreased significantly seedling vigor index. Significant decrease was observed at 120 mM NaCl salinity in genotype 2174-05. Data showed that the genotype 2174-05 had 92 % decline over control, while the GUYMON has 45 % decline over control (Fig. 2.5e).

Grouping of genotpes was done using principal component analysis. (Table 2.1). The plot of the PCA (Fig. 2.1) showed that the first two components (PCA1 and PCA2), account for about 76 % of the total variance (Table 2.1 and Fig. 2.1). The first PCA was related to seedling vigor index and seedling length, whereas the second PCA was related to germination index and germination % (Table 2. 1). The traits, which contributed more positively to PCA1, were seedling length, root length, shoot length, mean daily germination, and seedling dry weight, suggesting that these components reflected the salinity tolerance. In addition, the traits, which contributed positively to PCA2, were germination index and germination percentage. Correlation coefficients

for all the traits showed that salinity tolerance positively correlated with all the traits. The most noticeable relationships (shown in Figure 2.2) were a strong positive relationship between germination % and germination index and seedling vigor; between mean daily germination and salinity tolerance; between seedling dry weight and root length; between shoot length, seedling length and fresh weight as indicated by the small obtuse angles between their vectors. There was a negative correlation between germination rate and seedling length (Fig. 2.2). Table 2.2 showed that seedling vigor showed significant positive correlation with all traits except for germination rate. Germination per cent and mean daily germination showed strong correlation with germination index. Shoot and root length showed positive strong correlation with seedling length. In addition, seedling fresh weight showed positive correlation with seedling dry weight, and seedling dry weight showed strong positive correlation with salinity tolerance index (Table 2.2).

Ranking of Genotypes Based on PCA

The genotypes was ranked based on the seedling vigor index, such that those with the smallest and largest percent reduction over the control were ranked respectively as the most and least tolerant genotypes at 120 mM NaCl. According to that, genotypes were divided into three categories. (1) tolerant to salinity at germination stage (GAGE, OK04507, MTS0531, TASCOSA, ENDURANCE and GUYMON), (2) moderately tolerant to salinity at germination stage (AVALANCHE, NE05496, ENHANCER, OK05108, TX86A5606 and ONAGA), and (3) susceptible to salinity at germination stage (CO04W320, 2174-05, CARSON, OK1070275, TX02A0252 and TX04M410211).

Discussion

Wheat is considered to be moderately tolerant to salinity. The PCA is multivariate data analysis procedure used to know the relationship between various parameters for salinity tolerance. All the ten parameters were taken for PCA. PCA analysis reduced the variables to two components accounting for about 76 % of the total variation. The first component accounted for 58.68 % of the variability and the second component accounted for 16.93 % of the variability. Principal component analysis and correlation coefficients analysis in winter wheat genotypes simplify the identification of desirable traits and their correlation with salinity tolerance and consistent classification of genotypes,

The results showed that by increasing NaCl concentrations, the germination in winter wheat genotypes was delayed and decreased, also the germination percentage germination index, germination rate and mean daily germination were significantly ($P < 0.05$) decreased by salinity stress. Similar results were reported by Rahman et al. (2008); Khayatnezhad, and Gholamin, (2010); Kumar et al. (2012); and Hussain et al. (2013). These studies reported that there exists genetic variability among wheat germplasm for salinity tolerance based on seed germination percentage and seedling growth. Salinity affects germination in two ways: (1) high concentration of salt in the growth medium decreased the osmotic potential to a level that prevented water uptake and reduced utilization of nutrients essential for germination, and (2) Na^+ and Cl^- ions are toxic to the embryo (Kayani et al., 1990; Munns, 2006). Winter wheat genotypes responded differently to salinity level. It appears that at concentration up to 120 mM NaCl in the growth solution, the water potential of the seeds is still sufficiently low to bring adequate amount of water for the several metabolic processes that lead to germination. Other studies reported that the difficulty of growth under salinity stress may result from decreased water potential of the seeds (Rahman et al., 2008;

Muhammad and Hussain, 2012). The results in this study are analogous to those described by other researchers (Catalan et al., 1994; Kazemi and Eskandari, 2011; Muhammad and Hussain, 2012). Physiologically, salinity stress has negative impact on many processes, however the most significant effects are reducing cell division and expansion, which result in decreasing shoot and root length. With increasing NaCl concentration, it affected seedling fresh and dry weight. Reduction of seedling dry weight relatively depended on shoot and root lengths and branches. The results obtained in this study were consistent with previous findings that have indicated significant differences in the salt tolerance of wheat genotypes and their differential responses to increased salt concentrations (Catalan et al., 1994; Rahman et al., 2008; Adjel et al., 2013). In addition, the results showed that the most sensitive growth characters to salinity were root length and dry matter production, while germination percentage was least sensitive under salinity. Nevertheless; the genotypes which had higher germination percentage also had higher root length, shoot length, and dry matter production. For this reason, seedling length and dry weight are considered as selection criteria for salinity tolerance. It is estimated that in addition to higher dry weight, longer shoots and roots development will allow more successful selection for high salt tolerance. Yet, root length and dry weight can be considered as selection criteria only when there is a high germination percentage. For these reasons, the seedling vigor index, which is a function of both germination percentage and seedling length, was determined to be a more consistent selection criterion. Genotypes such GUYMON and TASCOSA were considered as salinity tolerant genotypes.

Conclusions

In conclusion, this investigation was carried out to screen winter wheat genotypes for salinity tolerance and to evaluate the effects of salinity on germination and seedling growth of 292 winter wheat genotypes. Genotypic variability for salt tolerance was found among different winter wheat

genotype. Seedling vigor index is a good parameter for evaluating salinity tolerance at germination stages. According to that the genotypes were ranked based on the seedling vigor index, such that those with the smallest and largest per cent reduction over the control were ranked respectively as the most and least tolerant genotypes at 120 mM NaCl. According to that genotypes were divided in to three categories (1) tolerant to salinity at germination stage (GAGE, OK04507, MTS0531, TASCOSA, ENDURANCE and GUYMON), (2) moderately tolerant to salinity at germination stage (AVALANCHE, NE05496, ENHANCER, OK05108, TX86A5606 and ONAGA), and (3) susceptible to salinity at germination stage (CO04W320, 2174-05, CARSON, OK1070275, TX02A0252 and TX04M410211). Overall, it can be determined that under control (0 mM NaCl) conditions, all winter wheat genotypes had good germination and growth attributes. However, wheat genotypes showed differential response at higher levels of salinity. Yet, salinity reduced all germination traits of wheat genotypes. These results indicate that genetic variation exists among winter wheat genotypes in terms of germination under salinity stress condition. Further studies are needed to see the effect of salt stress on the germination and seedling growth of theses germplasms under field conditions.

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Tables and Figures

Figure 2-1 Scree plot showing eigenvalues in response to number of components for the estimated variables of winter wheat germination. The first principal component (PC1) explains 58.68 % of the variance, and the second principal component (PC2) explains 16.93 % of the variance.
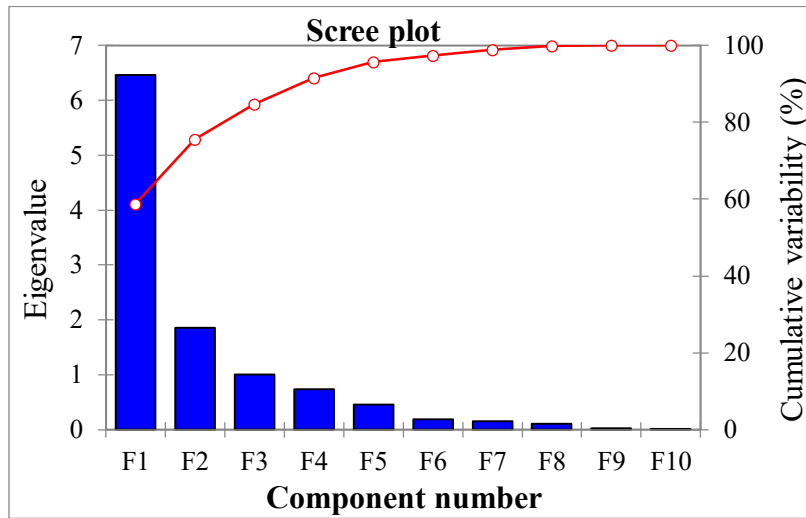
Figure 2-2 Plot of the first two PCAs showing relation among various traits measured in winter wheat germplasms.

Variables (PC1 and PC2: 75.62 %)
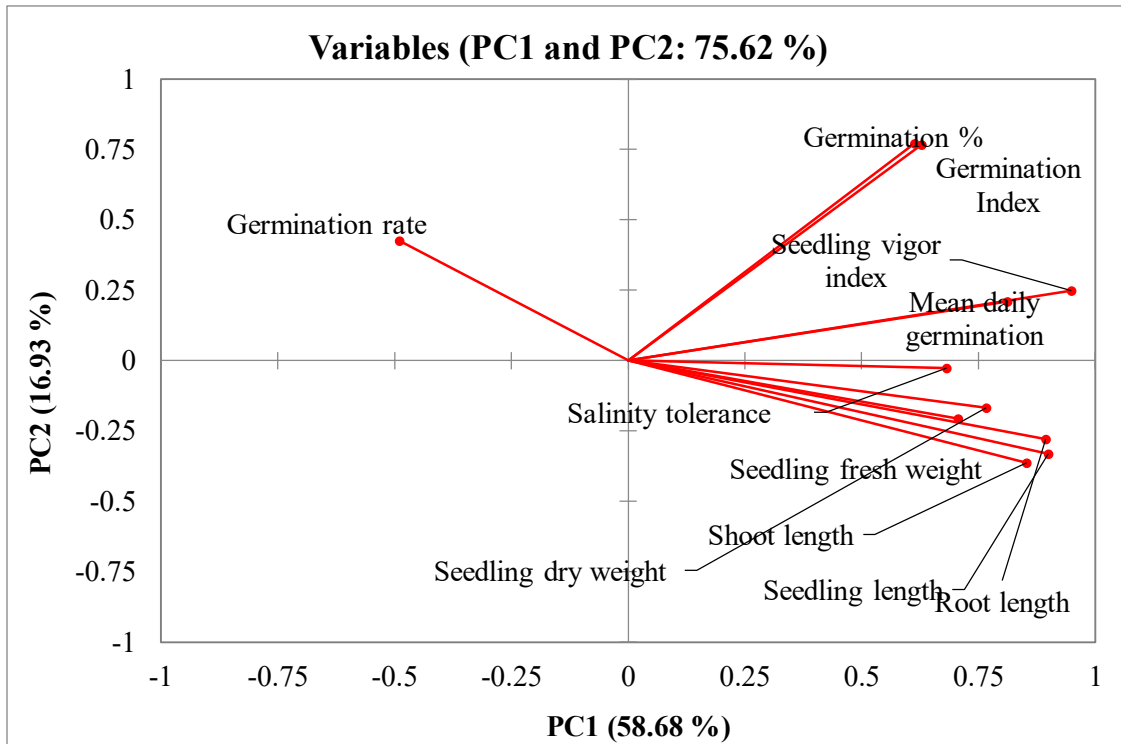
Figure 2-3 Biplot of wheat genotypes based on first and second components. The biplot did not show all genotypes, it only presents some genotypes.

Observations (PC1 and PC2: 75.62 %)
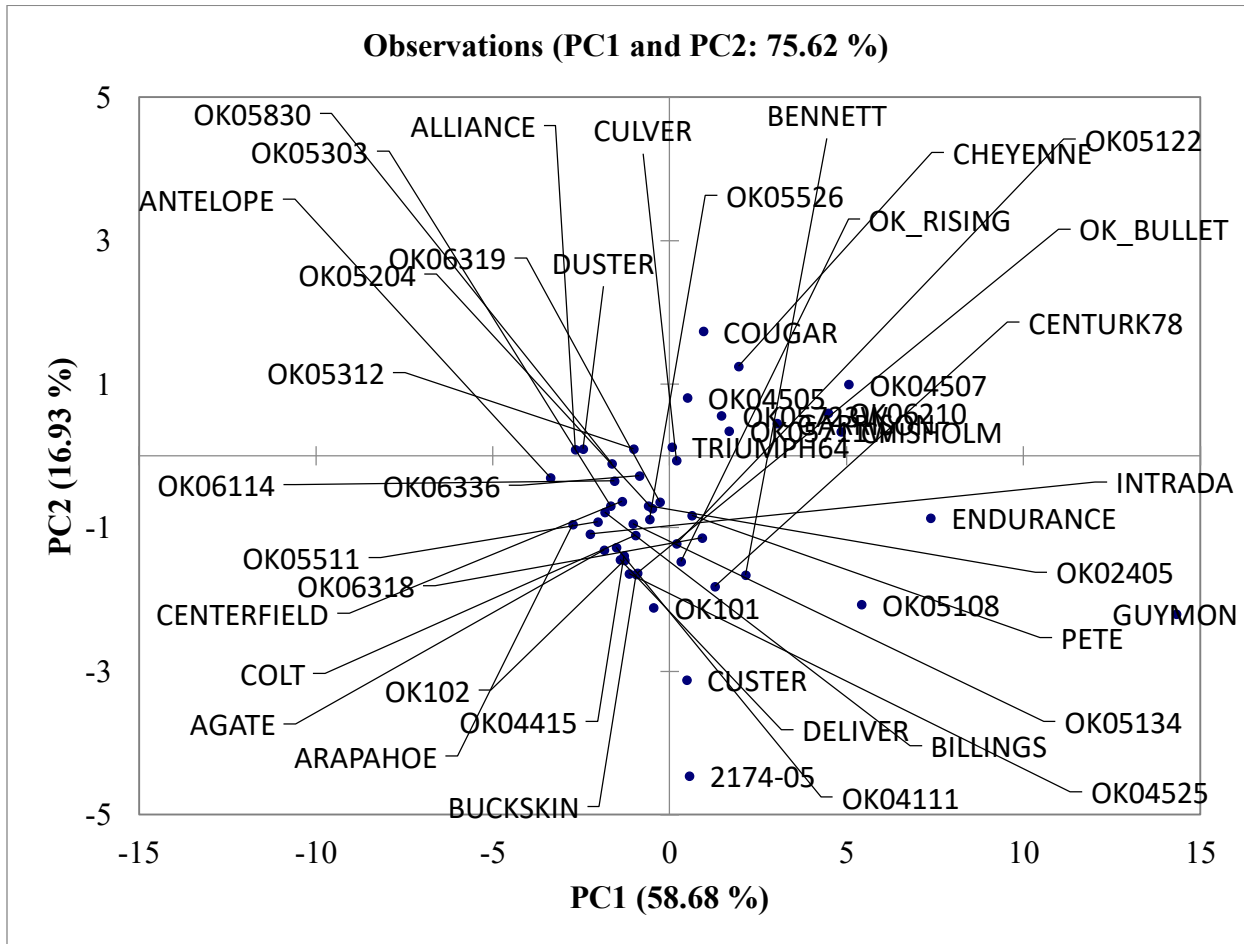
Figure 2-4 The effects of different salinity levels (0, 60,120 mM NaCl) on (A) germination percentage, (B) germination index (%), (C) mean daily germination and (D) germination rate (d) of twelve winter wheat genotypes. Percent decline of each trait due to high level of salinity (120 mM NaCl) as compared to control is indicated. Vertical lines on top of bars indicate standard error of means (n = 4).
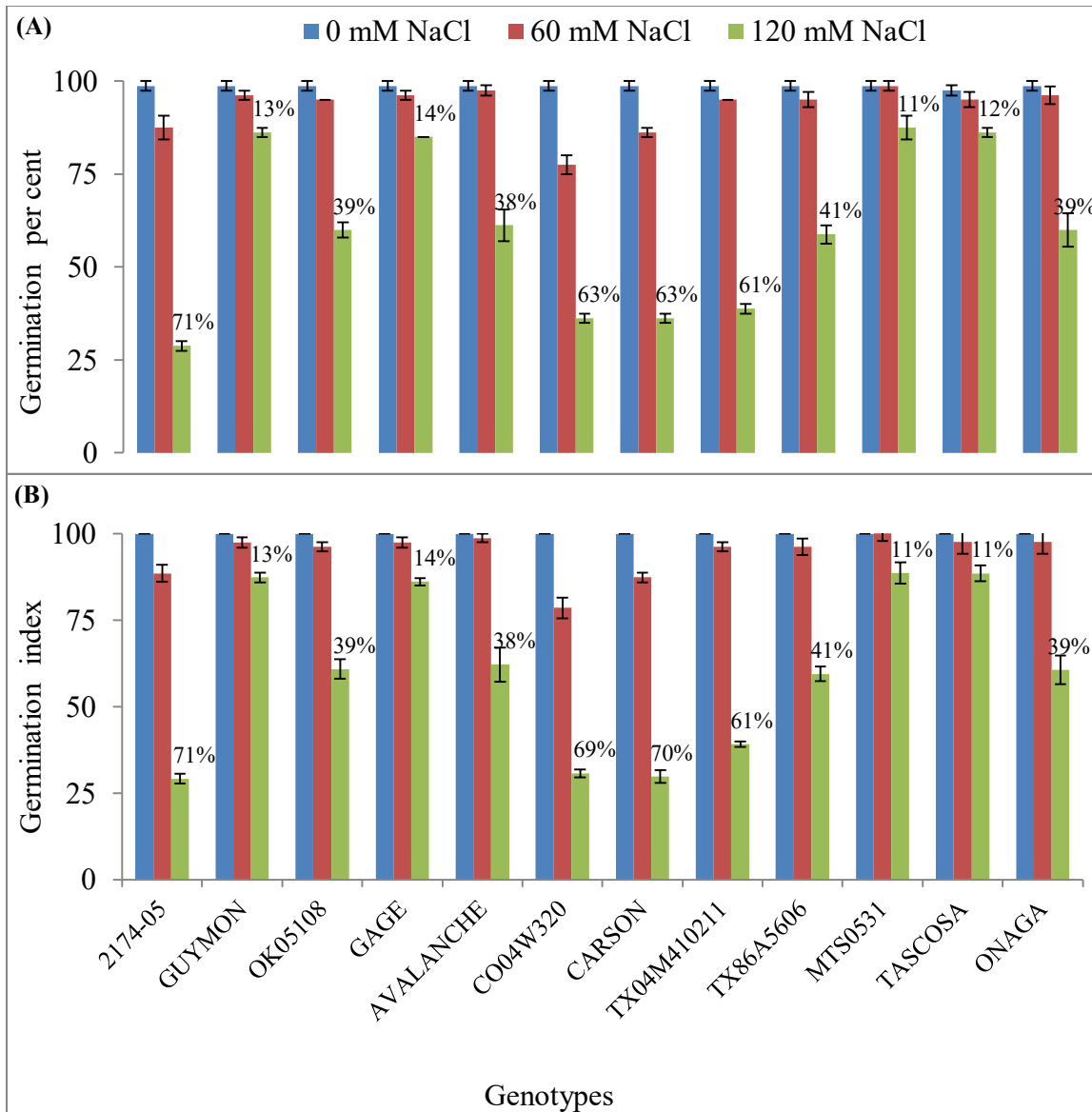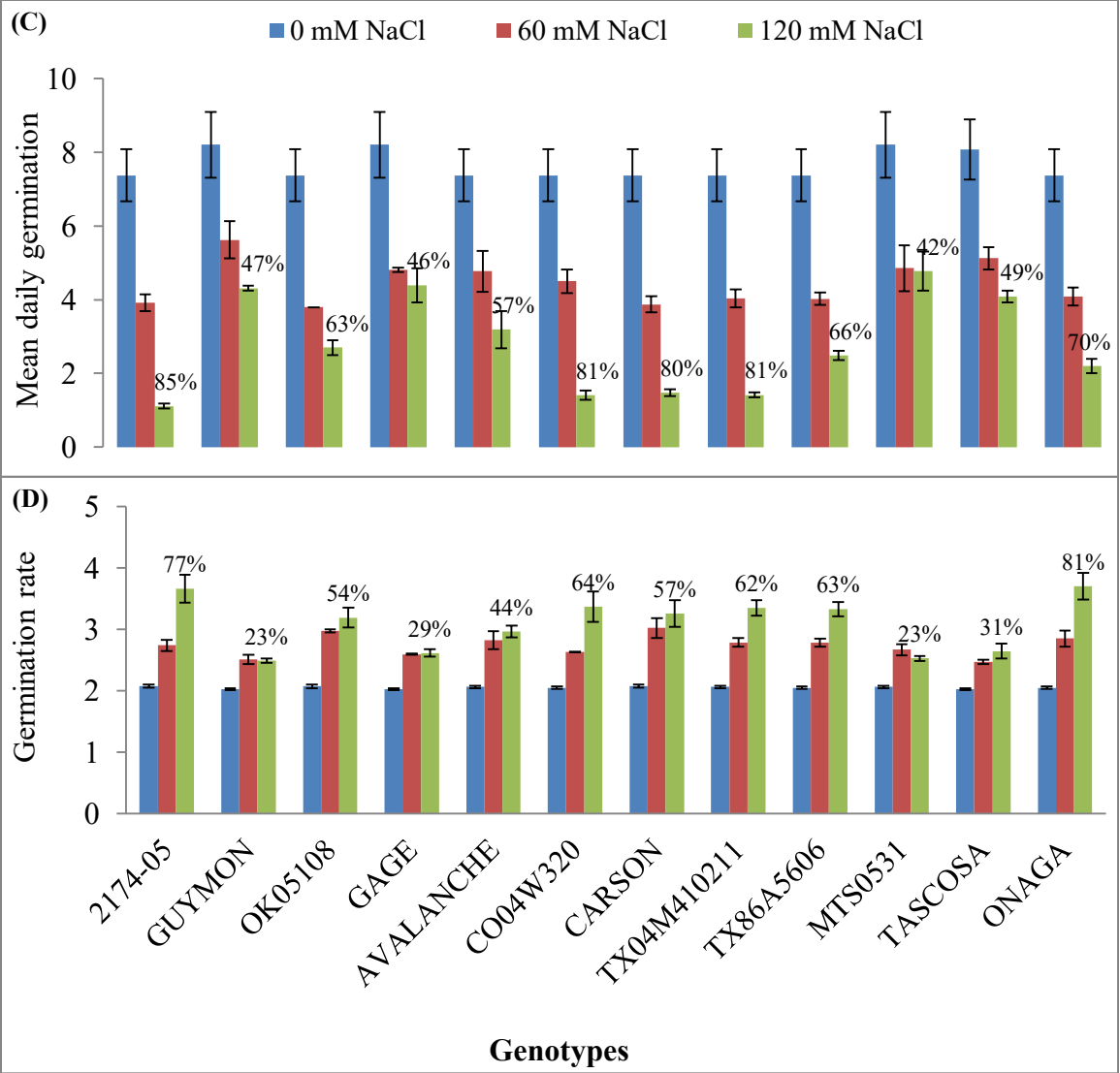
Figure 2-5 Effect of different salinity levels (0, 60,120 mM NaCl) on (A) shoot length (cm), (B) root length (cm), (C) seedling dry weight (g) (D) salt tolerance index, and (E) seedling vigor index of twelve winter wheat genotypes. Percent reduction in all traits due to high level of salinity (120 mM NaCl) as compared to control is indicated. Vertical lines on top of bars indicate standard error of means (n = 20).
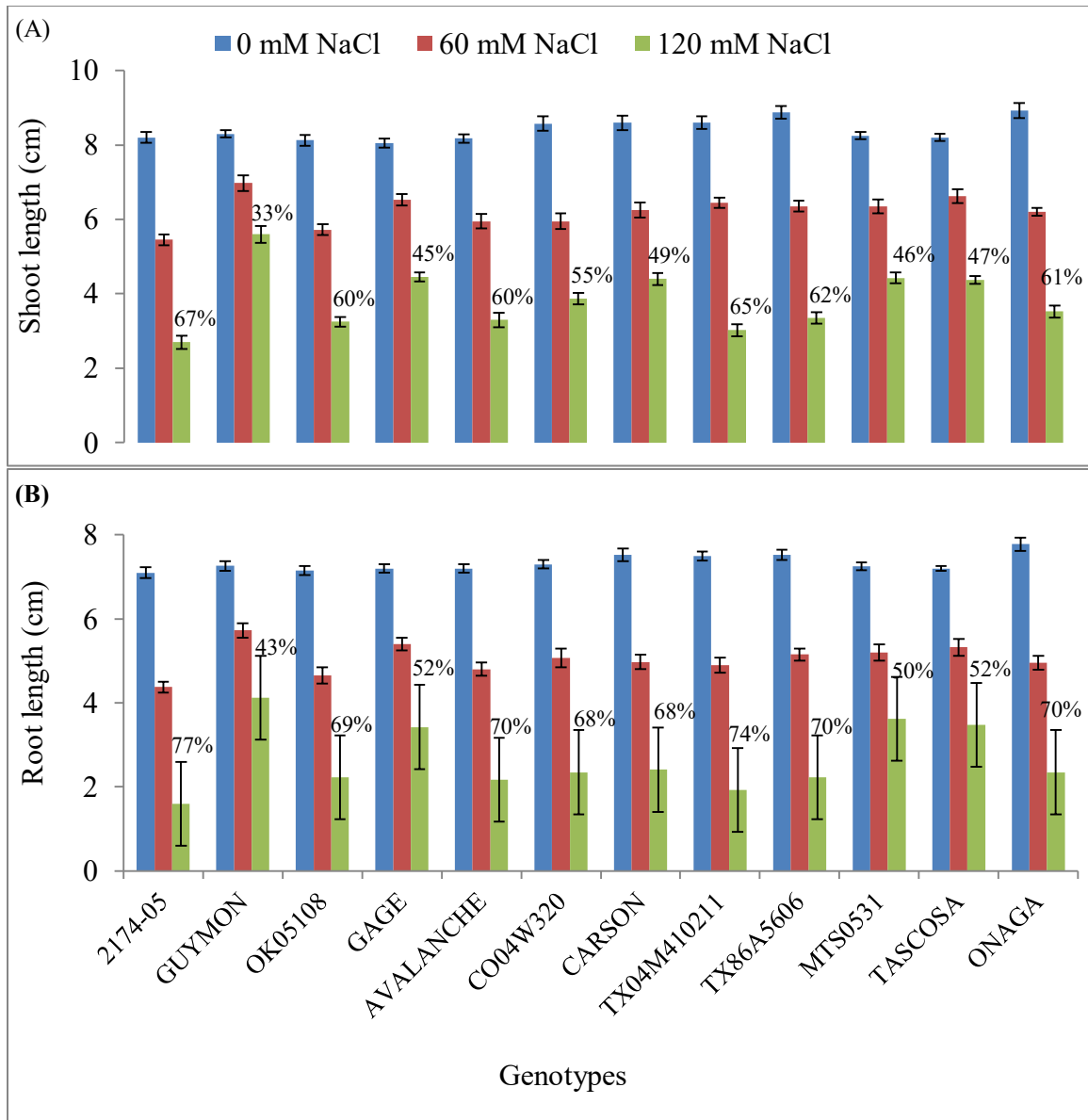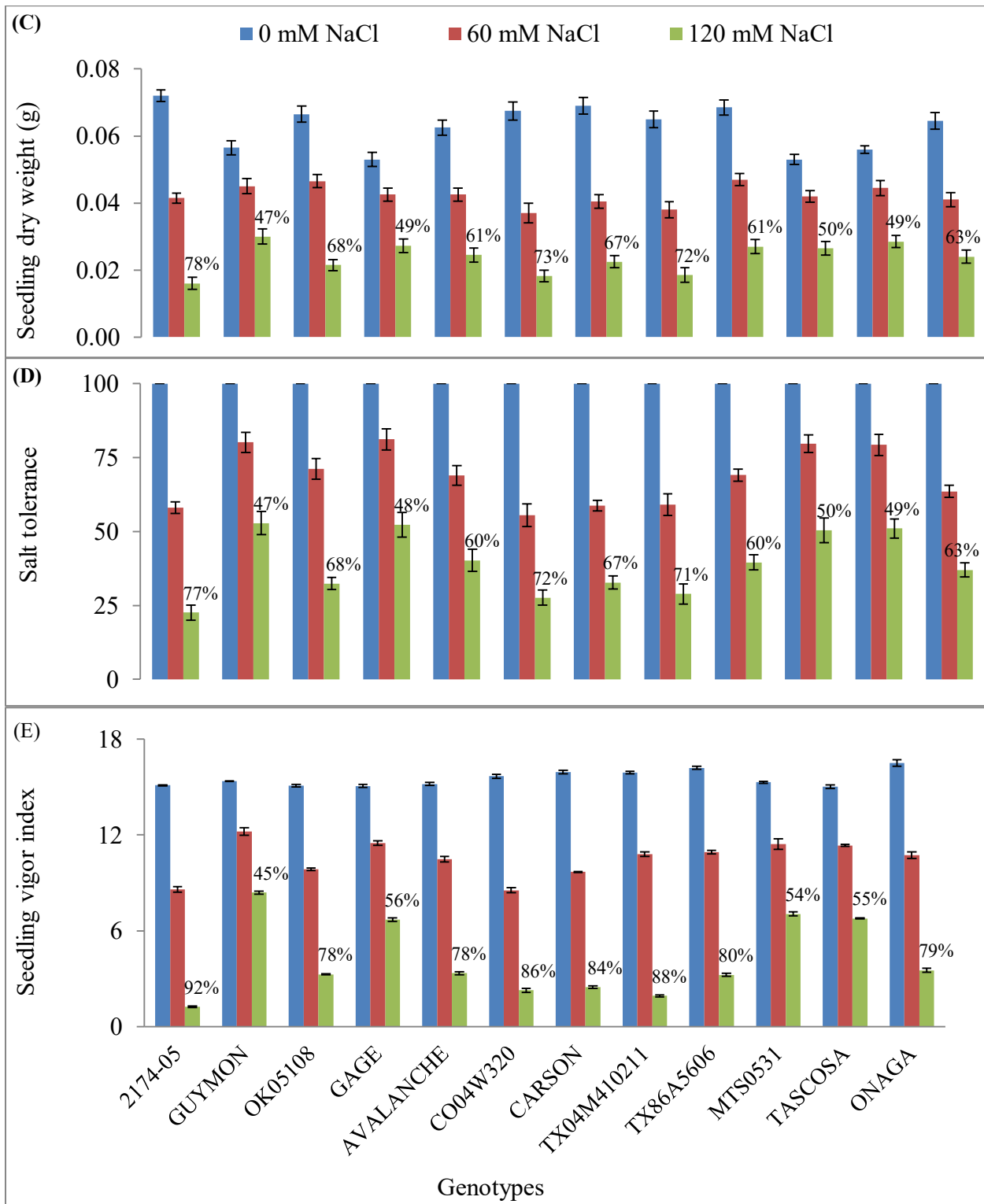
Table 2-1 Principal component analysis for the measured traits in winter wheat and the contribution of the traits (%) of winter wheat germination. F1-F5 represent the contribution of all the ten parameters taken for principal component analysis (PCA).

Traits	PC1	PC2	PC3	PC4	PC5
Germination %	6.101	31.670	0.017	0.204	0.577
Mean daily germination	10.217	2.346	16.203	3.557	1.689
Germination rate (d^{-1})	3.721	9.783	38.976	12.790	12.580
Germination index	5.811	31.901	0.132	0.139	0.284
Shoot length (cm)	11.263	7.094	0.249	8.693	4.515
Root length (cm)	12.368	4.161	0.056	6.036	4.240
Seedling fresh weight (g)	7.718	2.303	18.084	1.256	50.676
Seedling dry weight (g)	9.103	1.512	19.747	9.189	1.322
Seedling length (cm)	12.537	5.903	0.145	7.785	4.653
Salinity tolerance	7.206	0.036	6.130	46.921	18.383
Seedling vigor index	13.956	3.291	0.261	3.429	1.080
Eigenvalue	6.455	1.863	1.007	0.743	0.456
Variability (%)	58.684	16.932	9.155	6.757	4.145
Cumulative %	58.684	75.616	84.771	91.528	95.673

Table 2-2 Correlation matrix (Pearson (n-1)) Values in bold are different from 0 with a significance level alpha=0.05.

Variables	G%	MDG	GR	GI	ShL	RL	SFW	SDW	SL	ST	SVI
G %	1										
MDG	0.654	1									
GR	0.000	-0.577	1								
GI	0.977	0.635	-0.014	1							
ShL	0.262	0.575	-0.497	0.254	1						
RL	0.345	0.633	-0.471	0.332	0.882	1					
SFW	0.305	0.384	-0.247	0.274	0.607	0.638	1				
SDW	0.341	0.470	-0.269	0.320	0.623	0.644	0.715	1			
SL	0.312	0.622	-0.499	0.301	0.971	0.969	0.641	0.652	1		
ST	0.368	0.505	-0.305	0.361	0.469	0.529	0.434	0.704	0.514	1	
SVI	0.795	0.798	-0.333	0.776	0.773	0.823	0.580	0.612	0.822	0.557	1

Germination % (G %), Mean daily germination (MDG), Germination rate (GR), Germination index (GI), Shoot length (ShL), Root length (RL), Seedling fresh weight (SFW), Seedling dry weight (SDW), Seedling length Salinity (SL), tolerance Seedling (ST) and Seedling vigor index (SVI)

Table 2-3 Probability values of effects of salinity (S), genotype (G) and salinity x genotype interaction on germination percentage, germination index (%), mean daily germination, germination rate (d), shoot length (cm), root length (cm), seedling length (cm), seedling fresh weight (g), seedling dry weight (g), salt tolerance index and seedling vigor index of 292 winter wheat genotypes.

Traits	Salinity (S)	Genotype (G)	SxG
Germination %	0.0105	0.4565	0.4982
Germination index (%)	0.0119	0.5206	0.5548
Mean daily germination	0.0032	0.2690	0.4327
Germination rate (d $^{-1}$)	0.0048	0.3493	0.4163
Shoot length (cm)	< 0.0001	< 0.0001	< 0.0001
Root length (cm)	< 0.0001	< 0.0001	< 0.0001
Seedling length (cm)	< 0.0001	< 0.0001	< 0.0001
Seedling fresh weight (g)	< 0.0001	< 0.0001	< 0.0001
Seedling dry weight (g)	< 0.0001	< 0.0001	< 0.0001
Salt tolerance index	< 0.0001	< 0.0001	< 0.0001
Seedling vigor index	0.0023	0.2350	0.3749

Table 2-4 Effect of salinity stress on germination percentage, germination index (%), mean daily germination, germination rate (d), shoot length (cm), root length (cm), seedling length (cm), seedling fresh weight (g), seedling dry weight (g), salt tolerance index and seedling vigor index of 292 winter wheat genotypes. Individual datum is the mean of four replications. Means that have the same letter in each trait are not significantly different (p ≤ 0.05) from each other.

Traits	NaCl levels (mM)		
	0	60	120
Germination %	98 a	92 b	60c
Germination index (%)	100a	94a	60b
Mean daily germination	7 a	4b	2c
Germination rate (d $^{-1}$)	2c	3b	4a
Shoot length (cm)	8a	5b	2c
Root length (cm)	7a	4b	2c
Seedling length (cm)	14a	9b	4c
Seedling fresh weight (g)	0.16a	0.13b	0.09c
Seedling dry weight (g)	0.06a	0.04b	0.02c
Salt tolerance index	100a	63b	33c
Seedling vigor index	14a	9b	2c

Chapter 3 - The Combined Effects of Salinity and High Temperature on Winter Wheat at Booting Stage

Abstract

Salinity and high temperatures are the major environmental factors that limit wheat (*Triticum aestivum* L.) productivity. Climate change model forecast that in the future inland salinity and short or long episodes of high temperature can decrease the crop productivity. Therefore, the objective of this study was to evaluate the independent and combined effects of high temperature and salinity on winter wheat genotypes at the booting stages through growth, physiological, biochemical, and yield traits Twelve genotypes of winter wheat were grown in non-saline conditions at optimum temperatures (25/15 °C: d/ n; daytime maximum and nighttime minimum) until booting stage. At booting stages, plants were irrigated with three different levels of NaCl (0, 60, 120 mM) and exposed to two temperature regimes [optimum or high temperature (35/ 20 °C d/ n)] for 10 d. High temperature, when combined with salinity stress during booting stage, negatively affected the gas exchange, decreased contents of soluble sugars, starch, soluble proteins proline, MDA and grain yield. Greater impact on photosynthesis, stomatal conductance, proline accumulation, soluble sugar, soluble protein and grain yield was observed at the combined stresses compared with individual effects of salinity and/or high temperature. In addition, the study showed considerable variation in high temperature and salinity tolerance among winter wheat genotypes for leaf photosynthesis, chlorophyll concentration, sugars, proline and soluble proteins accumulation, seed set, grain number and grain yield per plant. The study conclude that genotypes varied in their response to independent and combined stresses and that genotype GUYMON, TX04M410211 and TASCOSA were the more tolerant genotypes.

Introduction

Wheat plants mature from seed germination to harvesting through distinct developmental phases include, germination, seedling emergence, vegetative, and reproductive phase. Each of these phases classified into distinct growth stages. Booting stage (Feekes 10, Zadoks 45) begins when the head of wheat is fully developed, but has not yet emerged from the leaf sheath below the flag leaf. The head can be seen in the swollen section of the leaf sheath below the flag leaf (Miller, 1992). The leaf sheath containing the fully developed head is called the boot (Herbek and Lee, 2009). This stage ends when the head is first visible at the flag leaf collar and the leaf sheath is forced open by the head. The initiation of the pollen in the anthers and the embryo sac in the carpel starts with booting stages (Acevedo et al., 2002). This stage is very sensitive to environmental stresses such that high temperature, drought, light and low temperature. In wheat, meiosis starts in the middle of the spike, continuing later above and below this zone (Zadoks et al., 1974). Abiotic stress include high temperature and drought stress around this stage is very critical for grain yield as it ultimately leading to seed-set failure (Acevedo et al., 2002; Alghabari et al., 2014).

Temperature plays an important role on wheat growth and development. Many biochemical and physiological processes are regulated by temperature such as evapotranspiration and water stress (Ritchie, 1972), cold hardening (Hurry et al., 1995), vernalization (Brooking, 1996), leaf formation and leaf senescence (Miglietta, 1989), photosynthesis and respiration (Evans and Rawson, 1969; Azcon-Bieto and Osmond, 1983), yield (Ferris et al., 1998; Lobell et al., 2005; Rahman et al., 2009; Kobata et al., 2012), and grain filling (Rahman et al., 2009; Kobata et al., 2012). High temperature stress is defined as the rise in temperature beyond a threshold level for a period of time sufficient to cause permanent damage to plant growth and development (Wahid et al., 2007). Scientists expect that an increase in average temperatures worldwide will lead to more

frequent and extreme heat events (Aydinal and Cresser, 2008; Bita and Gerats, 2013). High temperature usually affects water availability to the plant so that crop water requirements will increase with increased temperature (Simoes-Araujo et al., 2003; Saeedipour and Morad, 2011; Pradhan et al., 2012; Barber et al, 2015). The effect of high temperature on plants is primarily on photosynthetic functions. Many studies indicated that CO_2 assimilation is limited, in part, at high temperature by an imbalance in the regulation of the carbon metabolism, which is reflected in a down regulation of the ribulose-1,5-bisphosphate carboxylase oxygenase (Weis and Berry, 1988; Apel and Hirt, 2004; Pradhan et al., 2012; Narayanan et al., 2015). Another study by Djanaguiraman et al. found that high temperature stress during flowering decreased the photosynthetic rate because of ultra-structural damaging to chloroplast (Djanaguiraman et al., 2011; Pradhan et al., 2012). Many researchers agree that high temperature accelerates the increase in grain dry weight, but shortens the grain filling period, causing a yield reduction, that is, acceleration of the increase in grain dry weight cannot recompense for the shortening of the grain filling period and the reduction in yield is mainly caused by a failure of the sink function (Nicolas et al., 1984; Wheeler et al., 1996; Modhej et al., 2008; Kunar et al., 2013; Narayanan et al., 2015). In addition, high temperature stress induces synthesis of some harmful compounds such as reactive oxygen species (ROS) like super oxides and peroxides. ROS damage membranes and causing cellular damage (Djanaguiraman and Prasad, 2013; Narayanan et al., 2015).

Salinity affects crop plants in three major ways: (1) osmotic stress, decreasing water availability; (2) ionic stress; and (3) changes in the cellular ionic balance, which are in turn leading to deficiency and/or toxicity of some nutrients such as Ca^{2+} and K^+ (Kirst, 1989; Munns and Jermaat, 2003; Ahmad et al., 2010; Azooz et al., 2011). As a result of high concentration in soil solution the plant root are unable to uptake as much water from the soil as they require. At early

growth stage, water stress inhibits cell elongation and cell division, which results in reduced leaf area and so reduce photosynthesis rate (Prasad and Staggenborg, 2008). In wheat plant, salinity causes reduction of number of leaves in the main shoot and reduction of the number of spikelet in the main spike (Maas and Grieve, 1986). ROS damage membranes and causing cellular damage (Djanaguiraman and Prasad, 2013). This lead to oxidative damages in several cellular components such as proteins, lipids, nucleic acids and membranes (Pastori and Foyer, 2002; Apel and Hirt, 2004).

The studies on the response of wheat to abiotic stresses have been carried out widely and advanced significantly during the last decade. However, the majority of these studies on the response of wheat to abiotic stressors have focused on a single stress factor. It has been reported that the response of plants to a combination of drought and high temperature is different from the response of plants to each of these stressors applied individually (Pradhan et al., 2012). Temperature stress usually enhances transpiration, and with combination of salinity stress, this could result in enhanced movement and uptake of salt (Gale, 1975). Regardless of the many researchers have been carried out to study the effect of individual stress factor and in fact, little is known about the molecular, biological, and physiological mechanisms underlying the acclimation of plants to a combination of temperature and salinity stresses. Some studies showed that salinity has little effect on germination at low temperature, but that the effect of salinity is increasingly inhibitory as temperature increased (Khan and Rizvi, 1993; Khan et al., 2004). Salinity and high temperature can decrease the gas exchange properties of flag leaf and yield and yield components of some varieties of wheat (Anjum et al., 2008). Numerous works has been done to study the effect of high temperature alone and/or salinity alone. But, limited research has been done to study the interaction between high temperature and salinity stress and its impacts on wheat growth at

heading and reproductive stages. Therefore, the objectives of this study were to provide better understanding of individual and combined effects high temperature and salinity on winter wheat genotypes; and to evaluate the interaction effects of salinity and high temperature stress on physiological, biochemical, growth and yield of selected winter wheat genotypes.

Materials and Methods

This study was conducted in controlled environment facilities at the Department of Agronomy, Kansas State University Manhattan, KS, USA. Experiments were conducted in spring and summer of 2015 to determine the impact of salinity and high temperature stress on physiological, biochemical, growth and yield, of winter wheat genotypes.

Plant Material

Twelve genotypes were used in the study and these genotypes were selected based on earlier germination experiment. These genotypes were classified as tolerant to salinity include genotypes (GAGE, MTS0531, TASCOSA AND GUYMON). Moderately tolerant include genotypes (AVALANCHE, OK05108, TX86A5606 and ONAGA). Susceptible include genotypes (CO04W320, 2174-05, CARSON AND TX04M410211).

Experimental and Growth Conditions

Seeds of twelve winter wheat genotypes were sown in 4-cm deep trays containing commercial Sunshine Metro Mix 360 potting soil (Hummert International, Topeka, KS, USA). Seeds were sown at a depth of about 2 cm. The seedlings were raised in a growth chamber (Conviron Model CMP 3244, Winnipeg, MB, Canada) maintained at 25/15 °C d/ n. After 8 d the

seedlings were vernalized for 56 days at 4 °C with 8 h photoperiod. Following vernalization, three seedlings of the same genotype were transplanted into 1.6-L pots (24 cm length and 10 cm width, MT49 Mini-Treepot, Stuewe & Sons, Inc., Tangent, OR, USA). Rooting medium in pots was commercial Sunshine Metro Mix 360 potting soil. The rooting medium was fertilized with Osmocote (Scotts, Marysville, OH, USA), a controlled-release fertilizer with 14: 14: 14 N: P_2O_5:, K_2O respectively, at 5 g per pot before transplanting. Two growth chamber were used for the study. both growth chambers were maintained at optimum temperature (OT; 25/15 °C d/ n) until booting stage. At booting, one growth chamber was maintained at optimum temperature (OT; 25/15 °C d/ n) and the other growth chamber was maintained at high temperature (HT; 35/25 °C d/ n) for 10 d. In each growth chamber there were 15 trays, and each tray has 12 pots. Twelve winter wheat genotypes were in each tray, with a total of 180 pots in the growth chamber. Pots were watered daily and kept in trays containing about 1 cm water during the experiment to avoid water stress. Pots were moved randomly for each week to avoid positional effects. After seedling establishment, seedlings were thinned to two per pot, which was maintained until maturity. At thinning, a systemic insecticide, Marathon 1 % G (a.i.: Imidacloprid: 1–((6–Chloro–3–pyridinyl) methyl)–N–nitro–2–imidazolidinimine), was applied at 1.5 g per pot to avoid infestation of sucking insect pests. The plants were maintained at a photoperiod of 16 h with a light intensity of 800 µmol m^{-2} s^1 and 70 % relative humidity. The daytime maximum temperature/nighttime minimum temperature was maintained for 8 h with a transition period between daytime and night time temperatures of 4 h to imitate the diurnal temperature fluctuation of outside atmospheric condition and *vice-versa*. Both growth chambers were divided into three sets each set consist of 5 trays representing five replications. At the onset of booting stages (Feekes growth stage 10.0), one set of plants were irrigated with distilled water and served as control and the other two served as salinity treatment.

Two levels of salinity (60 and 120 mM of NaCl, EC value of 7.5 and 14.5 dSm^{-1}) solution was used to irrigate the plants. Salinity treatments were applied by irrigating each plant with 250 mL of NaCl solution to all treated plants and as mentioned above in both growth chambers for 10 d. Also, at the same time plants grown at high temperature were exposed to high temperature (HT; 35/25 °C d/ n) for 10 d after that, the plants were returned optimum temperature (OT; 25/15 °C d/ n) and irrigated with normal water till plants attained physiological maturity. Similar management practices were followed in both experiments.

Data Collection

At booting stages, the main stem of all plants was tagged for the measurements of chlorophyll content, chlorophyll *a* fluorescence, and gas exchange. Measurements were taken on three plants of each genotype in each treatment at 2, 5, and 10 d after stress imposition. Leaf samples were collected for biochemical analysis on 2, 5, and 10 d after stress imposition and at maturity, plant height, tiller number per plant, spike number per plant, spike length, spikelet number per spike, and grain number per spike were measured. All the above traits were measured on attached fully expanded flag leaves of the main stems of three plants per genotype from each treatment during 10:00 and 14:30 h. The leaf chlorophyll was measured using a self-calibrating chlorophyll meter (SPAD-502, Spectrum Technologies, Plainfield, IL, USA) on the fully expanded flag leaf of the main stem. Each time, data were taken four times from the middle portion of the leaf and the readings were averaged to get a single value for a plant. The Chlorophyll *a* fluorescence parameters were measured using a modulated fluorometer (OS30p; OptiSciences, Hudson, NH, USA). The minimum fluorescence (Fo) and maximum fluorescence (Fm) measurements were taken after the flag leaf was dark adapted for 1 h. The maximum quantum yield of PS II is the ratio of variable

fluorescence [difference between maximum and minimum fluorescence (Fv) to maximum fluorescence (Fm)], which decreases with stress (Rohacek, 2002). The leaf level photosynthesis was measured using the LI-COR 6400 portable photosynthesis system (LI-COR, Lincoln, NE, USA). Measurements were taken at daytime growth temperature and ambient CO_2 conditions (390 mol^{-1}). The internal light emitting diode (LED) light source in the LI-COR 6400 was set at 1600 mol m^{-2} s^{-1}. For all the biochemical analysis, the flag leaf and next leaves from main stem were collected at 2, 5, and 10 d during the stress period. Samples placed in aluminum paper and immediately frozen in liquid nitrogen and transported to the laboratory where samples were stored at - 80 °C until processing.

Carbohydrate content: A known weight of (0.2 g) frozen leaf sample from each treatment was ground in liquid nitrogen to a fine powder using a pestle and mortar followed by the addition of 10 mL of 80 % ethanol and kept in a preheated (70 °C) water bath for 30 min. After the expiry of time, the homogenate was filtered through Whatman No. 1 filter paper and then re-extracted using 80 % ethanol (10 mL) and dried in a water bath to evaporate the ethanol and then 10 mL of distilled water was added and vortexed for 2 min. These extractions then used to determine soluble sugars, reducing sugar and non-reducing sugars.

Soluble sugars were determined based on the method of phenol sulphuric acid described by Dubois et al. (1956). Briefly, 0.2 ml of sample exact was used with 0.8 ml distilled water. To the diluted extract, 1 mL of phenol reagent and 5 mL of 96 % sulphuric acid were added and incubated for 30 min at 30 °C. The optical density reading was taken at 490 nm using a UV-spectrophotometer.

The reducing sugars were quantitatively estimated in the obtained extract following the method of Somogyi (1952). Briefly, 0.2 ml of sample exact was taken and 0.8 mL of distilled water

and 1 mL of alkaline copper tartrate was added and the reaction mixture was heated for ten min in a boiling water bath and cooled rapidly in an ice bath. Then 1 mL of arsenomolybdate reagent and 10 mL of distilled water were added and mixed well. The reaction mixture was incubated for ten min at room temperature. The optical density reading was measured at 620 nm using UV-spectrophotometer.

The difference between total sugar and reducing sugar corresponds to the non-reducing sugar. Starch content was determined using anthrone (Hedge and Hofreiter, 1962). A known weight of 0.2 g of frozen leaf samples from each treatment were ground in liquid nitrogen to a fine powder and homogenized in a pestle and mortar using 10 mL of 80 % ethanol and kept in preheated (70 °C) water bath for 30 min. The homogenate was filtered through Whatman No. 1 filter paper and then re-extracted using 10 mL of 80 % ethanol for removing the soluble sugars. The residue was retained and was washed with hot 20 % ethanol till the washings did not give color with anthrone reagent. Sample residue was dried in oven at 70 °C. To the dry sample residue, 5 ml of distilled water and 6.5 ml of 52 % perchloric acid were added. Starch was extracted at 0 °C for 20 min. The extract was retained after centrifugation. The extraction was repeated with fresh perchloric acid. The extracts were pooled after centrifugation and the volume was made up to 50 mL with distilled water. To 0.2 ml of the extract, 0.8 ml of distilled water and 4 ml of anthrone reagent were added. The reaction mixture was heated for 8 min in a boiling water bath and cooled rapidly in ice bath. The optical intensity was read at 630 nm using a UV- spectrophotometer.

Free proline content was quantified according to the method of Bates et al. (1973). Briefly, 0.5 g of frozen leaf sample from each treatment was ground in liquid nitrogen to a fine powder and homogenized in a pestle and mortar in 3 % (w/v) sulfosalicylic acid, and the residue was removed by centrifugation. From the supernatant, 2 mL was mixed with 2 mL of glacial acetic acid and with

2 mL of acid ninhydrin (1.25 g of ninhydrin was warmed in a mixture of 30 mL of glacial acetic acid and 20 mL of 6 mM phosphoric acid until dissolved) for 1 h at 100 °C; the reaction was terminated in an ice bath. The reaction mixture was extracted with 4 mL of toluene. The chromophore-containing toluene was warmed to room temperature and its optical density was measured at 520 nm using UV- spectrophotometer. Proline content was calculated according to Bates et al. (1973).

Lipid peroxidation was measured in terms of content of malondialdehyde (MDA, $\varepsilon = 155$ $mmol^{-1}\ cm^{-1}$) a product of lipid peroxidation, following the method of Heath and Packer (1968). Briefly, 0.5 g of frozen leaf samples from each treatment were ground in liquid nitrogen to a fine powder and homogenized in a pestle and mortar with 10 mL of extraction buffer (0.1% trichloro acetic acid (TCA). The homogenate was centrifuged for 10 min at 10,000 rpm. For every 1 mL of the aliquot, 4 mL of 20 % TCA containing 0.5% thio barbituric acid (TBA) was added. The mixture was kept in water bath at 95 °C for 30 min and cooled rapidly in an ice bath to stop the reaction. The optical density reading of the mixture was immediately taken at 532 nm using UV- visible spectrophotometer, and the value for the non-specific absorption at 600 nm was subtracted. The concentration of malondialdehyde (MDA) was calculated using coefficient of absorbance of 155 $mM^{-1}\ cm^{-1}$. MDA content expressed as mmol/g fw. The MDA content was calculated as follows: MDA concentration $=(Abs532-Abs600)\ xVx1000/\ (\varepsilon\ x\ W)$. Where: V = extraction volume, ε = extinction coefficient and W = sample weight.

Total soluble protein content was determined as by Bradford (1976). Briefly, 0.5 g of frozen leaf sample from each treatment was ground in liquid nitrogen to a fine powder and homogenized in a pestle and mortar with 15 mL of extraction buffer (0.1M Tris buffer 8 pH) and then centrifuged at 12000 rpm at 4 °C for 15 min. Then 5 ml of Coomasie brilliant blue reagent

(CBB) and 0.5 ml of distilled water were added to 0.5 ml of the supernatants. Spectrophotometer cuvettes and absorbance were measured using a UV- visible spectrophotometer at 595 nm.

At maturity, plants were hand-harvested by cutting them at the soil level. Data on plant height, number of tillers plant^{-1}, spike number per plant, and spike length were recorded at the day of harvesting on five plants per genotype from all the temperature and salinity levels. Plant height was determined as the distance between base of the plant and the spike. For vegetative dry weight measurements, plant parts - leaves, stems, and spikes (main spike and other spikes separately) were collected and dried at 40 °C for 10 d. Vegetative dry weight was determined as the weight of leaves, stems, and spikes per plant. After drying for 5 d, spikelet number was counted for main spike, then main spikes were hand threshed to separate grains, and grain number per spike was counted manually. Grain yield for main spike and per plant were calculated and individual grain weight was calculated by dividing grain yield per spike by grains number per spike. Harvest index was calculated as the ratio of grain yield to the total vegetative dry weight for each plant.

Experiment Design and Data Analysis

The experimental design was a randomized complete block with a split split-plot treatment structure in five replications. Temperature was the main plot factor, salinity was assigned to sub-plots and genotypes to sub-sub-plots. For the treatments, temperature had two levels (OT and HT), salinity had three levels (0, 60, 120 mM NaCl), and genotype had twelve levels (GAGE, MTS0531, TASCOSA, GUYMON, AVALANCHE, OK05108, TX86A5606, ONAGA, CO04W320, 2174-05, CARSON AND TX04M410211). Data were analyzed using MIXED procedure in statistical software SAS 9.4 for mean and standard error estimation. Separation of means was carried out

using the LSD test (P < 0.05). The PROC MIXED procedures were used with block, temperature, salinity, and genotypes as class variables.

Results

The P-values for physiological, biochemical, growth and yield traits obtained with SAS PROC MIXED are presented in tables 3.1, 3.2 and 3.3. The independent effects of high temperature and salinity were significant (P < 0.001) on leaf photosynthesis, stomatal conductance, maximum quantum yield of PS II, thylakoid membrane damage, chlorophyll concentration, soluble sugars, reducing sugars, non-reducing sugars, starch, proline content, soluble proteins, MDA, plant height, tiller number, spike number, spike length spikelet number, dry weight, grain number, individual grain weight, grain yield, and harvest index. The main effect of genotype was significant for leaf photosynthesis, stomatal conductance, maximum quantum yield of PS II, thylakoid membrane damage, chlorophyll concentration, soluble sugars, reducing sugars, non-reducing sugars, starch, proline content, soluble proteins, MDA, plant height, tiller number, spike number, spikelet number, dry weight, grain number, and grain yield. Interaction effects of temperature x salinity were significant (P < 0.05) for leaf photosynthesis, stomatal conductance, maximum quantum yield of PS II, thylakoid membrane damage, chlorophyll concentration, soluble sugars, reducing sugars, non-reducing sugars, starch, proline content, soluble proteins, MDA, spike length, spikelet number, grain number, individual grain weight, grain yield, and harvest index. Interaction effects of temperature x genotype were significant (P < 0.05) for maximum quantum yield of PS II, thylakoid membrane damage, chlorophyll concentration, soluble sugars, reducing sugars, non-reducing sugars, proline content, soluble proteins, MDA, spikelet number, grain number, and grain yield. Interaction effects of salinity x genotype were significant (P < 0.05) for leaf photosynthesis, stomatal conductance, thylakoid membrane damage, chlorophyll concentration, soluble sugars,

reducing sugars, proline content, soluble proteins, and MDA content. The temperature x salinity x genotype interactions, were significant for thylakoid membrane damage, chlorophyll concentration, soluble sugars, reducing sugars, non-reducing sugars, proline content, soluble proteins, and MDA content.

Physiological Traits

Results of the effect of high temperature, salinity and combined stresses on leaf level photosynthesis are presented in (Table 3.1 and Figures 3.1a, 3.2a, and 3.4a). The photosynthetic rate was significantly decreased by high temperature (28 %), salinity (17 %) and combined high temperature and salinity stress (40 %) (Figures 3.1a, 3. 2a, 3.4a). Genotypes responded differently to the stresses. Figure 3.3a shows that the genotypes GUYMON, TX04M410211 and TASCOSA had the highest level of leaf photosynthesis. Temperature and genotype interaction also affect leaf photosynthesis Fig. 3.5a shows the percent reduction over the control in all genotypes due to high temperature. GUYMON, TX04M410211 and TASCOSA had the lowest reduction of leaf photosynthesis, which was about 24 %, whereas other genotypes had reductions of 30 %. Salinity and genotype interaction decreased leaf photosynthesis by 11 % in genotype TASCOSA as lowest reduction and 21% in genotypes 2174-05 and CO04W320 as the highest reduction (Fig. 3.6a). The interactions of high temperature, salinity and genotypes reduced leaf level photosynthesis in all genotypes with genotypes GUYMON, TX04M410211 and TASCOSA having the lowest reduction (Fig. 3.7a).

Stomatal conductance was significantly affected by high temperature, salinity and combined stresses (Table 3.1). Results of the effect of high temperature, salinity and combined high temperature and salinity stress on stomatal conductance are presented in (Table 3.1 and

Figures 3. 1b, 3.2b, and 3.4b). The mean values of stomatal conductance were 0.68 mmol m^{-2} s^{-1}. stomatal conductance was significantly decreased by high temperature 56 %, high salinity level 28 % and combined stresses 66 % (Figures 3.1b, 3.2b, 3.4b), which indicates decreased stomatal conductance due to high temperatures, salinity and their interaction. Genotypes responded differently to the stresses. The values of stomatal conductance ranged between 0.73 and 0.65 mmol m^{-2} s^{-1}. The result showed that genotypes GUYMON, TX04M410211 and TASCOSA had the lowest reduction (Fig 3.3b and Table 3.1). High temperature and genotype interaction had no significant effect on stomata conductance. Salinity and genotype interaction also affect stomata conductance where stomata conductance reduced by 20 % in genotypes GUYMON, TX04M410211 and by 34 % in genotype 2174-05 (Fig. 3.6b). In addition, high temperature, salinity and genotypes interactions significantly affected stomata conductance in all genotypes tested (Table 3.1 and Fig. 3.7b).

Significant differences were observed in maximum quantum yield of PS II by high temperature and salinity. The genotypes were also significantly ($P < 0.05$) differed themselves for maximum quantum yield of PS II (Table 3. 1). Values of Fv/Fm ratio were significantly decreased by high temperature 10 %, salinity 8 % and combined stresses 18 % (Figures 3.1c, 3.2c and 3.4c), which indicates decreased photochemical efficiency of PS II due to high temperatures, salinity and their interaction. Genotype also significantly effects maximum quantum yield of PS II in all genotype tested (data not shown). In addition, maximum quantum yield of PS II was significantly affected by temperature and genotype interaction (Table 3.1). However, salinity and genotype interaction as well as high temperature, salinity, and genotype interactions had no significant effect on maximum quantum yield of PS II (Table 3.1).

Thylakoid membrane damage (Fo/Fm) was significantly affected by high temperature salinity, genotype and combined stresses as well as their interactions (Table 3. 1). Values of Fo/Fm ratio were significantly increased by high temperature (19 %), salinity (10 %) and combined stresses (34 %) (Figures 3.1d, 3.2d, 3.4d.), which indicates increased thylakoid membrane damage due to high temperatures, salinity and their interaction. Genotype also significantly effects thylakoid membranes in all genotype tested. Figure 3.3c showed that genotypes TX04M410211 and TASCOSA had the lowest value of thylakoid membrane damage, whereas genotype OK05108 had the highest membrane damage. In addition, thylakoid membrane damage was significantly affected by temperature and genotype interaction (Fig. 3.5c). The result indicated that genotypes had diverse response to high temperature. The percent increase in membrane damage was 12 % in GUYMON and 25 % in ONAGA. Salinity and genotype interaction also affected membrane damage in all genotypes tested (data not shown), and the same trend was found in high temperature, salinity and genotype interactions (Table 3.1), where all genotypes show varied respond in increased thylakoid membrane damage due to high temperature x salinity interaction (data not shown).

Chlorophyll concentration was significantly affected by high temperature, salinity and combined stresses (Table 3.1). Values of SPAD unit were significantly decreased by high temperature 9 %, salinity 7 % and combined stresses 14 % (data not shown), which indicates decreased chlorophyll concentration due to high temperatures, salinity and their interaction. Genotypes responded differentially to high temperature and salinity (data not shown). Interaction effect of salinity and genotype; and high temperature, salinity and genotype was also significant on chlorophyll concentration (Fig 3.7c). However; high temperature and genotype interaction had no effect on chlorophyll concentration (Table 3.1)

Biochemical Traits

Analysis of variance for soluble sugars, reducing and non- reducing sugars, starch, proline, soluble proteins and MDA obtained with SAS PROC MIXED are presented in table 3. 2. The independent effects of temperature, salinity, and genotypes; and interaction effects of temperature x salinity were significant ($P < 0.0001$) for total soluble sugars, reducing and non-reducing sugars, starch, proline, soluble protein, and MDA contents (Table 3.2). Interaction effect of temperature x genotype was significant ($P < 0.05$) for total soluble sugars, reducing and non-reducing sugars, proline, soluble protein, and MDA contents. Interaction effects of salinity x genotype was significant ($P < 0.05$) for soluble sugars, proline, soluble protein, and MDA contents. Interaction effects of temperature x salinity; and temperature x salinity x genotype were significant ($P < 0.05$) for total soluble sugars, reducing and non-reducing sugars, proline, soluble protein, and MDA contents (Table 3.2).

Total Soluble Sugars, Reducing Sugars, Non-Reducing Sugars, and Starch Contents

The mean value of starch, soluble sugars, reducing sugars, and non-reducing sugars were, 75, 54, 21, and 80 gkg^{-1}, respectively The main effect of high temperature reduced starch content by 24 % and increased soluble sugar, reducing sugar, and non-reducing sugar, by 42, 49 and 25 %, respectively (Fig. 3.8a-d). Whereas, salinity stress reduced starch content by 10 % and increased soluble sugar, reducing sugar, and non-reducing sugar by 25, 23 and 30 %, respectively (Fig. 3.9a-d). The combination of high temperature and salinity also resulted in a significant decrease in starch content with about 34 % reduction over control and increase in soluble sugar, reducing sugar and non-reducing sugar which were about 84, 83, 86 % of control, respectively (Fig. 3.11a-d).

Genotype responded differently to stresses. Total soluble sugars ranged between 72 and 77 g/kg. The result showed that genotypes 2174-05, TX04M410211 and TASCOSA had the highest value in soluble sugar accumulations (Fig. 3.10a). High temperature and genotype interaction had significant effect ($P < 0.05$) on soluble sugar accumulation. Figure 3.12a shows the increase in soluble sugars accumulation in each genotypes due to high temperature effect. The result showed that genotypes OK05108 and GAGE had 47 % increase in soluble sugar. Salinity and genotype interaction also affect soluble sugar accumulations ($P < 0.0001$). Soluble sugars increased by 17 - 30 % across all genotypes, with ONAGA accumulating the highest amount of soluble sugars and TX86A5606 accumulating the lowest amount. In addition, high temperature, salinity and genotypes interactions significantly ($P < 0.0001$) affected soluble sugar accumulation in all genotypes tested (Fig. 3.14a). The genotype TASCOSA showed the best performance under combined stresses condition.

Genotypes responded differently to these stresses in term of reducing sugars with values of reducing sugars ranging between 51 and 56 g/kg. The result showed that genotypes AVALANCHE, TX04M410211 and TASCOSA had the highest value in reducing sugar accumulations (Fig 3.10b). High temperature x genotype interaction had significant effect ($P < 0.0001$) on reducing sugar accumulation. The results showed that in genotypes GAGE and TASCOSA the reducing sugars increased by 64 and 60 % respectively and by 40 % in CO04W320 and CARSON genotypes (Fig. 3.12b). Reducing sugar accumulation also increased due to salinity x genotype interaction. The interaction effect increased reducing sugar by 16-30 % in all genotypes, with genotype ONAGA, AVALANCHE and MTS0531 accumulated the highest quantity and genotype CARSON accumulated the lowest quantity. Reducing sugars significantly affected ($P < 0.01$) by temperature x salinity x genotypes interaction (Fig. 3.14b). The genotype

TASCOSA showed the best performance under combined stresses condition. Non- reducing sugars significantly (P < 0.0001) affected by high temperature, salinity and combination of high temperature and salinity stresses. The main effect of genotype significantly (P < 0.0001) affected non-reducing sugar accumulation. (Table 3.2). The values of non-reducing sugars ranged between 19 and 23 g/kg. Figure 3.10c show that genotypes ONAGA had the highest amount of non-reducing sugars accumulation as compared to other genotypes. High temperature x genotype interaction had significant (P < 0.0001) effect on non-reducing sugar accumulation. The result showed that in genotype 2174-05, the non-reducing sugars increased by 41 % and only by 7 % in CARSON genotype (Fig 3.12c). Salinity x genotype interaction had no effect on non-reducing sugars accumulations. On the contrast, high temperature x salinity x genotype interactions had significant (P < 0.05) effect on non-educing sugars accumulation (Fig. 3.14c). The genotypes GUYMON, ONAGA and 2174-05 showed the best performance under combined stresses condition. In addition, the amount of starch in wheat leaves were significantly decreased by high temperature, salinity and combined high temperature and salinity stress. Genotypes responded differentially to high temperature and salinity stress (data not shown). Interaction effect of high temperature x genotypes, salinity x genotype; and high temperature x salinity x genotype had no significant effect on starch content.

 Proline, Soluble Protein, and MDA contents

The mean value of proline, soluble protein and MDA were, 4 μmoles/g, 15 g/kg and 3 μmol/g, respectively. The main effect of high temperature resulted in a significant (P < 0.0001) increase proline soluble protein, and MDA content in almost all genotypes tested. High temperature increased proline, soluble protein and MDA 197 62 and 147 %, respectively (Fig. 3.15). While,

salinity stress increased proline, soluble protein and MDA by 83, 24, and 68 %, respectively (Fig. 3.16a-c). The combination of salinity stress and high temperature also resulted in a significant (P < 0.0001) increase in proline, soluble protein and MDA, which were 913, 95 and 450 % of control, respectively (Fig. 3.18a-c).

Proline content in all genotypes increased with increase in the level of temperature, salinity, and combined high temperature and salinity stress (Fig. 3.15a, 3.16a and 3.18a), and genotypes responded differently to the stresses as the values of proline ranged between 3.6 and 4.6 µmoles/g and genotype GUYMON, TX04M410211 and TASCOSA had maximum values for proline content as compared to the other genotypes. In contrast genotype MTS0531 possessed the least amount of proline (Fig. 3.17a). Temperature and genotypes interaction was significant (P < 0.0001) on proline accumulation. Salinity and genotype interaction had significant (P < 0.05) effect on accumulation of proline. Figure 3.19a showed that accumulation of proline increased in all genotypes with percent increase between 148-278 % in genotype CO04W320 and 2174-05, respectively. A percent increase between 52 and 95 % were recorded in CARSON and AVALANCHE genotype, respectively (Fig. 3.20a). An increase of proline accumulation was significant (P < 0.001) due to temperature x salinity and genotype interaction (Fig 3.21a). The genotypes GUYMON, TX04M410211 and TASCOSA showed the best performance under stress condition.

Salinity and high temperature significantly (P < 0.0001) increased total soluble protein concentrations in all genotypes (Fig. 3.15b and 3.16b) and a significant (P < 0.0001) interaction between salinity and high temperature was seen in term of total soluble protein. Protein content of all genotypes tested varied at high temperature and high salinity levels (120 mM NaCl) treatments when averaged across all genotypes (Fig. 3.18b). The values of soluble proteins ranged between

14 and 15 g/kg. Genotypes TX04M410211 and TASCOSA had the highest accumulation of soluble proteins and genotypes OK05108, GAGE, and CO04W320 had the lowest protein accumulation (Fig 3.17b). High temperature and genotype interaction effect was significant (P < 0.05), in which genotypes showed increase in soluble protein accumulation due to high temperature as compared to optimum temperature. Genotypes include GAGE, and ONAGA showed percent increase of about 70 %, and genotype CO04W320 showed 52 % percent increase in protein accumulation. (Fig. 3.19b). Salinity and genotypes interaction had significant (P < 0.0001) effect on protein accumulation. Figure 3.20b showed that genotypes GUYMON possessed maximum values with percent increase of 38 % followed by genotype TASCOSA 36 % increase in soluble protein content as compared to the other genotypes. In contrast genotype CARSON possessed the lowest amount of protein with increase of 17 % of soluble protein. Also high temperature, salinity and genotypes interactions had significant (P < 0.05) effect on soluble protein accumulation (Fig. 3.21b). The genotypes GUYMON, TASCOSA, and TX04M410211 showed the best performance under combined stresses condition.

The main effect of high temperature, salinity, and genotypes resulted in a significant (P < 0.0001) increase in MDA production. An enhanced level of lipid peroxidation was observed in wheat leave with increase of 147 % in response to high temperature, 68 % in response to salinity, and 450 % in respond to combined high temperature and salinity stress when averaged across genotypes (Fig. 3.15c, 3.16c and 3.18c). MDA values ranged between 2.7 and 3.3 (µmol/g). Figure 3.17c showed that genotypes GUYMON, TASCOSA, and TX04M410211 accumulated less MDA and genotypes GAGE and MTS0531 accumulated high amount of MDA. High temperature and genotype interaction significantly (P < 0.0001) increased MDA content in wheat leaves. An increase of 155 % in MDA was seen in genotype AVALANCHE due to high temperature, whereas

genotypes GUYMONE accumulated less MDA (134 %) under the same condition (Fig. 3.19c). Salinity and genotype interaction was also significant (P < 0.001). MDA induced in all genotypes due to high salinity level. An increase of 74 % was seen in genotypes TX86A5606 and the lesser increase 62 % was seen in genotype TASCOSA (Fig. 3. 20c). Also high temperature, salinity and genotypes interactions had significant (P <0.05) effect on MDA production (Fig. 3. 21c). The genotypes GUYMON and TASCOSA showed the best performance as they accumulate less MDA under combined stresses condition.

Growth and Yield Traits

The mean effect of high temperature was significant (P < 0.0001) on plant height, tiller number, number of spike, spike length, spikelet number, dry weight, grain number, individual grain weight, grain yield, and harvest index (Tables 3.3, 3.4, and 3.5). The mean effect of salinity was significant (P < 0.0001) on spikelet number, dry weight, grain number, individual grain weight, grain yield, and harvest index, and it was significant (P < 0.05) for plant height, tiller number, number of spike, and spike length. The interaction effect of high temperature and salinity was significant (P < 0.05) on spike length and grain number per spike, and it was significant (P < 0.0001) for spike length, spikelet number, grain yield, and harvest index. However, plant height, number of tiller, number of spike, biomass dry weight, and grain number per plant were not significantly influenced by combined high temperature and salinity stress. The main effect of genotype was significant (P < 0.0001) on plant height, tiller number, number of spike, spikelet number, and grain number, and it was significant (P < 0.05) for dry weight, grain number per spike, grain yield, and harvest index. High temperatures x genotype interaction was significant (P < 0.05) on spikelet number, grain number, grain yield per spike. Salinity x genotype interaction and high temperature x salinity x

genotype interactions had not significant effect on all yield traits measured in the experiment (Table 3. 3)

The main effect of high temperature, salinity, genotype, and combined stresses of high temperature and salinity stress significantly ($P < 0.0001$) decreased spikelet number per spike by 22, 17 and 35 %, respectively (Figures 3.22a, 3.23a, and 3.25a). The same trend ($P < 0.0001$) was found in the effect for high temperature, salinity, and genotype on grain number per plant. Figures (Figures 3.22b, 3.23b, and 3.25b) showed number of grains per plant significantly decreased due to high temperature, salinity, and combined stresses by 30, 21 and 46 %, respectively. Also high temperature, salinity, and combined stresses significantly decreased individual grain weight by 27, 19 and 39 %, respectively. Grain yield per plant significantly ($P < 0.0001$) decreased by 49, 36 and 67 % due to high temperature, salinity, and combined high temperature and salinity stress respectively (Figures 3.22ac 3.23c, and 3.25c). In addition, the main effect of high temperature, salinity, and combined high temperature and salinity stresses significantly ($P < 0.0001$) decreased harvest index by 42, 30, and 59 %, respectively (Figures 3.22d, 3.23d, and 3.25d).

Genotypes responded differently to the stress in term of spikelet number, grain number, and grain yield and harvest index. The value of spikelet number ranged between and 17 and 18 spikelet per spike, the value of grain number ranged between 226 and 256 grains per plant, the value of grain yield ranged between 8 and 10 gram per plant, and the value of harvest index ranged between 0.43 and 0.46. Figure 3.24a, b and c showed that genotypes such as GUYMON, TX04M410211 and TASCOSA had the highest value in term of spikelet number per spike, grain number per plant, grain yield per plant, and harvest index. Whereas, genotypes 2174-05, OK05108 and MTS0531 had the lowest value in term of spikelet number per spike, grain number per plant, grain yield per plant. High temperature x genotype interaction had significant ($P < 0.01$) effect

only on spikelet number, number of grain per spike and grain yield per spike (Table 3.3). Figure. 3. 26a, b, and c shows the percent reduction in spikelet number, number of grain per spike and grain yield per spike for all genotypes tested. Salinity x genotype interaction as well as temperature x genotype x salinity interactions showed no significant effect on all yield traits.

Discussion

Under natural conditions in arid and semi-arid regions, wheat plant mostly subjected to combined stresses of salinity and high temperature. Exposure to high temperatures and salinity stress may vary with the stage of plant development, but all vegetative and reproductive stages are affected by high temperature stress (Wahid et al., 2007) and salinity stress (Munns and Termaat, 1986; Maas and Grattan, 1999). Under high temperature and salinity stress condition, plants may subjected to water stress which may result in reduced in leaf photosynthesis and stomata conductance, damaged thylakoid membrane, reduced seed set, spikelet number per spike, and grain number per plant, harvest index and ultimate yield per plant. Under stress condition, plants are induced to synthesize many biochemical substances such as proline, sugars, and soluble proteins. Such biochemicals are called osmoprotectants (Hamada and Khulaef, 1995; Yang et al., 2009; Radi et al., 2013; Sabbagh et al., 2014).

In this study, we investigated the response of different winter wheat genotypes to an individual and combination of salinity and high temperature stress in order to evaluate the response of wheat to these stresses. The results suggest that there is genetic variability among winter what genotypes so that some genotypes were capable of adapting to salinity stress. More importantly, our results revealed that in addition to their ability to adapt to high salinity, these genotypes are also capable of adapting to high temperature stress also.

Elevated temperature and salinity directly affected photosynthetic enzymes and decreased gas exchange and light reactions (Wahid et al., 2007; Djanaguiraman et al., 2011; Sabbagh et al., 2014). Comparisons of leaf photosynthesis, stomata conductance, Fv/Fm, Fo/Fm, and chlorophyll concentration between high temperature, salinity, and a combination of salt stress and high temperature indicate that there was significant decrease of leaf photosynthesis, stomata conductance, chlorophyll concentration, Fv/Fm, and increase in Fo/Fm under a combination of salt stress and high temperature than under high temperature and/ or salinity individually. These results suggest that salt-stressed plants led to enhanced sensitivity of plants to high temperature. High temperature, salinity and the combination of salt stress and high temperature led to a decrease in stomatal conductance and such the decrease was greater under the combination of salt stress and high temperature than under high temperature alone. These results indicated that high temperature and the combination of salt stress and high temperature were accompanied by closing of stomata, which may cause reduction in CO_2 uptake by wheat leaves. In this study, photosynthetic rate, stomatal conductance and limitation to CO_2 uptake were decreased under salinity but severely dropped with the addition of high temperature stress. This finding agreed with a study that concluded that the combined stresses was much more severe on gas exchange and photosynthesis processes under combined stresses than individual stresses (Anjum et al., 2008; Dadkhah and Rassam, 2016). These results suggest that the combination of salinity stress and high temperature stress affects wheat plants differently than if salt stress or high temperature are applied individually. The interaction effect was hypo-additive (negative interaction) the combined effect (high temperature and salinity) was less than the sum of the individual effect (high temperature or salinity) on all physiological traits (Fig. 3.4a-d). In addition, the present study found that genotypes responded differently to the individual and combined stresses and that some genotypes such as

GUYMON, TX04M410211 and TASCOSA performed well under individual and combined stresses as compared to other genotypes (Fig. 3.3a-c). The tolerance of photosynthetic system to salinity may be related to the capacity of some plant species to successfully compartmentalize the salts in the vacuole (Sabbagh et al., 2014).

Salinity and high temperature induced an accumulation of sugars, proline, and soluble protein and reduction in starch content in wheat leaves. In fact, the accumulation of soluble compounds in plants has been widely reported as a response to salinity and temperature (Yang et al., 2009; Sabbagh et al., 2014; Dadkhah and Rassam, 2016). It is well known that soluble sugars play an important role in plant metabolism such as products of hydrolytic processes, substrates in biosynthetic processes, and energy production. The present study indicates that salinity and high temperature stress individually and/or in combination increased proline, soluble protein and soluble sugars. The increase in proline and sugar content may be due to osmotic regulation. Some plants are able to stand salinity by reducing the cellular osmotic potential as a result of a net increase in inorganic and solute accumulation (Yang et al., 2009; Sabbagh et al., 2014). Numerous studies have tried to link the increase of soluble carbohydrate to temperature stress tolerance (Radi et al., 2013) and salinity stress tolerance (Ashraf and Tufail, 1995). The present result is in agreement with other results on wheat seedling treated with high temperature and salinity, which also found that high temperature and salinity treatments resulted in a significant increase in soluble sugar, reducing and non-reducing sugar, soluble protein and proline in some genotypes (Hamada and Khulaef, 1995). The study herein reported that the interaction effect was additive or synergistic (positive interaction) the combined effect (high temperature and salinity) was higher than the sum of the individual effect (high temperature or salinity) on solute sugar accumulation (Fig. 3.11a-d). High temperature and salinity treatments resulted in a significant increase, in the total of soluble

sugar, reducing and non-reducing sugar in all genotypes, however there was a trend that some genotypes accumulated high amount of these carbohydrates. TX04M410211 and TASCOSA genotype were more tolerant to high temperature and salinity stress (Fig 3.10). Starch is the most abundant storage carbohydrate produced in plants. The result of this study found that starch contents in wheat leaves of all genotypes were reduced as a result of high temperature and salinity stress. The result herein agreed with a study on the effect of water stress on wheat plant (Saeedipour and Morad, 2011). The study reported that decreased starch content was due to decreased photosynthesis rate, also increased soluble sugars may have related to degradation of starch in wheat leaves. Another explanation of high sugar content in wheat leaves at the same time reduction in starch content may be due to the inhibition of distribution of these sugars to storage tissues. However, another study had reported contrasting result and stated that starch concentration of wheat leaves increased with increasing salinity (Dadkhah and Rassam, 2016).

Proline is critical for osmoprotection in many plants, and one of the most common responses of many plants subjected to abiotic stresses is the accumulation proline (Hare and Cress, 1997; Ashraf and Foolad, 2007). It has been reported that proline plays a protective role in plants exposed to stress and is thought to be acting as a cellular osmotic regulator and plays a role in ROS detoxification. (Hare and Cress, 1997; Ashraf and Foolad, 2007; Tatar and Gevrek 2008; Yu et al., 2015). In the present study an increase of proline was seen in all genotypes tested and that the interaction effect was hypo-additive (negative interaction) the combined effect (high temperature and salinity) was less than the sum of the individual effect (high temperature or salinity) on proline accumulation (Fig. 3.18a-c). Genotypic variation in proline accumulation under high temperatures were reported in this study as the increase was greater in GUYMON, TX04M410211 and TASCOSA genotypes and lowest in AVALANCHE and MTS0531 genotypes (Fig. 3.17a-c).

Similar result was obtained in another study reported that genotypic differences in proline accumulation under high temperatures were seen in 20 wheat genotypes (Ahmed and Hassan, 2011). In addition, many studies found that proteins play a key role in salt stress acclimation and plant cellular regulation as these proteins are utilized in many cellular processes associated with salt acclimation (Farooq et al., 2011; Kosová et al., 2013). In this study an increase in soluble proteins was found in all genotypes, however some genotypes accumulated more proteins than others. Other studies also agreed with this study and they concluded that soluble protein were increased under high temperature stress (Farooq et al., 2011) and under also in salinity stress condition (Radi et al., 2013). The MDA content is linked with the oxidization of the cell membrane and the content of MDA is often used as an indicator of lipid peroxidation resulting from oxidative stress. MDA has been considered an indicator of salt-induced oxidation in cell membranes and a tool for determining salt tolerance in plants (Ghafiyehsanj et al., 2013; Radi et al., 2013). In this study, MDA content were significantly increased by high temperature, salinity and combined stresses. However, the accumulation of MDA content was increased to a greater degree in some genotypes than in other genotypes, this suggest that within the genotypes tested there were some susceptible genotypes that accumulated more MDA such as MTS053 and GAGE; and some were tolerant genotypes include GUYMON, TX04M410211 and TASCOSA. Many studies agree that increasing MDA content is linked with increasing the degree of stress in wheat plants (Tatar and Gevrek, 2008; Mansoor and Naqvi 2013) and that plants that accumulate less MDA are more tolerant.

In wheat, yield is determined by the number of spikes per plant and yield components such as spikelet number, grain number and grain weight (El-Hendawy et al., 2005). The result from this study showed that spikelet number per spike had a positive and highly significant relationship with

grain yield under high temperature and salinity stress. This result agree with other studies, which concluded that there was a reduction of spikelet number per spike and grain number per spike and per plant under high temperature stress (Nahar et al., 2010; Pradhan et al., 2012; Narayanan et al., 2015), under salinity condition (Maas and Grieve, 1990; Sairam et al., 2002), under combined salinity and high temperature stress (Anjum et al., 2008)) and under combined high temperature and drought stress (Pradhan et al., 2012; Alghabari et al., 2015). The different yield components showed different responses to high temperature, salinity and combined stresses. The individual grain weight was least sensitive to salinity at booting stage. This is because of the fact that grain weight is determined between flowering and maturity, which was after the time of stress for the plants in this study. However, spikelet number and grain number were the most sensitive yield component at booting stage. This because of the fact that spikelet number and grain number are determined during the period of spike emergence to flowering, which in this experiment was the stress period. This result agreed with (El-Hendawy et al., 2005). The study herein reported that spikelet number per spike was reduced due to high temperature and salinity stress. This could be due to the fact that spikelet number initiation occurs at the vegetative stage and stress may have resulted in shortening the vegetative stage, in turn causing a reduction in number of spikelet per spike. This agreed with the another study which reported a positive correlation between the length of the vegetative phase and the number of spikelet number per spike and that the increase the duration of the vegetative stage of the apex induces more spikelet numbers per spike (Rahman et al., 1977). However, another study showed that the actual number of spikelet is determined by the length of the reproductive phase and reveled that short days from double ridge to terminal spikelet initiation stimulate a large number of spikelet (Rahman and Wilson, 1978). This suggests that assessment for combined stresses of high temperature and salt tolerance among genotypes can be

based on the genetic diversity in spikelet number per spike. The yield component (seed set and grain yield) reduction is positively related to some environmental conditions such as high temperature, drought, light and cold during the stem elongation phase until after anthesis (Prasad et al., 2008). Harvest index also had very significant relationship with grain yield under stress condition. The study found that grain yield and harvest index of the twelve wheat genotypes tested in this experiment significantly decreased with increasing temperature and salinity levels. The study revealed that genotypes include GUYMON, TX04M410211 and TASCOSA showed highest grain yield and genotypes 2174-05 and OK05108 showed the lowest grain yield and harvest index values. These results were similar to the results reported from other studies (El-Hendawy et al., 2005; Asgari et al., 2012, Prasad et al., 2008; Narayanan et al., 2015). These studies reported that grain yield and harvest index were reduced under stress and that the interaction effect was hypo-additive (negative interaction) the combined effect (high temperature and salinity) was less than the sum of the individual effect (high temperature or salinity) on grain yield and harvest index (Fig. 3.25a-d). From this study we found that genotypes who performed well under stress were the same genotypes that had high yield component. These genotypes had a high level of photosynthesis and high chlorophyll content, higher proline, soluble sugar and soluble protein content in their leave. A good explanation for that is that accumulation of osmo-protectant may have enhanced the maintenance of turgor by osmotic adjustment which may led to stomata opening and maintain CO_2 level to the level required for photosynthesis. In this study and based on grain yield reduction, genotype TASCOSA was the most tolerant to high temperature stress (46 % decline) and genotype GUYMON was the most tolerant to salinity stress (32 % decline) at booting stage. These genotypes are best adapted to the High Plains regions, which expected to have better drought tolerance and because high temperature and salinity are a dehydration stresses, therefore these genotypes were

high temperature and salinity tolerance. Whereas, genotypes CARSON was highly susceptible to high temperature stress (52 % decline) and AVALANCHE was highly susceptible to salinity stress (42 % decline) at booting stage.

Conclusions

In conclusion, high temperature 35 ºC and salinity 120 mM NaCl and their combined effects at booting stage were negatively influenced wheat growth and yield. Combined stresses was more damaging to wheat than the individual effect of each stress, which indicated that the interaction effect was additive. High temperatures, salinity and their interaction at booting stage, had negative effects on wheat physiology, biochemical, yield and yield component as indicated by the reduced leaf level photosynthesis, reduced chlorophyll content, starch content, increased sugars, proline and soluble proteins, increased MDA level, and reduced grain yield and harvest index. Also the study concludes that winter wheat genotypes diverse in their response to combination stress of high temperature stress and salinity stress. Genotypes GUYMON, TX04M410211 and TASCOSA were the more tolerant ones. There were some traits that can be selected for breeding programs such as photosynthesis rate, leaf chlorophyll content, grain number and weight. However, the screening for wheat genotypes can be based on characteristics related to high yields under stress condition. These criteria better be stable and easy to evaluate especially with the need to screen a high number of genotypes. Still, further research is needed to confirm these interaction effects with other wheat genotypes and under field condition.

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Figures and Tables

Figure 3-1 The main effect of high temperature on (A) leaf photosynthetic rate ($\mu mol\ m^{-2}\ s^{-1}$), (B) stomata conductance ($mmol\ m^{-2}\ s^{-1}$), (C) maximum quantum yield of PS II (Fv/Fm ratio; unit less), and (D) thylakoid membrane damage (Fo/Fm ratio; unitless) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, three replications of each genotype and three measurements taken on each plant on d 2, 5 and 10 d during the stress period. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase or decrease in each trait due to high temperature as compared to optimum temperature is indicated.

Figure 3-2 The main effect of salinity on (A) leaf photosynthetic rate ($\mu mol\ m^{-2}\ s^{-1}$), (B) stomata conductance ($mmol\ m^{-2}\ s^{-1}$), (C) maximum quantum yield of PS II (Fv/Fm ratio; unitless), and (D) thylakoid membrane damage (Fo/Fm ratio; unitless) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, three replications of each genotype and three measurements taken on each plant on d 2, 5 and 10 d during the stress period. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase or decrease in each trait due to salinity as compared to the control is indicated.

Figure 3-3 The effect of genotype on (A) leaf photosynthetic rate ($\mu mol\ m^{-2}\ s^{-1}$), (B) stomata conductance ($mmol\ m^{-2}\ s^{-1}$), and (C) thylakoid membrane damage (Fo/Fm ratio; unitless) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Separation of means was carried out using the LSD test ($P < 0.05$). Means with different letters are significantly different according to the LSD test at $P < 0.05$.
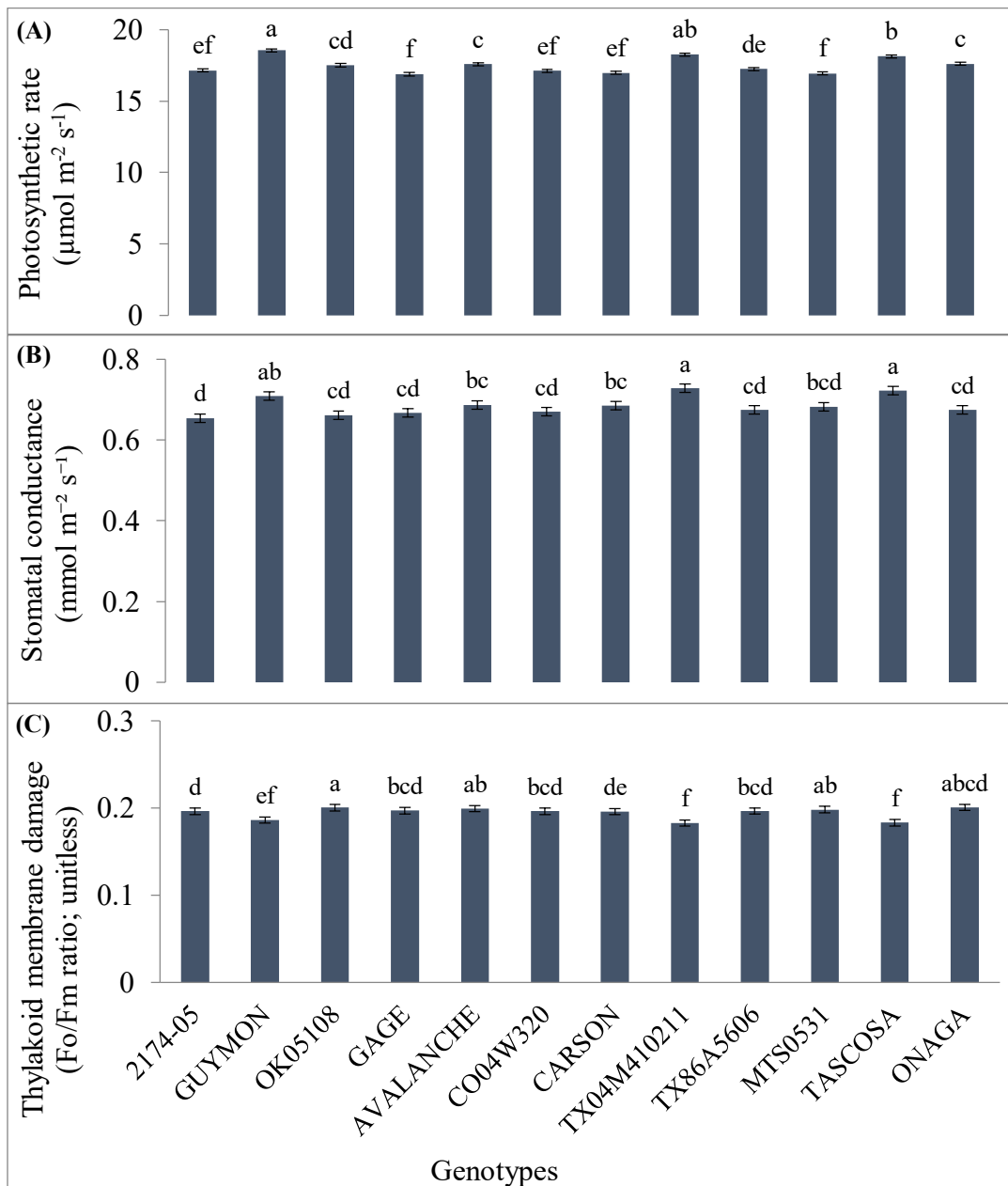
Figure 3-4 The effect of combined stresses of high temperature and salinity on (A) leaf photosynthetic rate (μmol m^{-2} s^{-1}), (B) stomata conductance (mmol m^{-2} s^{-1}), (C) maximum quantum yield of PS II (Fv/Fm ratio; unitless), and (D) thylakoid membrane damage (Fo/Fm ratio; unitless) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, three replications of each genotype and three measurements taken on each plant on d 2, 5 and 10 d during the stress period. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase or decrease in each treatment as compared to control is indicated.

Figure 3-5 The interaction effect of high temperature and genotype on (A) leaf photosynthetic rate (μmol m^{-2} s^{-1}), and (B) thylakoid membrane damage (Fo/Fm ratio; unitless) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, three replications of each genotype and three measurements taken on each plant on d 2, 5 and 10 d during the stress period. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase or decrease due to high temperature as compared to optimum temperature is indicated.
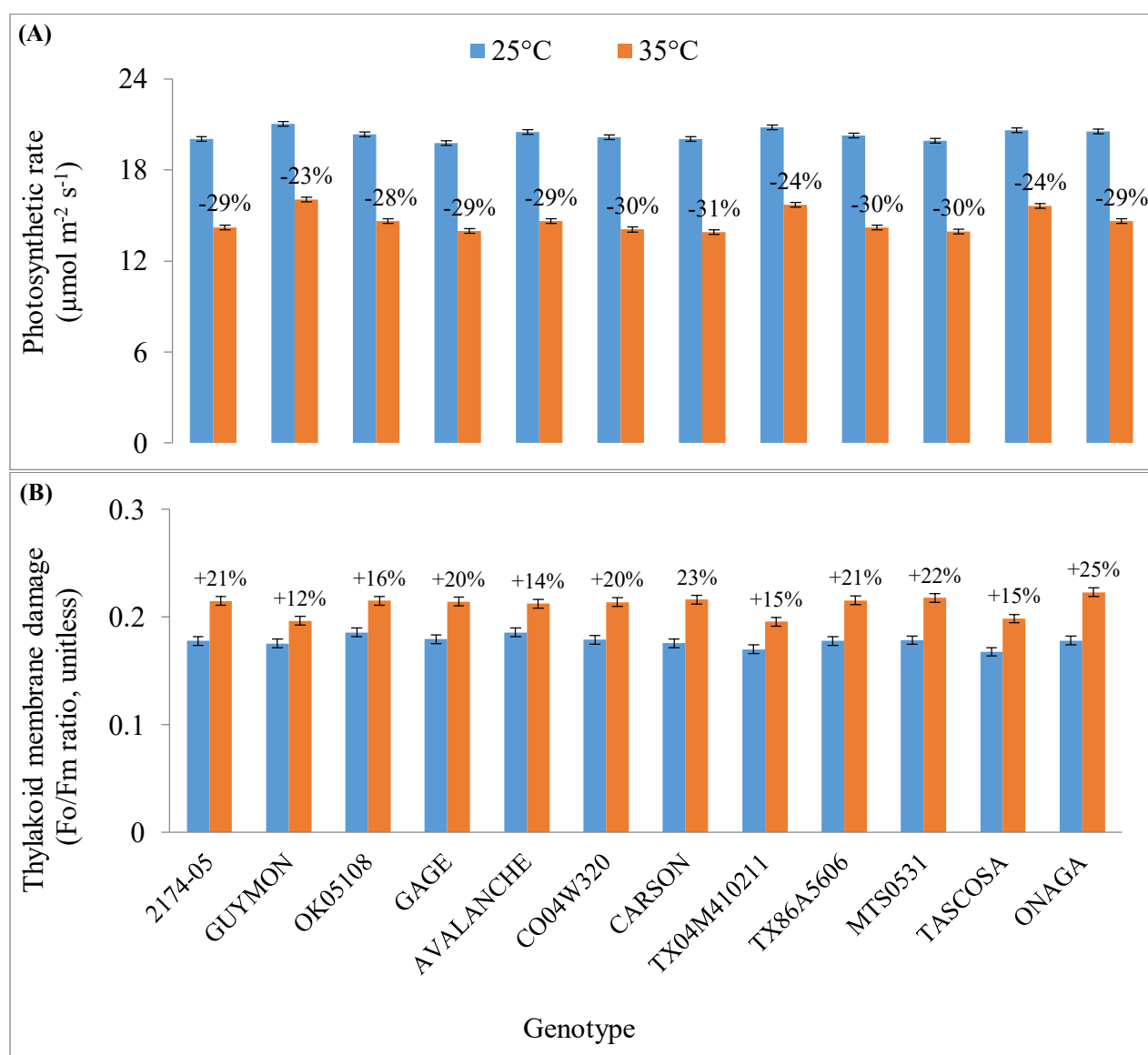
Figure 3-6 The interaction effect of salinity and genotype on (A) leaf photosynthetic rate (μmol m^{-2} s^{-1}), (B) stomata conductance (mmol m^{-2} s^{-1}), and (C) thylakoid membrane damage (Fo/Fm ratio; unitless) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, three replications of each genotype and three measurements taken on each plant on d 2, 5 and 10 d during the stress period. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase or decrease in each trait due to salinity as compared to the control is indicated.

Figure 3-7 The interaction of high temperature, salinity and genotype on (A) leaf photosynthetic rate (μmol m $^{-2}$ s $^{-1}$) (B) stomata conductance (mmol m^{-2} s^{-1}) and (C) chlorophyll index (SPAD units) of twelve winter wheat genotypes Data are averaged across two experiments, twelve genotypes, three replications of each genotype and three measurements taken on each plant on days 2, 5 and 10 d during the stress period. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS.
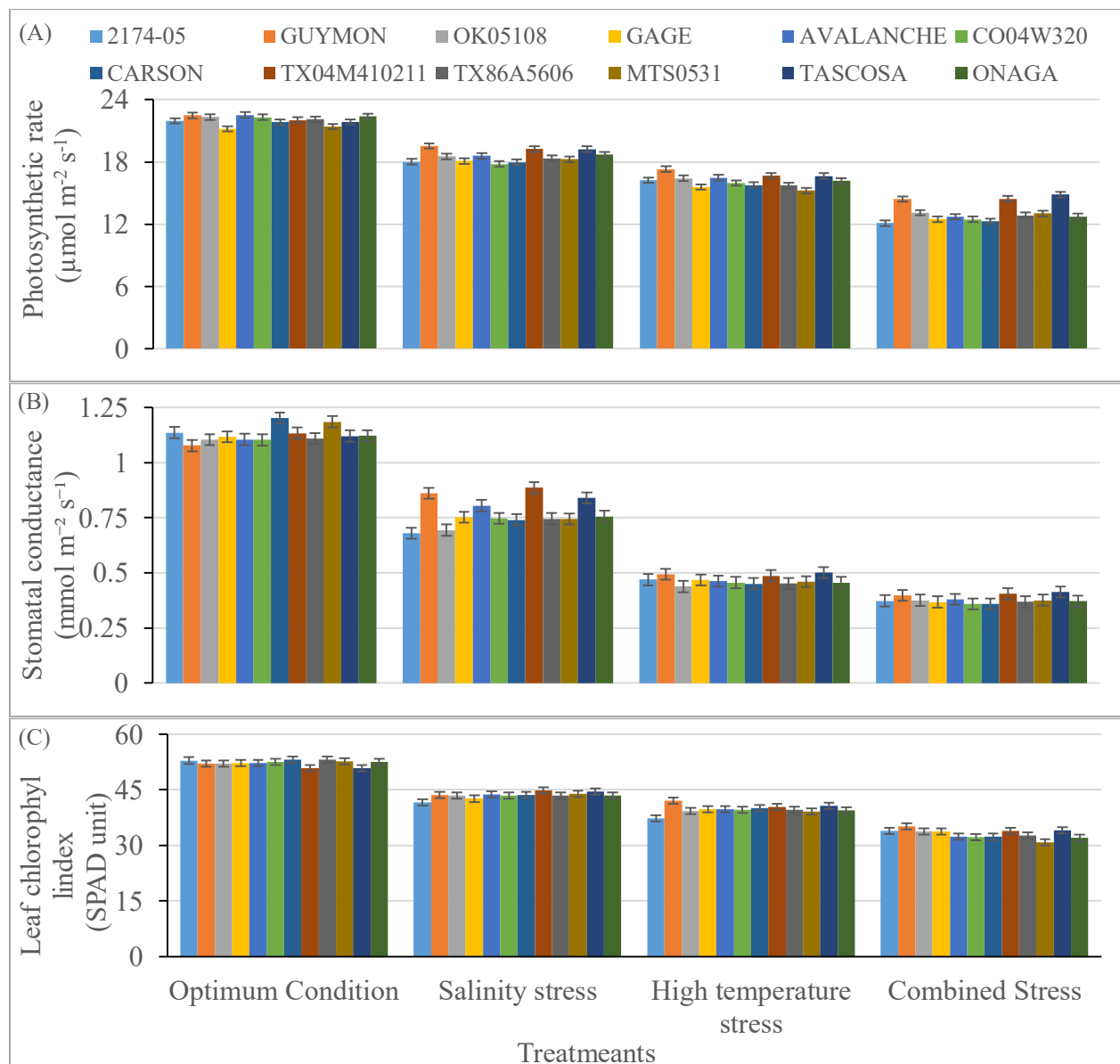
Figure 3-8 The main effect of high temperature on (A) total soluble sugar (g/kg), (B) reducing sugar (g/kg), (C) non-reducing sugar (g/kg), and (D) starch content (g/kg) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase or decrease in each trait due to high temperature as compared to optimum temperature is indicated.
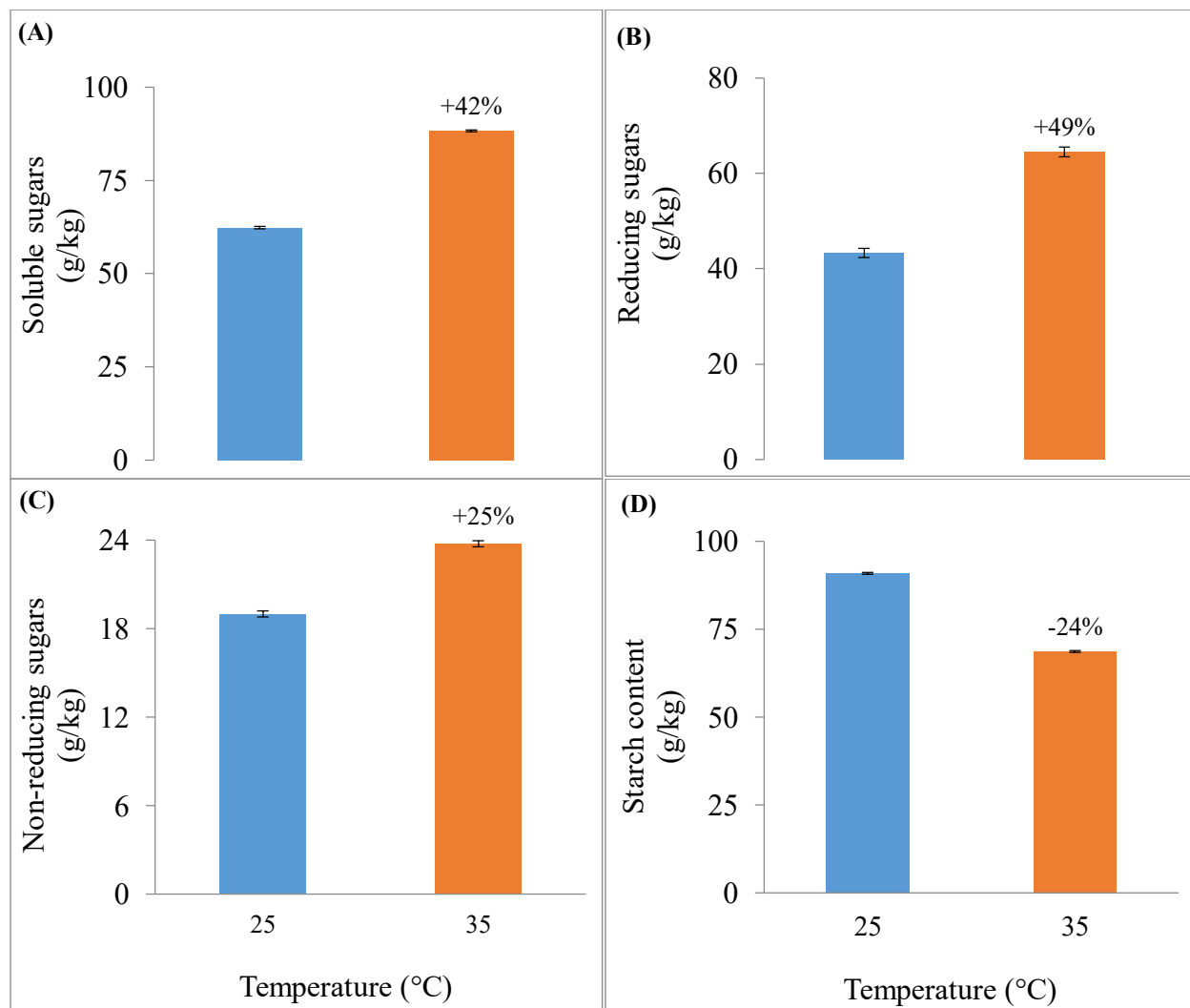
Figure 3-9 The main effect of salinity on (A) total soluble sugar (g/kg), (B) reducing sugar (g/kg), (C) non-reducing sugar (g/kg), and (D) starch content (g/kg) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase or decrease in each trait due to salinity as compared to the control is indicated.
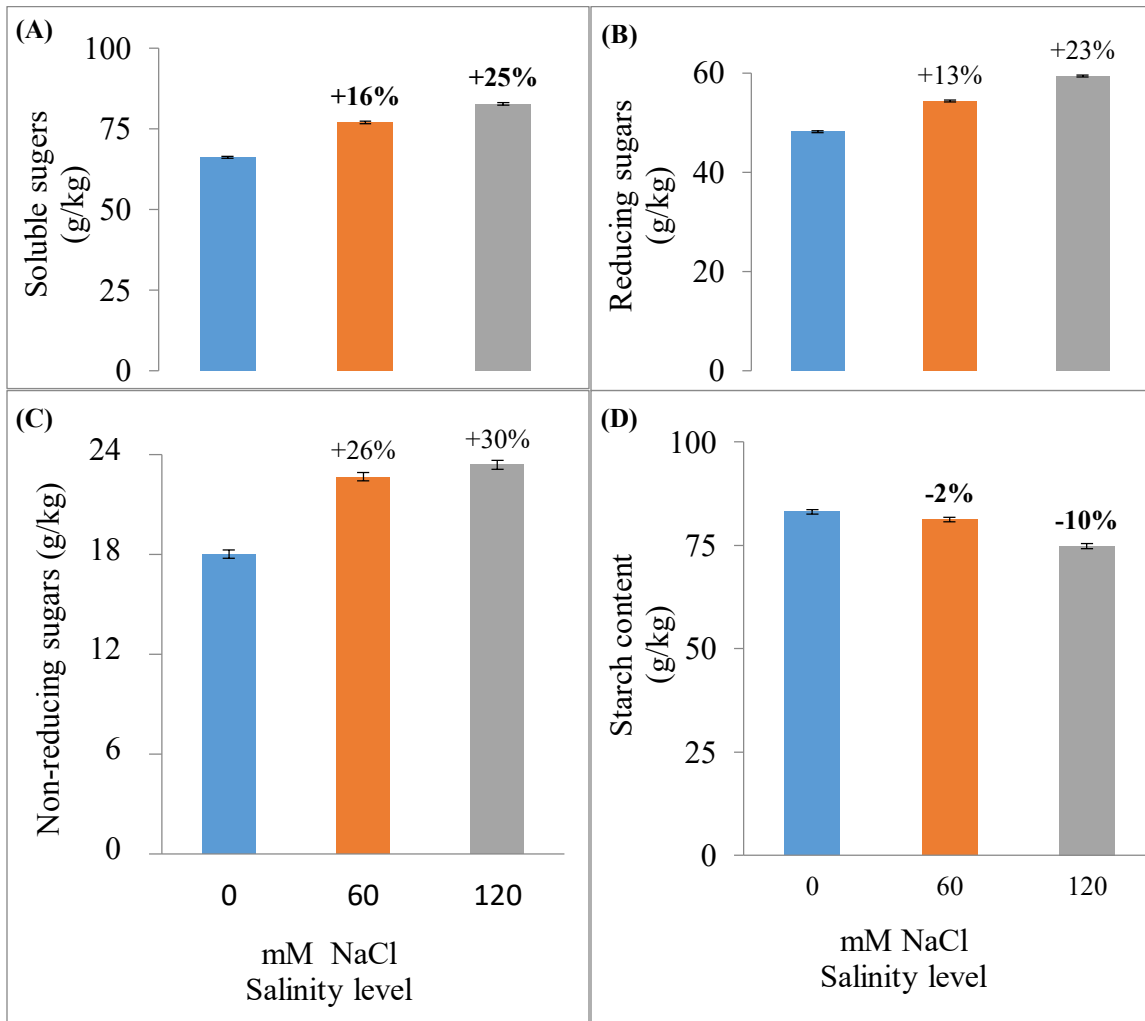
Figure 3-10 The main effect of genotype on (A) total soluble sugar (g/kg), (B) reducing sugar (g/kg), and (C) non-reducing sugar (g/kg) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Separation of means was carried out using the LSD test ($P < 0.05$). Means with different letters are significantly different according to the LSD test at $P < 0.05$.
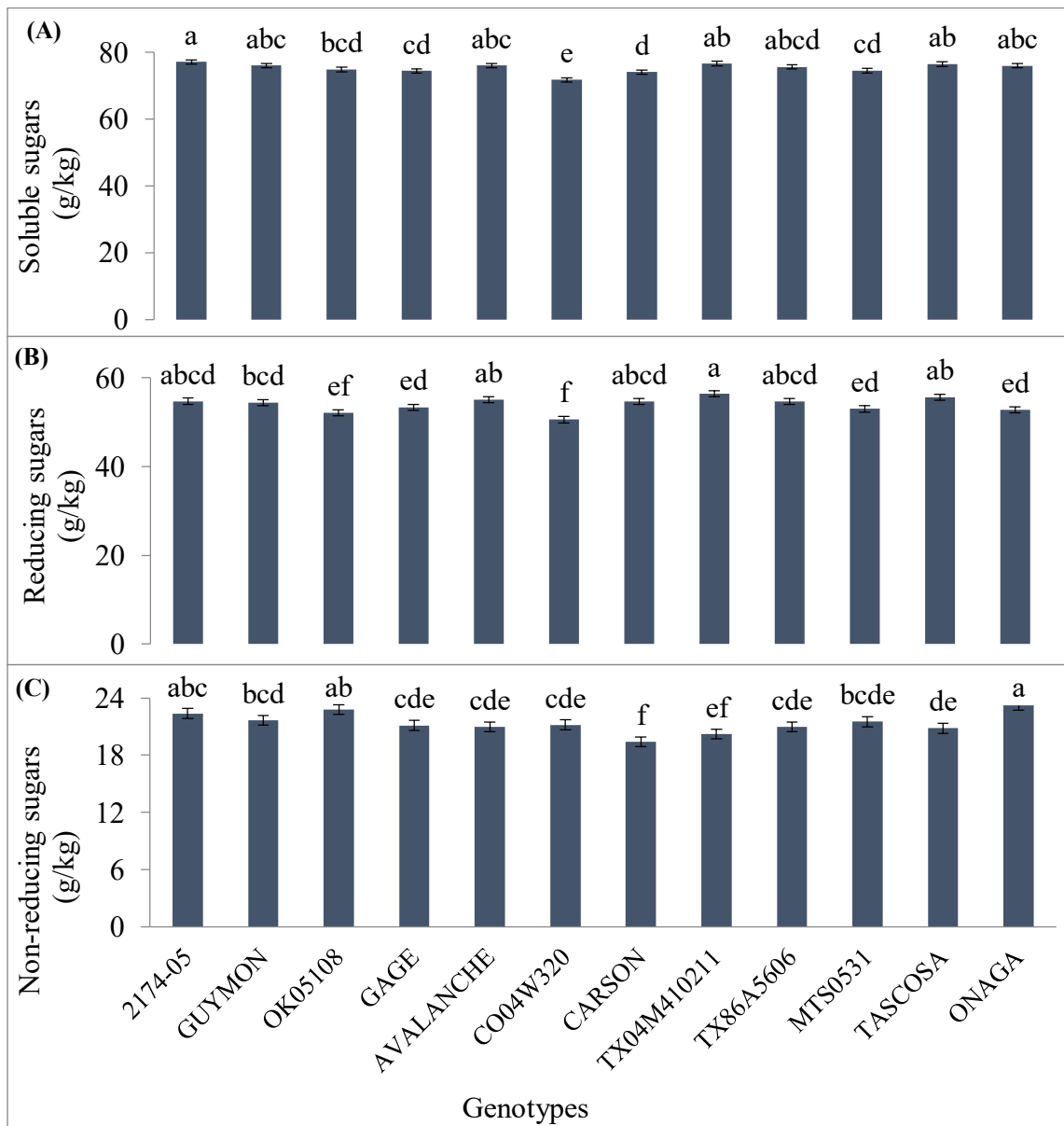
Figure 3-11 The interaction of combined stresses of high temperature and salinity on (A) total soluble sugar (g/kg), (B) reducing sugar (g/kg), (C) non-reducing sugar (g/kg), and (D) starch content (g/kg) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase or decrease in each treatment as compared to control is indicated.
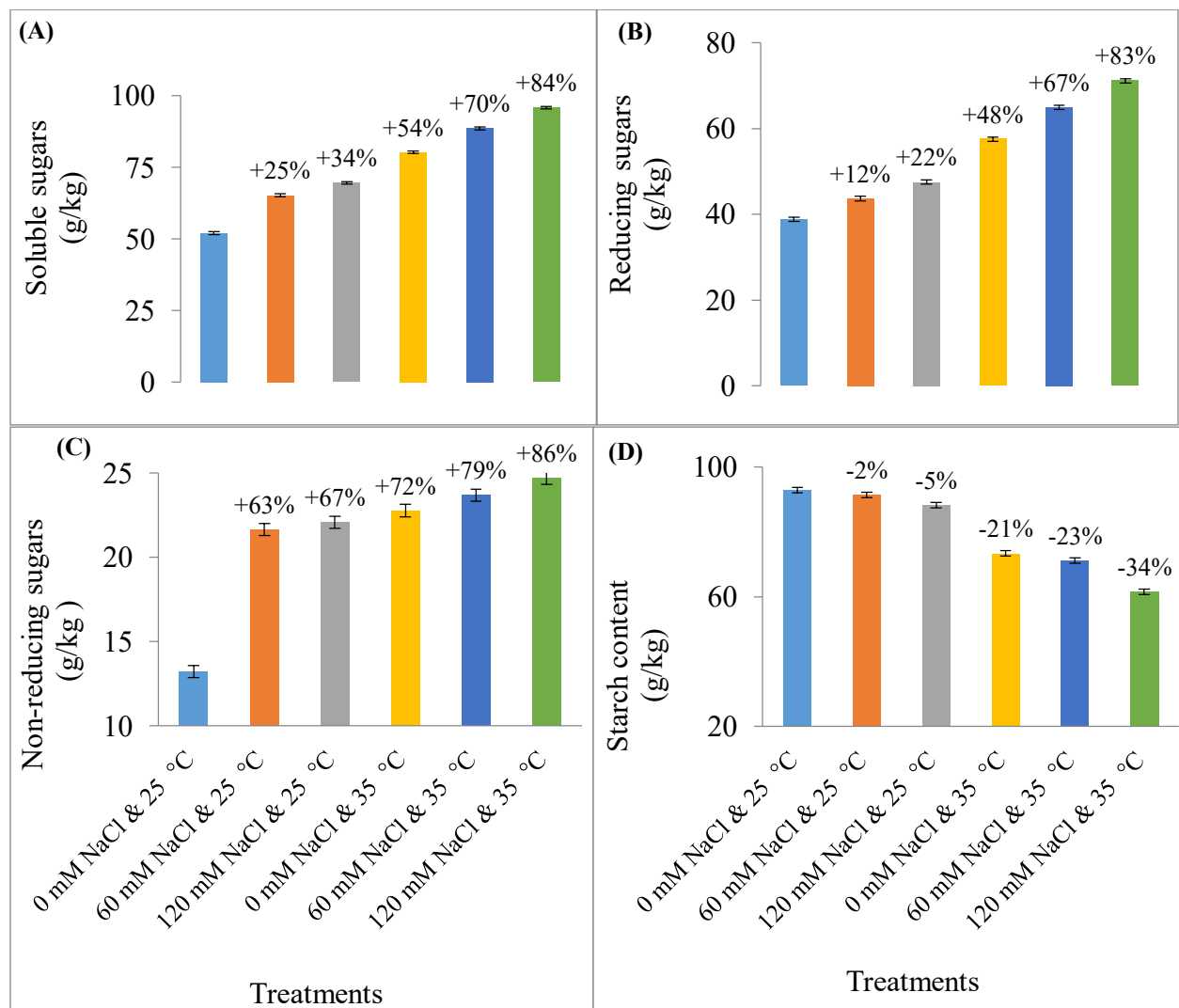
Figure 3-12 The interaction of high temperature and genotype on (A) total soluble sugar (g/kg), (B) reducing sugar (g/kg), and (C) non-reducing sugar (g/kg) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase in each trait due to high temperature as compared to optimum temperature is indicated on each genotype.
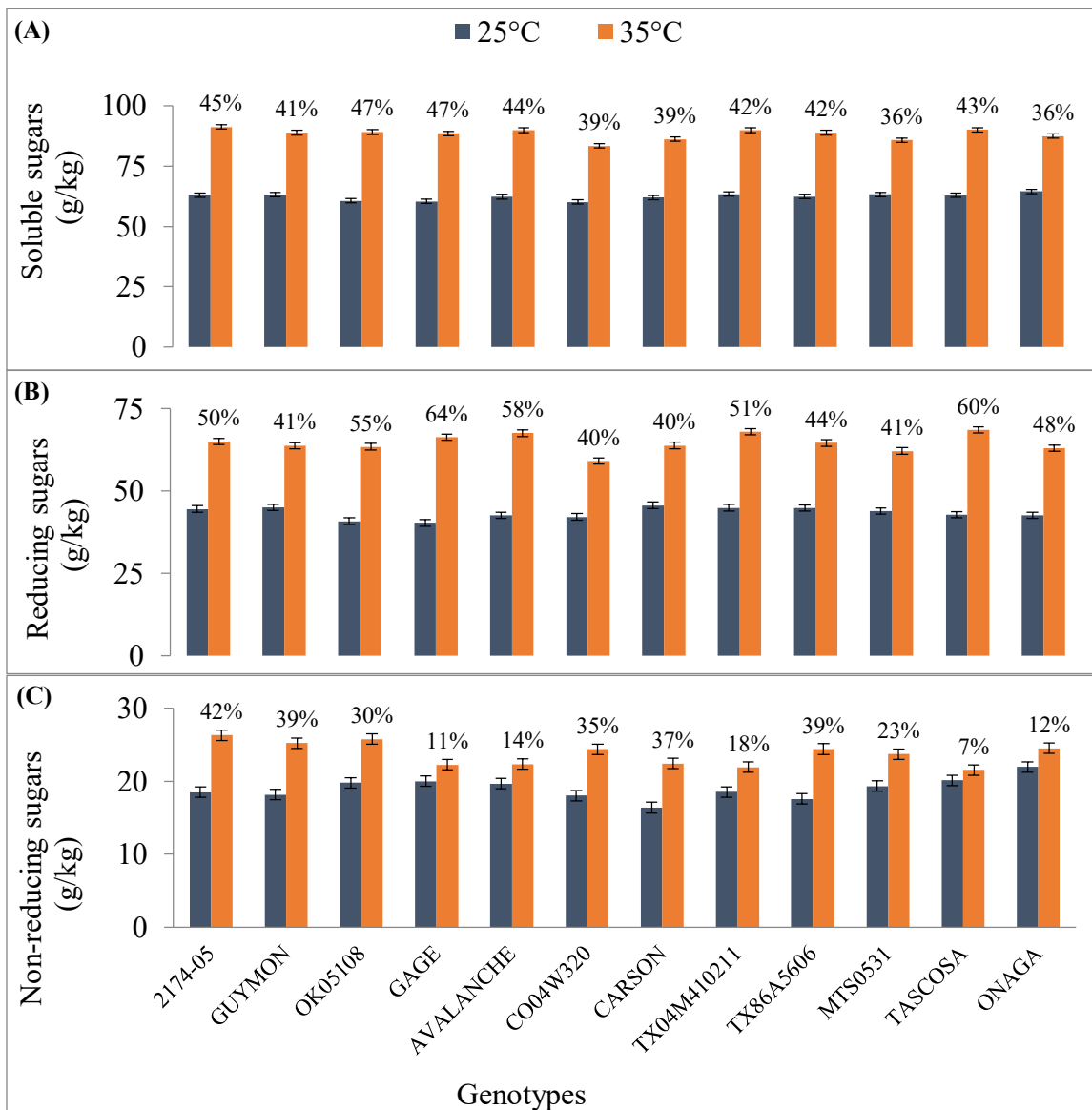
Figure 3-13 The interaction of salinity and genotype on (A) total soluble sugar (g/kg), (B) reducing sugar (g/kg) and (C) non-reducing sugar (g/kg) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase in each trait due to high salinity as compared to the control is indicated.
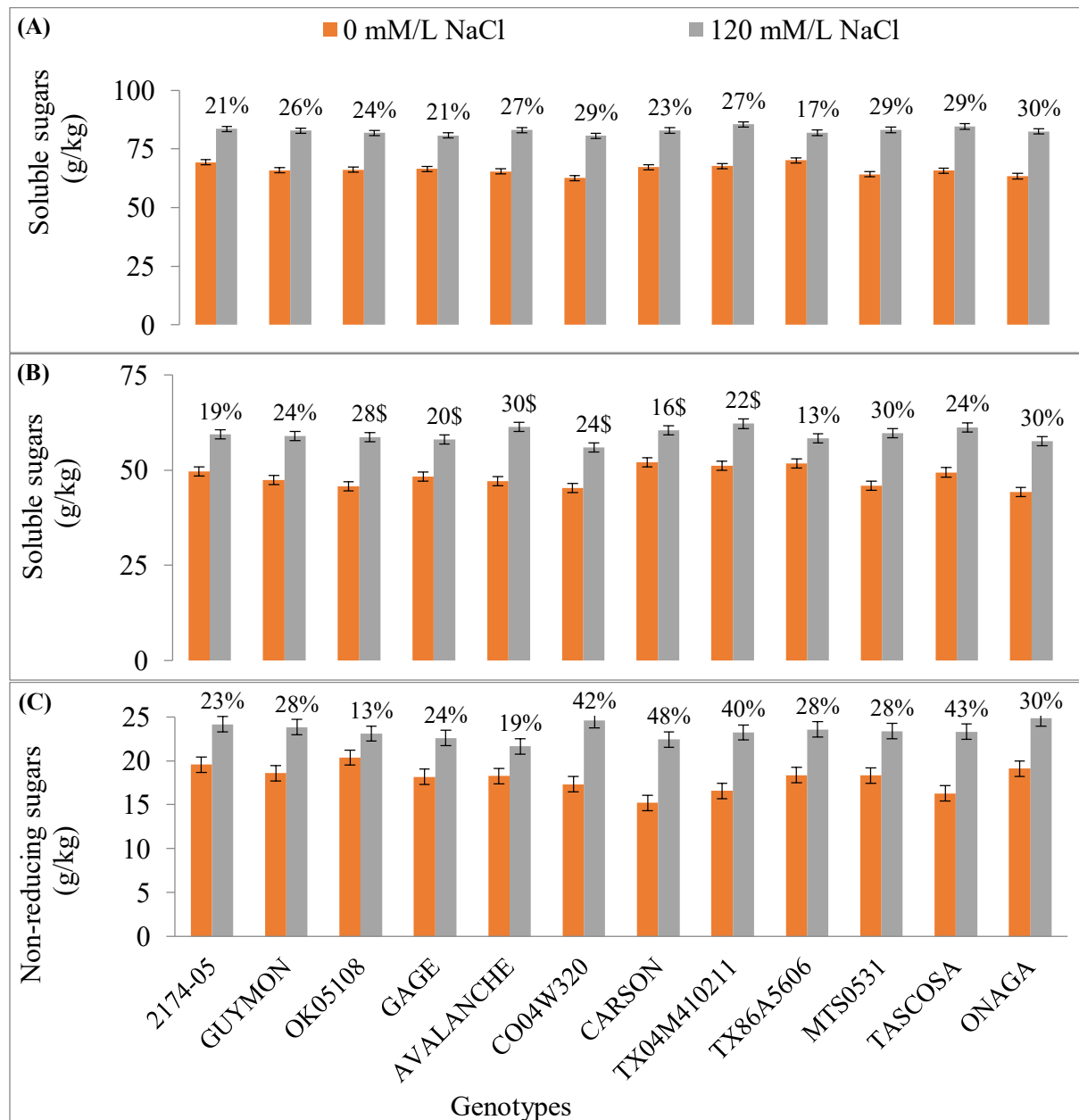
Figure 3-14 The interaction of high temperature, salinity and genotype on (A) total soluble sugar (g/kg), (B) reducing sugar (g/kg), and (C) non-reducing sugar (g/kg) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS.
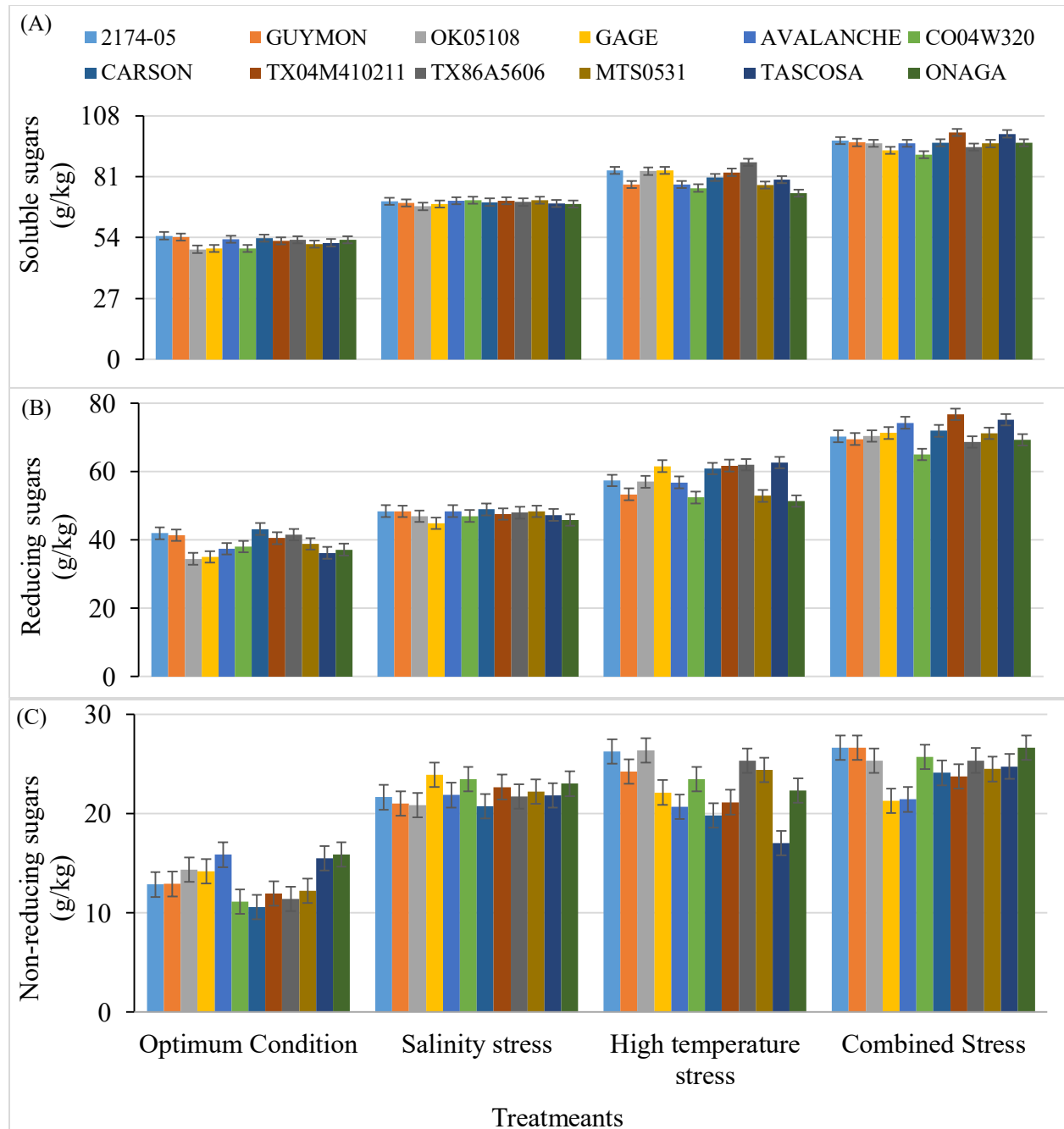
Figure 3-15 The main effect of high temperature on (A) proline content (μmoles/g), (B) soluble protein content (g/kg) and (C) MDA content (μmoles/g) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase in each trait due to high temperature as compared to optimum temperature is indicated.
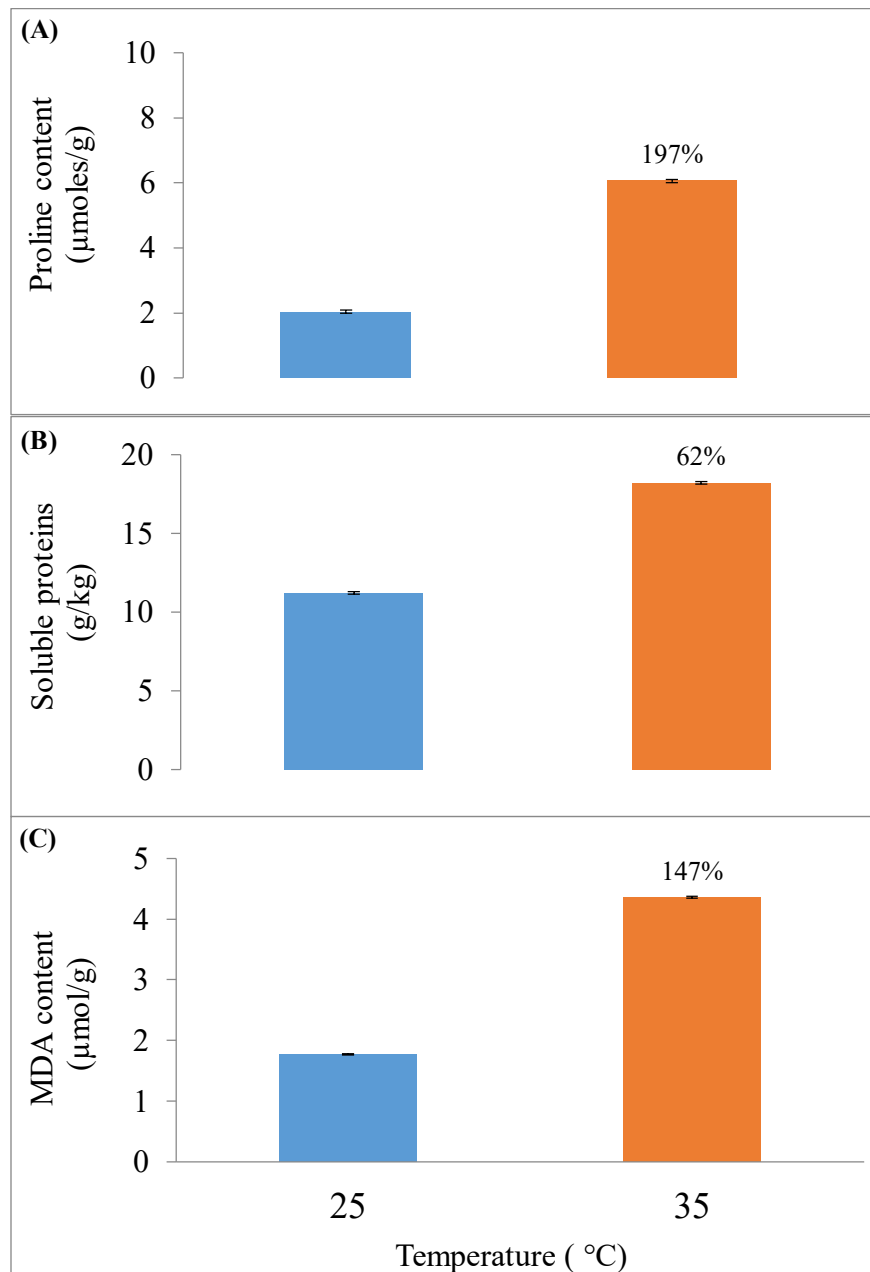
Figure 3-16 The main effect of salinity on (A) proline content (μmoles/g), (B) soluble protein content (g/kg) and (C) MDA content (μmoles/g) of twelve winter wheat genotypes Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase in each trait due to salinity as compared to the control is indicated.
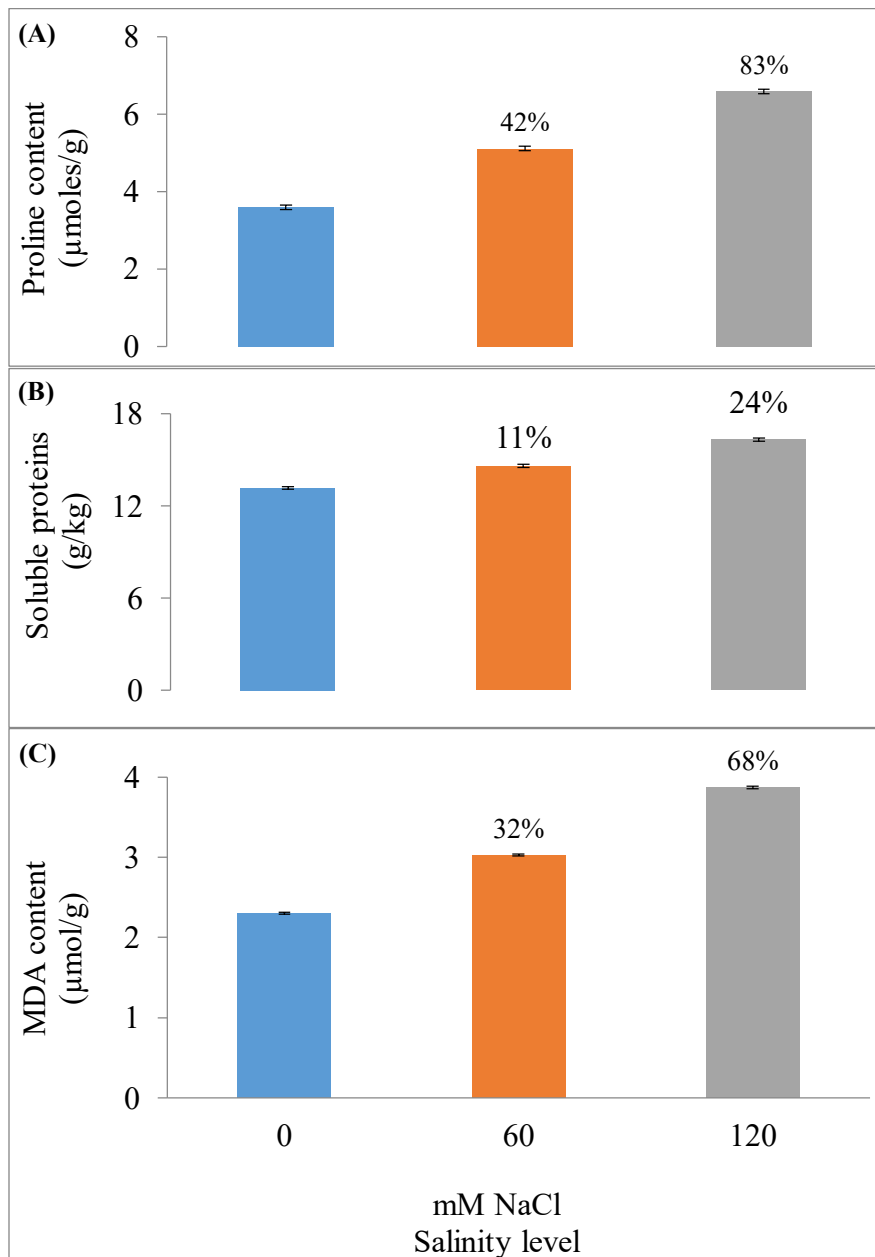
Figure 3-17 The main effect of genotype on (A) proline content (μmoles/g), (B) soluble protein content (g/kg) and (C) MDA content (μmoles/g) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means.. Separation of means was carried out using the LSD test (P < 0.05). Means with different letters are significantly different according to the LSD test at P < 0.05.
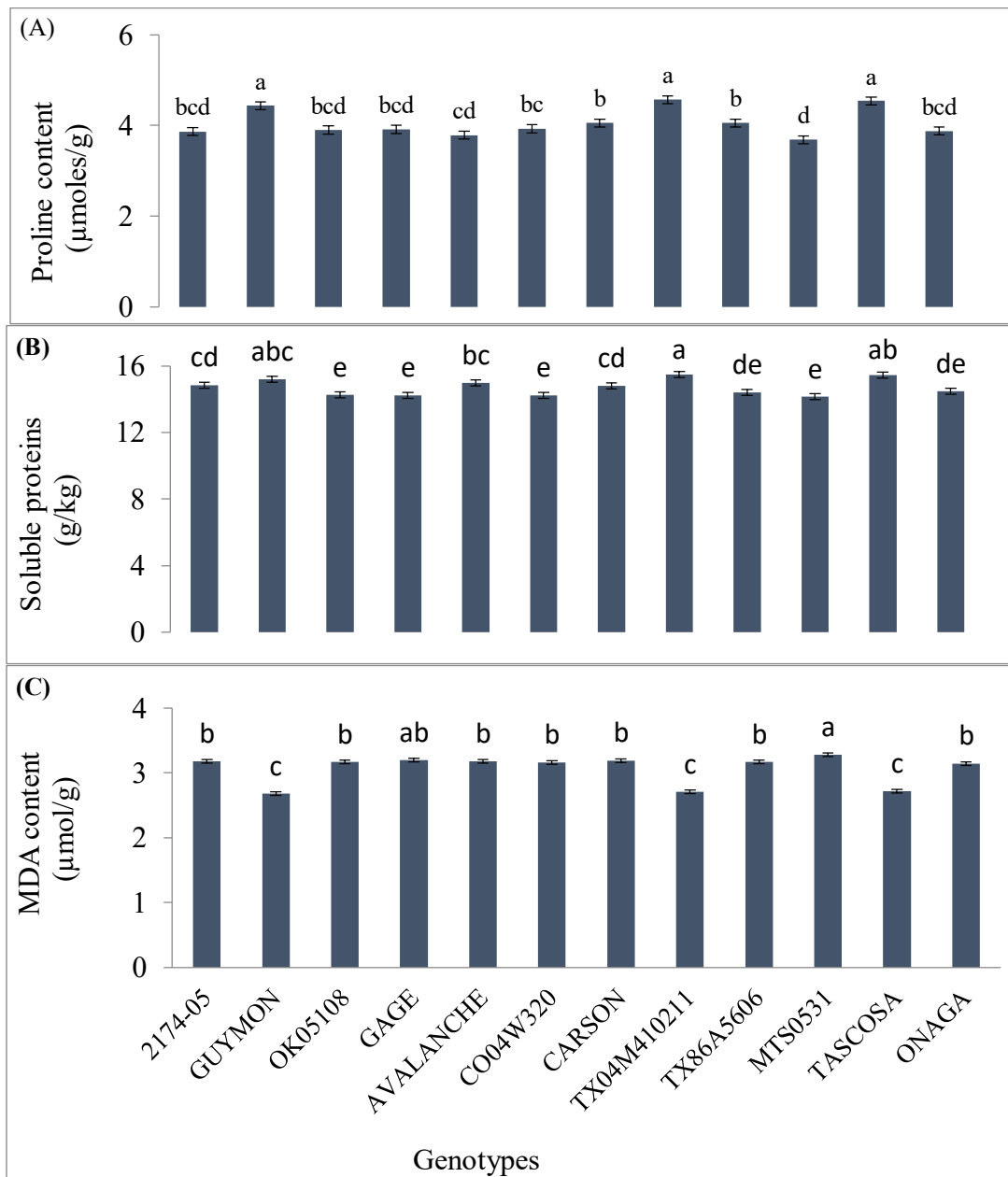
Figure 3-18 The interaction of high temperature and salinity stress on (A) proline content (µmoles/g), (B) soluble protein content (g/kg) and (C) MDA content (µmoles/g) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase in each treatment as compared to control is indicated.
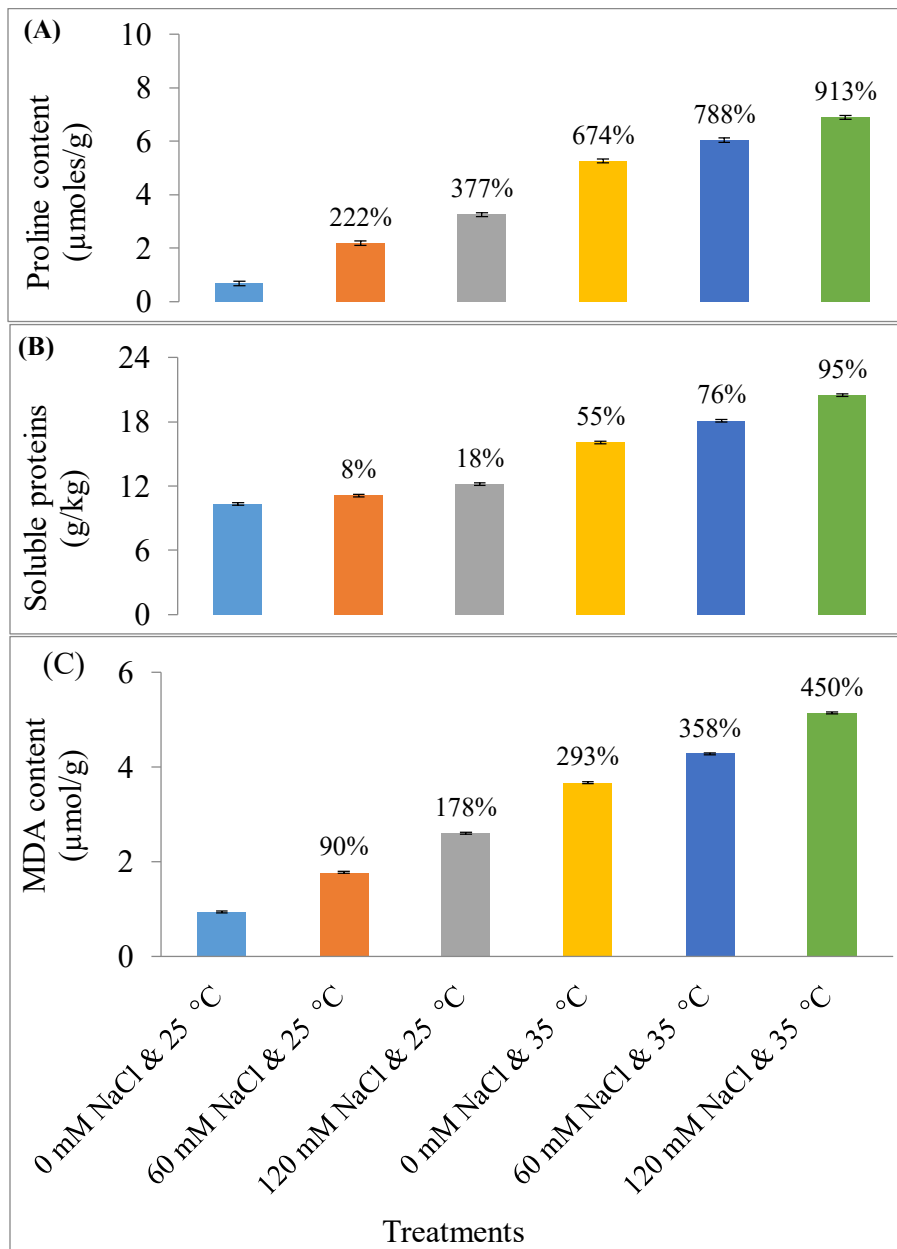
Figure 3-19 The interaction of high temperature and genotype on (A) proline content (μmoles/g), (B) soluble protein content (g/kg) and (C) MDA content (μmoles/g) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase in each trait due to high temperature as compared to optimum temperature is indicated on each genotype.
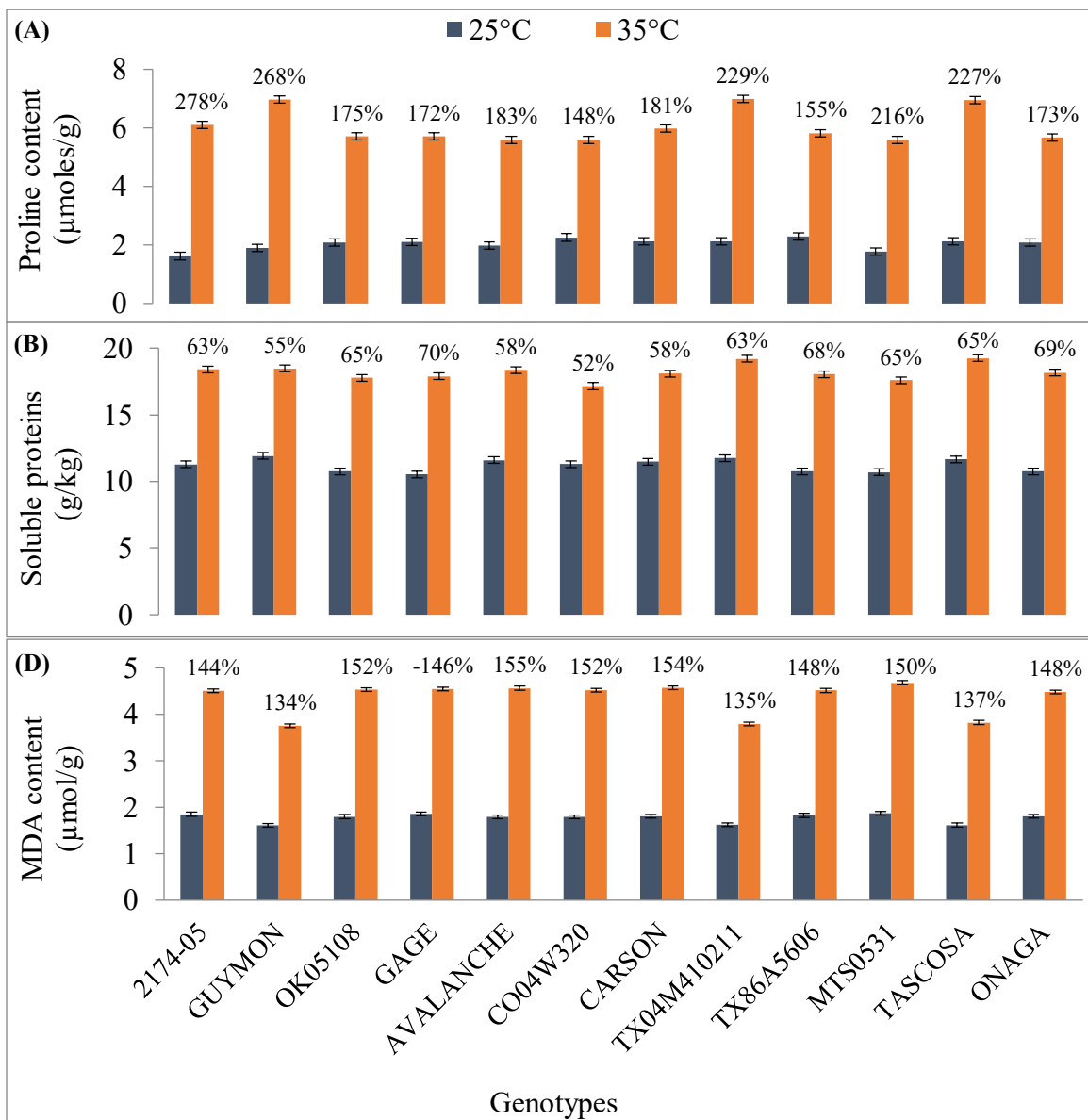
Figure 3-20 The interaction of salinity and genotype on(A) proline content (µmoles/g), (B) soluble protein content (g/kg) and (C) MDA content (µmoles/g) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase in each trait due to salinity as compared to the control is indicated.
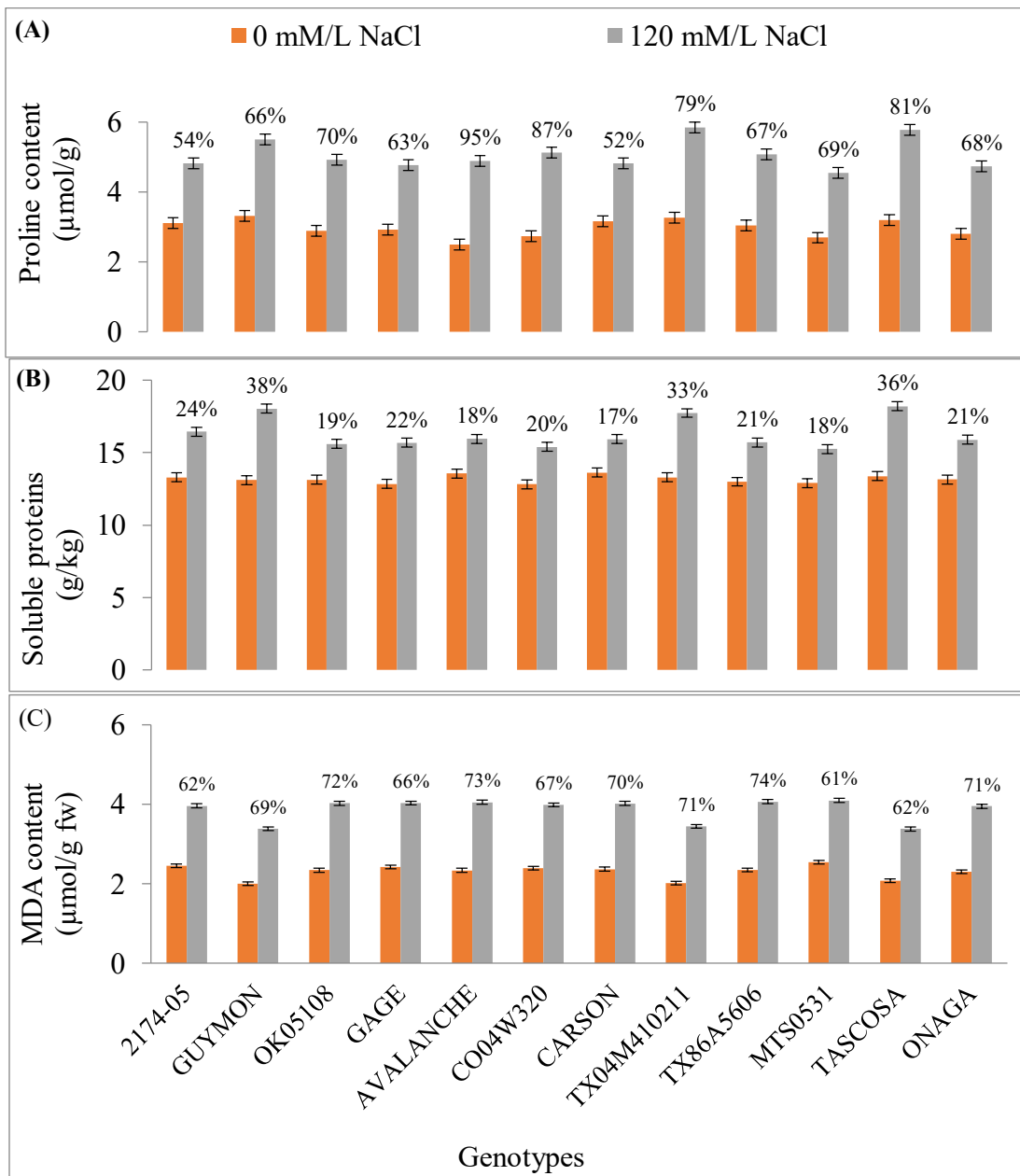
Figure 3-21 The interaction of high temperature, salinity and genotype on (A) proline content (µmoles/g), (B) soluble protein content (g/kg) and (C) MDA content (µmoles/g) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS.
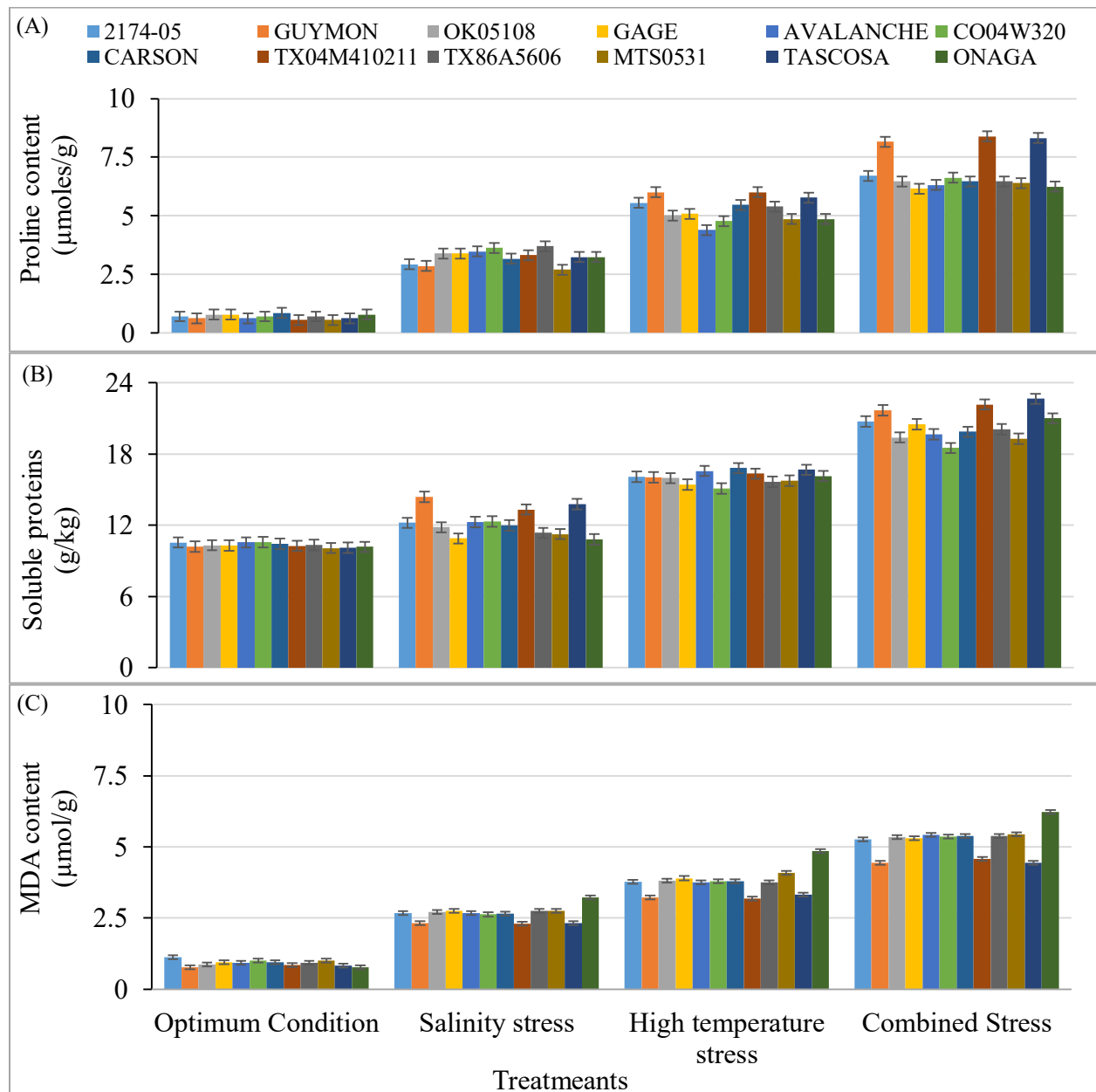
Figure 3-22 The main effect of high temperature on (A) spikelet number per spike, (B) grain number per plant, (C) grain yield per plant (g), and (D) harvest index of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent decrease in each trait due to high temperature as compared to optimum temperature is indicated.
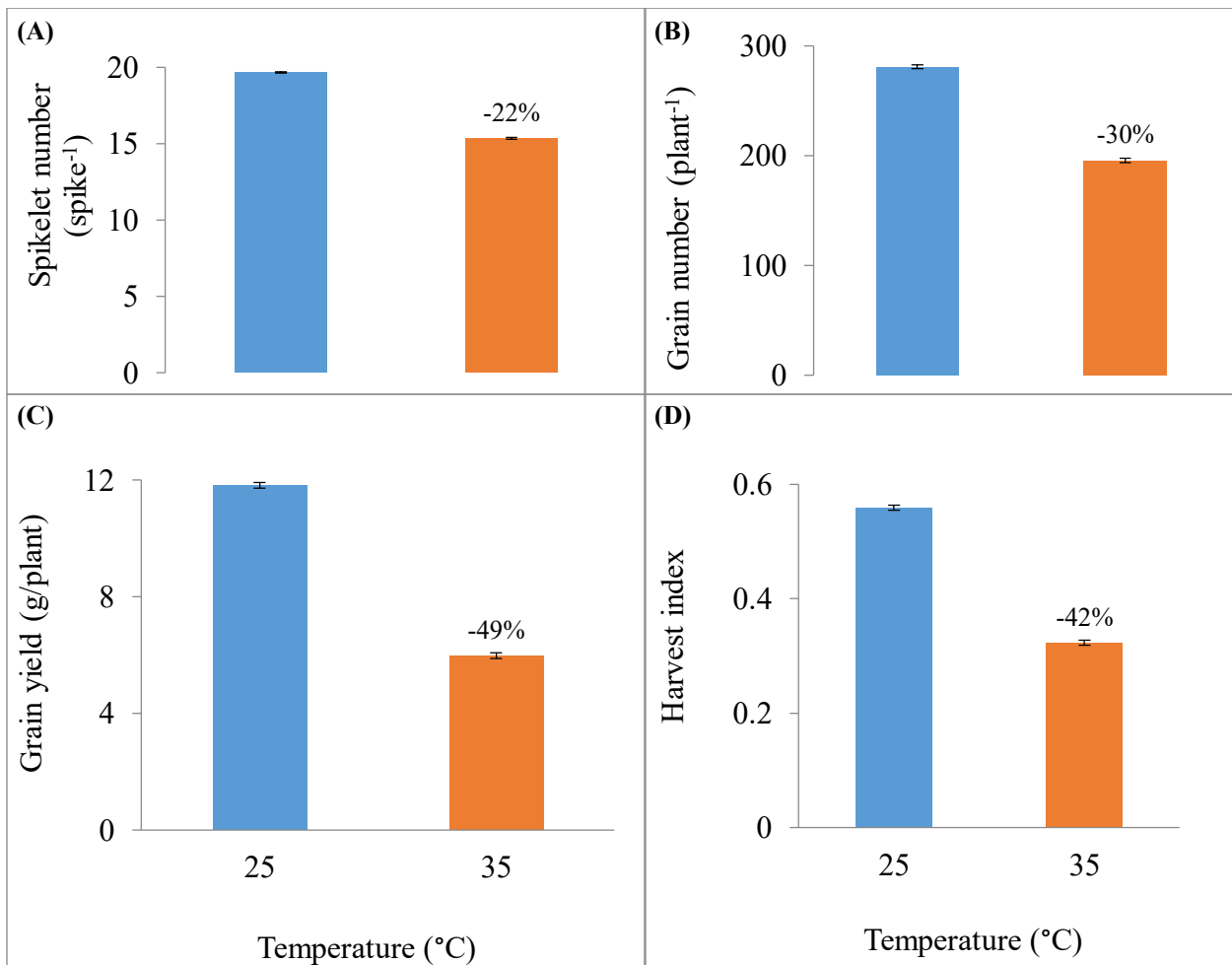
Figure 3-23 The main effect of salinity on (A) spikelet number per spike, (B) grain number per plant, (C) grain yield per plant (g), and (D) harvest index of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent decrease in each trait due to salinity as compared to the control is indicated.
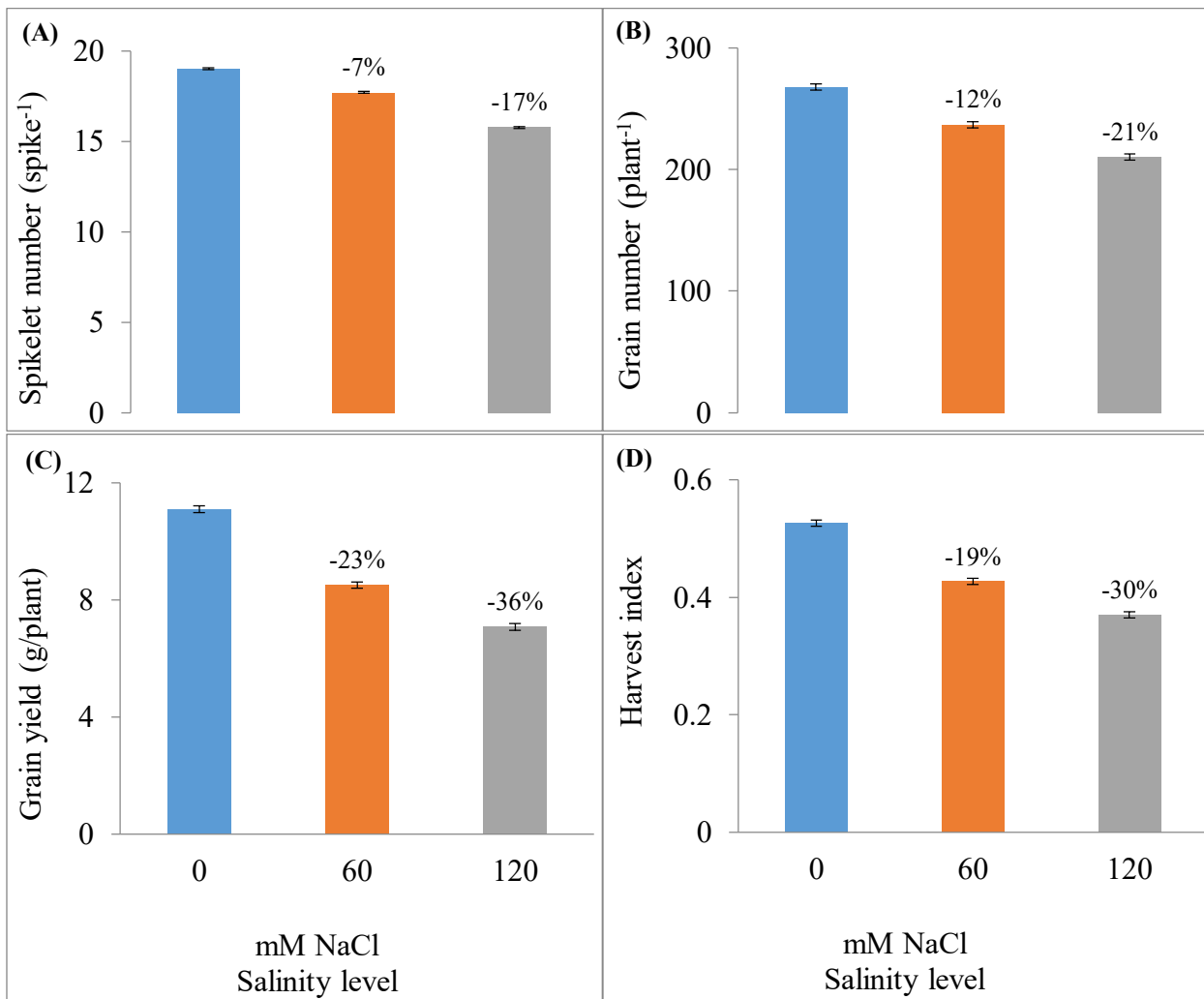
Figure 3-24 The effect of genotype on (A) spikelet number per spike, (B) grain number per plant, (C) grain yield per plant (g), and (D) harvest index of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Separation of means was carried out using the LSD test (P < 0.05). Means with different letters are significantly different according to the LSD test at P < 0.05.
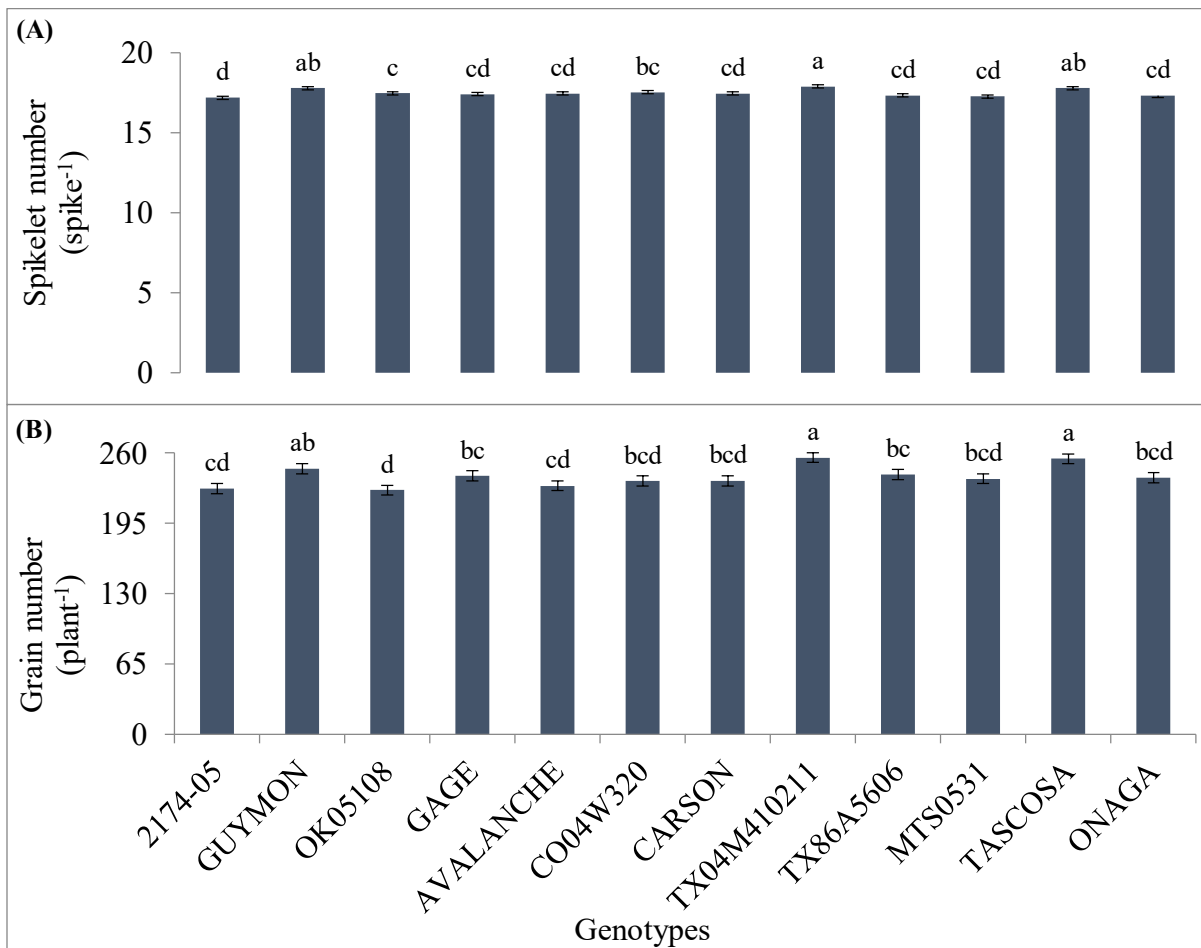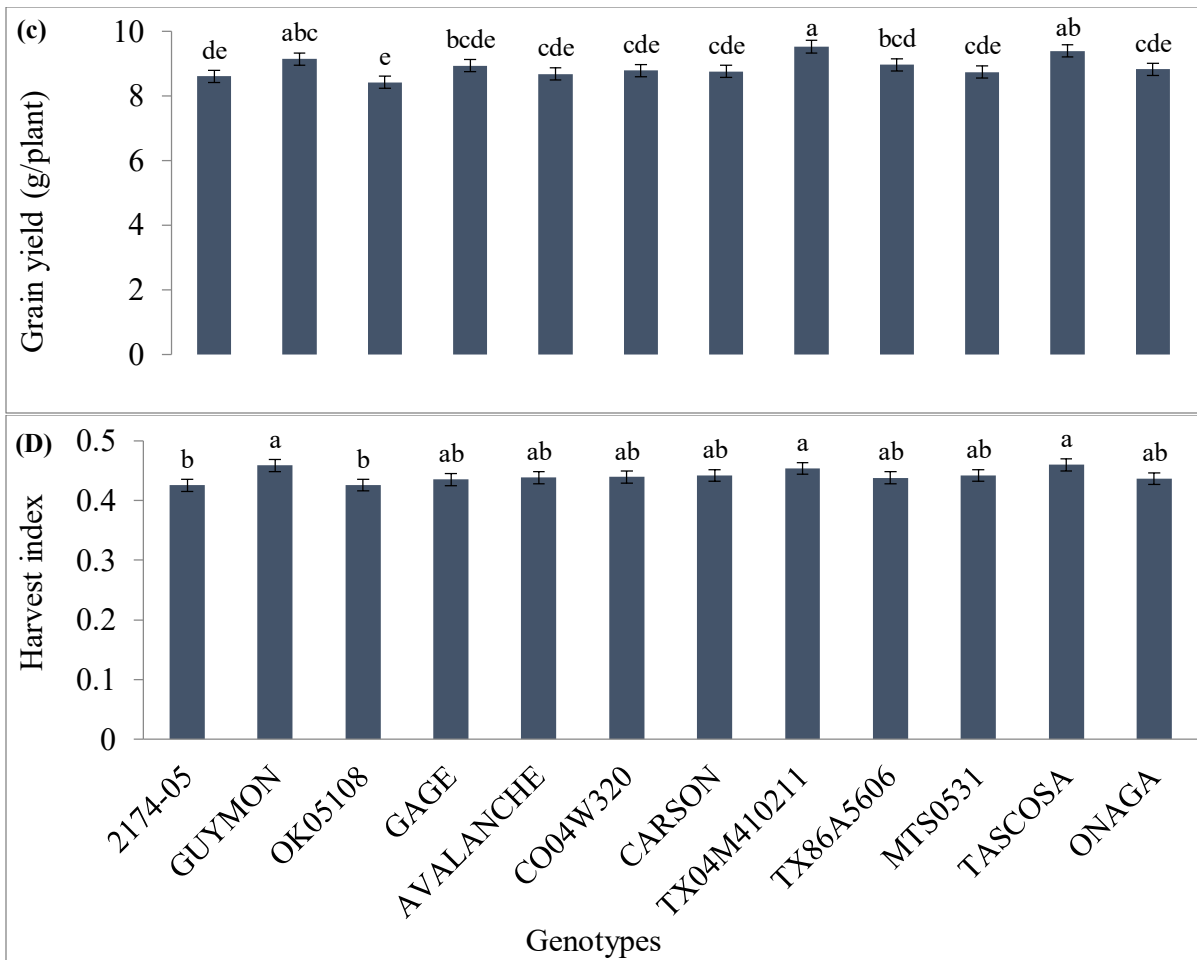
Figure 3-25 The interaction of high temperature and salinity stress on (A) spikelet number per spike, (B) grain number per plant, (C) grain yield per plant (g), and (D) harvest index of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent decrease in each treatment as compared to control is indicated.
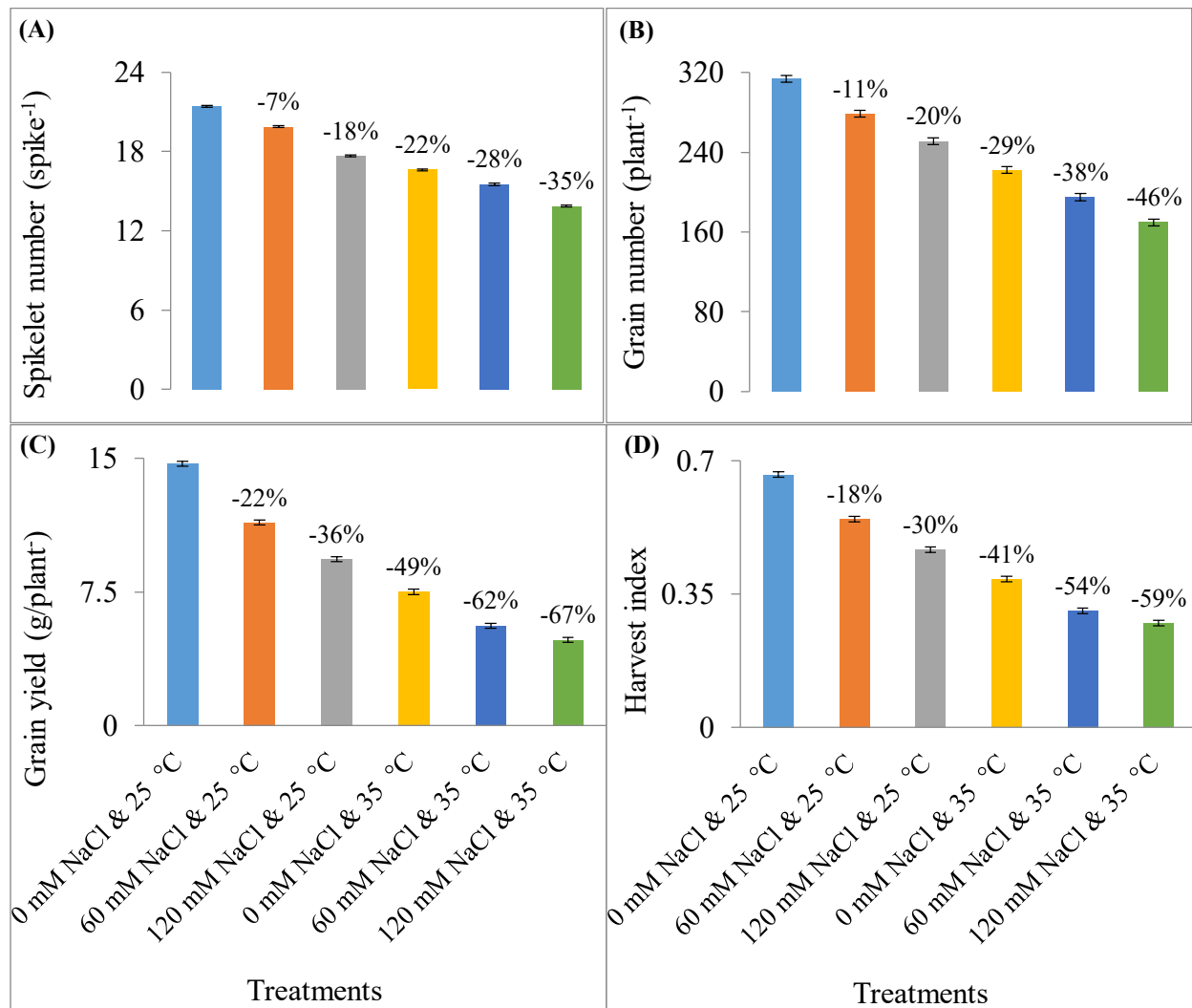
Figure 3-26 The interaction of high temperature and genotype on (A) spikelet number per spike (B) grain number per spike, (C) grain yield per spike (g) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent decrease in each trait due to high temperature as compared to optimum temperature is indicated on each genotype.
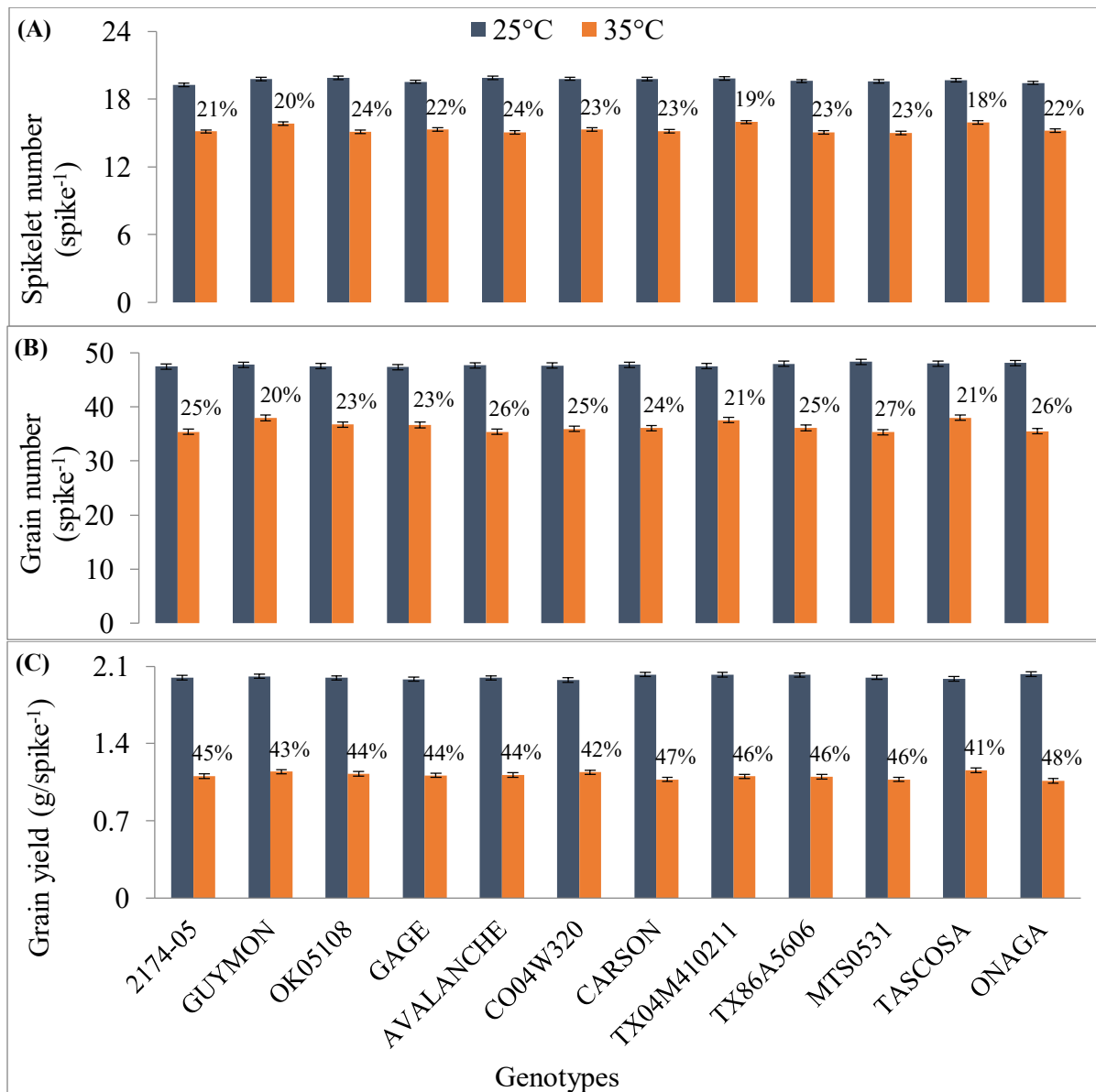
Table 3-1 Probability values of effects of temperature (T), salinity (S), genotype (G), T x S interaction, T x G interaction, S x G interaction and T x G x S interaction on various physiological traits.

Traits	Temperature (T)	Salinity (S)	Genotype (G)	T x S	T x G	S x G	T x G x S
Maximum quantum yields of PS II (Fv/Fm ratio; unitless)	<0.0001	<0.0001	<0.0001	<0.0001	0.0011	0.3041	0.2904
Thylakoid membrane damage (Fo/Fm ratio; unitless)	<0.0001	<0.0001	<0.0001	0.0267	<0.0001	<0.0001	0.0324
Leaf photosynthesis (μmol m^{-2} s^{-1})	<0.0001	<0.0001	<0.0001	0.0031	<0.0001	<0.0001	0.7034
Stomatal Conductance (mmol m^2 s^1)	<0.0001	<0.0001	<0.0001	<0.0001	0.1526	0.0424	0.0502
Chlorophyll index (SPAD units)	0.0012	<0.0001	<0.0001	0.0002	0.0933	<0.0001	0.0001

Table 3-2 Probability values of effects of temperature (T), salinity (S), genotype (G), T x S interaction, T x G interaction, S x G interaction and T x G x S interaction on various biochemical traits.

Traits	Tempera ture (T)	Salinity (S)	Genotyp e (G)	T x S	T x G	S x G	T x G x S
Soluble sugars content (g/kg)	<0.0001	<0.0001	<0.0001	<0.0001	0.0016	<0.0001	<0.0001
Reducing sugars content (g/kg)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0005	0.0085
Non reducing sugars content (g/kg)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.1877	0.0047
Starch content (g/kg)	<0.0001	<0.0001	<0.0001	<0.0001	0.8232	0.7235	0.2812
Proline content content (µmol/g)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0338	0.0004
Soluble proteins content (g/kg)	<0.0001	<0.0001	<0.0001	<0.0001	0.0304	<0.0001	0.0371
MDA content (µmol/g)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0009	0.0233

Table 3-3 Probability values of effects of temperature (T), salinity (S), genotype (G), T x S interaction, T x G interaction, S x G interaction and T x G x S interaction on various yield traits.

Traits	Temperature (T)	Salinity (S)	Genotype (G)	T x S	T x G	S x G	T x G x S
Plant height (cm)	<0.0001	0.0060	<0.0001	0.3020	0.3355	0.3046	0.5863
Tiller number (plant^{-1})	<0.0001	0.0004	<0.0001	0.6678	0.4230	0.8834	0.7249
Spike number (plant^{-1})	<0.0001	0.0043	<0.0001	0.1880	0.9975	0.9951	0.8873
Spike length (cm)	<0.0001	0.0002	0.0973	0.0324	0.8675	0.0852	0.9213
Spikelet number (spike^{-1})	<0.0001	<0.0001	<0.0001	<0.0001	0.0006	0.8450	0.8607
Dry weight (g plant^{-1})	<0.0001	<0.0001	0.0018	0.4682	0.1803	0.9972	0.5578
Grain number (spike^{-1})	<0.0001	<0.0001	0.0226	0.0041	0.0052	0.4582	0.2076
Grain number (plant^{-1})	<0.0001	<0.0001	<0.0001	0.2872	0.9851	0.9976	0.8953
Grain yield (g spike^{-1})	<0.0001	<0.0001	0.7469	<0.0001	0.0064	0.7202	0.8994
Individual grain weight (mg)	<0.0001	<0.0001	0.9706	<0.0001	0.2369	0.6501	0.8540
Grain yield (plant^{-1})	<0.0001	<0.0001	0.0008	<0.0001	0.6761	0.9919	0.9855
Harvest index	<0.0001	<0.0001	0.1909	<0.0001	0.8698	0.9896	0.8839

Table 3-4 Mean growth and morphological parameters for twelve winter wheat genotypes. Separation of means was carried out using the LSD test (P < 0.05). Means with different letters are significantly different according to the LSD test at P < 0.05.

Genotypes	Plant height	Number of tillers plant^{-1}	Spike number panicle^{-1}	Vegetative biomass (g plant^{-1})
2174-05	68.5e	8.4de	6.4cd	19.9abc
GUYMON	70.2d	8.6bcd	6.7bc	19.7bc
OK05108	70.4cd	8.4e	6.3d	19.4c
GAGE	70.2d	8.6bcd	6.7bc	20.3ab
AVALANCHE	71.3abcd	8.3e	6.5cd	19.4c
CO04W320	71.5abc	8.5cde	6.6cd	19.7bc
CARSON	71.9a	8.6bcd	6.6cd	19.4c
TX04M410211	71.2abcd	8.8a	7a	20.5a
TX86A5606	71.5abc	8.7abc	6.7bc	20ab
MTS0531	71.6abc	8.7ab	6.6c	19.4c
TASCOSA	71.8ab	8.7ab	6.9ab	20.2ab
ONAGA	70.6bcd	8.5bcde	6.6bc	19.8bc

Table 3-5 Mean growth and yield parameters for twelve winter wheat genotypes. Separation of means was carried out using the LSD test (P < 0.05). Means with different letters are significantly different according to the LSD test at P < 0.05.

Genotypes	Spikelet number (spike$^{-1)}$	Grain yield (g plant^{-1})	Grain number plant^{-1}	Harvest index
2174-05	17.2d	8.6de	227.2cd	0.43b
GUYMON	17.8ab	9.1abc	245.7ab	0.46a
OK05108	17.5c	8.4e	225.6d	0.43b
GAGE	17.4cd	8.9bcde	238.8bc	0.43ab
AVALANCHE	17.5	8.7cde	229.7cd	0.44ab
CO04W320	17.6bc	8.8cde	234bcd	0.44ab
CARSON	17.5cd	8.8cde	234.4bcd	0.44ab
TX04M410211	17.9a	9.5a	255.8a	0.45a
TX86A5606	17.3cd	9bcd	240.1bc	0.44ab
MTS0531	17.3cd	8.7cde	236.3bcd	0.44ab
TASCOSA	17.8ab	9.4ab	254.7a	0.46a
ONAGA	17.3cd	8.8cde	237.bcd	0.44ab

Chapter 4 - The Combined Effect of Salinity and High Temperature on Winter Wheat at Flowering Stages

Abstract

Salinity and high temperature are the major abiotic stresses that reduce plant growth and crop productivity worldwide. The objectives of this study were to quantify independent and combined effects of salinity and high temperature on physiological, biochemical, growth and yield characters of winter wheat genotypes and to define if responses varied among winter wheat genotypes. 12 genotypes of winter wheat were grown in non-saline medium and at optimum temperatures (25/15 °C; daytime maximum/nighttime minimum; d/n) until flowering stages. At flowering plants were irrigated with three different salinity levels (0, 60, 120 mM NaCl) and exposed to optimum and high temperature (35/ 20 °C day/night) for 10 d. Physiological, biochemical data were collected during treatment period and yield data were collected at full maturity. The study indicated that high temperatures, salinity and their interaction at flowering stage, had negative effects on wheat physiology, biochemical and yield component as indicated by the reduced leaf level photosynthesis, reduced chlorophyll content, starch content, increased sugars, proline and soluble proteins, increased MDA level, and reduced grain yield and harvest index. Additionally, the study showed considerable variation in high temperature and salinity tolerance among winter wheat genotypes for leaf photosynthesis, chlorophyll concentration, sugars, proline and soluble proteins accumulation, seed set, grain number and grain yield per plant. The study conclude that there is genetic variability among winter wheat genotypesand that genotypes varied in their response to independent and combined stresses and that genotype CARSON, TX04M410211 and TASCOSA were the more tolerant genotypes.

Introduction

Flowering stage (Feekes growth stage 10.5.1, Zadoks 62). It starts just a few day after heading is completed. Once flowering begins, pollination will be complete in about four or five d (Peterson, 1965). Flowering begins in the head and it is starting first with the florets in the central spikelet then progresses both up and down the spike. Flowering is usually noted by extrusion of the anthers from each floret (Herbeck and Lee, 2009). If the anthers within a floret are yellow or gray rather than green, it is reasonably certain that pollination of the floret has occurred. The period of pollination within a single head is about three to five d (Herbeck and Lee, 2009). During this stage the kernels per spike are determined by the number of flowers that are pollinated (Acevedo et al., 2002). This stage is very sensitive to environmental stresses such as high temperature, drought, and salinity. Under extreme environmental stress, all of the florets in each spikelet at the top and bottom of the head may terminate prior to flowering (Warrington et al., 1977).

High temperatures severely limit wheat yield and decreases total above-ground biomass and grain yield (Acevedo et al., 2002). Wheat is particularly subjected to high temperature stress around anthesis stages and the effect is marked by the reduction in kernel number and grain yield (Nicolas et al., 1984; Fischer, 1985; Wheeler et al., 1996; Acevedo et al., 2002; Modhej et al., 2008; Barnabas et al., 2008; Farooq et al., 2011). The decrease in grain yield of wheat under high temperature stress is due to the reduction in number of spikes, number of fertile spikes per plant or number of grain per spike and grain weight (Acevedo et al., 2002; Narayanan et al., 2015). High temperature stress reduces plant photosynthetic due to the oxidative damage of chloroplast, which result in grain yield reduction (Seeman et al., 1984; Farooq et al., 2011). Also high temperature decreases leaf chlorophyll content and accelerates senescence (Zhao et al., 2007; Pradhan et al., 2012). High temperature decreases the duration of each growth stage and affects crop performance

and yield. High night temperature resulted in decrease in time to flowering, grain set, and physiological maturity in spring wheat (Prasad et al., 2008). During flowering stages, high temperature stress affected morphological abnormalities in pollen, stigma and style, which resulted in decreased grain numbers, decreased individual grain weights and decreases in grain yield (Prasad and Djanaguiraman, 2014). High temperature tolerance is associated with membrane stability, increased compatible solutes, increased protein stability and the synthesis of heat shock proteins (Acevedo et al., 2002). Plants have developed adaptive mechanism to high temperature stress. These mechanisms include morphological, physiological, and biochemical changes such that leaf orientation, leaf anatomy, stomata conductance, changes in membrane lipid composition, ion transporters, and synthesize protective chemicals including proteins, proline, antioxidants such as ascorbic acid, glutathione, peroxidase and superoxide dismutase (Morgan, 1984; Touchette et al., 2007; Srivastava el al., 2012).

Agricultural productivity is severely affected by soil salinity. Soil and water salinity is caused by the presence of excessive amounts of salts. Most commonly, high Na^+ and Cl^- cause the salt stress. Wheat is moderately tolerant to salinity stress (Shannon, 1997). However, salt stress effects plant as it reduces water potential, cause ions imbalance, disturbances in ion homeostasis, and toxicity (Maas, and Grattan. 1999; Munns, 2002; Sairam, 2002). This results in changing of water status, which leads to initial growth reduction and limitation of plant productivity due to reduced cell growth and leaf area (Acevedo et al., 2002). Under saline condition, relative water content, leaf water potential, water uptake, transpiration rate, water retention, and water use efficiency decreased (Nishida et al., 2009). Photosynthesis, altogether with cell growth, is among the primary processes to be affected by salt stress due to the production of ROS such as the superoxide radical (O_2^-), hydrogen peroxide (H_2O_2), and the hydroxyl radical (OH^-). These free

radicals are produced during salinity stress and cause severe damage to membranes and other essential macromolecules such as chlorophyll pigments, proteins, and fats (Sairam et al., 2005; Krieger-Liszkay et al., 2008; Behairy et al., 2012; Djanaguiraman and Prasad, 2013). Also, salinity hastens all phenological phases (Grieve et al., 1994), decreases number of fertile tillers (Mass et al., 1994; Abbas et al., 2013), reduces the number of spikelet number per spike (Frank et al., 1987), kernel weight (Abbas et al., 2013). As a result grain yield and aboveground biomass are reduced due to salt stress. Additionally, the number of effective ears per plant is the most seriously affected yield component in wheat under saline conditions (Maas and Hoffmann, 1977; Munns et al., 2006). Plant salinity tolerance is the inherent ability of the plant species to tolerate the effects of high salts without a significant adverse effect on the plant (Munns and James, 2003). Some plant have developed different adaptation mechanisms, which include the accumulation of osmo-protectants, exclusion of sodium and chloride, tissue tolerance to accumulated sodium and chloride, and detoxification of ROS by producing antioxidants compounds (Rathinasabapathy, 2000; Zhang et al., 2001; Munns and Tester, 2008; Ashraf et al., 2010; Djanaguiraman and Prasad, 2013).

Due to increased climatic variability and more frequent events of extreme conditions also effect in plants being exposed to not only one single abiotic stress but also multiple abiotic stresses at different stage of plant growth and development. Under filed condition, wheat plant is subject to combination of high temperature and salinity stress. Combined stresses become more acute and lethal threats to plant growth and development compared to individual stresses (Rizhsky et al., 2004; Mittler, 2006; Ramegowda and Senthil-Kumar, 2015). High temperature and salinity stresses cause water stress leading to loss of turgor in guard cell which induces the production of stress hormone, abscissic acid (ABA). As abscissic is produce it accelerates stomatal closure, which limits the gas exchange and reduce CO_2 concentration in mesophyll tissues. This leads to

reduction in photosynthetic rate. High temperature stress influence germination (Tadmor et al., 1969; Sharma, 1976), and enhances transpiration, and, with combination of salinity stress, this could result in enhanced uptake of salt, which may cause salt toxicity (Keles and Oncel, 2002; Atkinson and Urwin, 2012). High temperature and salt stress inhibit growth and increase the carotenoids and growth regulator activities (Keles and Oncel, 2002), induce alterations in ion transport and compartmentalization (Munns, 2002), damage gas exchange properties of the flag leaf, yield, yield components of some varieties of wheat plants (Anjum et al., 2008). Plants recognize and respond to these stresses by rapidly altering gene expression along with physiological and biochemical alterations. The combined effect of high temperature and salinity stress has received comparatively little study. Therefore the objective of this research was to investigate the effect of salinity, high temperature, and their interactions at flowering stage of winter wheat genotypes.

Materials and Methods

This study was conducted in controlled environment facilities at the Department of Agronomy, Kansas State University Manhattan, KS, USA. Experiments were conducted in spring and summer of 2016 to determine the impact of salinity and high temperature stress on physiological, biochemical, growth and yield, of winter wheat genotypes.

Plant Material

12 genotypes were used in the study and these genotypes were selected based on earlier germination experiment. These genotypes were classified as tolerant to salinity (GAGE, MTS0531, TASCOSA AND GUYMON), moderately tolerant (AVALANCHE, OK05108,

TX86A5606 and ONAGA) and susceptible (CO04W320, 2174-05, CARSON AND TX04M410211) to salinity stress

Experimental and Growth Conditions

Seeds of twelve winter wheat genotypes were sown in 4-cm deep trays containing commercial Sunshine Metro Mix 360 potting soil (Hummert International, Topeka, KS, USA). Seeds were sown at a depth of about 2 cm. The seedlings were raised in a growth chamber (Conviron Model CMP 3244, Winnipeg, MB, Canada) maintained at 25/15 °C (daytime maximum/nighttime minimum; d/n). After 8 d, the seedlings were vernalized for 56 days at 4 °C with 8 h photoperiod. Following vernalization, three seedlings of the same genotype were transplanted into 1.6-L pots (24 cm length and 10 cm width, MT49 Mini-Treepot, Stuewe & Sons, Inc., Tangent, OR, USA). Rooting medium in pots was commercial Sunshine Metro Mix 360 potting soil. The rooting medium was fertilized with Osmocote (Scotts, Marysville, OH, USA), a controlled-release fertilizer with 14: 14: 14 N: P_2O_5:, K_2O respectively, at 5 g per pot before transplanting. Two growth chamber were used for the study. Both growth chamber were maintained at optimum temperature (OT; 25/15 °C d/n) until flowering stage. At flowering, one growth chamber was maintained at optimum temperature (OT; 25/15 °C d/n) and the other growth chamber was maintained at high temperature (HT; 35/25 °C d/n) for 10 d. In each growth chamber there were 15 trays, and each tray has 12 pots. Twelve winter wheat genotypes were in each tray, with a total of 180 pots in the growth chamber. Pots were watered daily and kept in trays containing about 1 cm water during the experiment to avoid water stress. Pots were moved randomly for each week to avoid positional effects. After seedling establishment, seedlings were thinned to two per pot, which was maintained until maturity. At thinning, a systemic insecticide, Marathon 1 % G (a.i.:

Imidacloprid: 1–((6–Chloro–3–pyridinyl) methyl)–N–nitro–2–imidazolidinimine), was applied at 1.5 g per pot to avoid infestation of sucking insect pests. The plants were maintained at a photoperiod of 16 h with a light intensity of 800 µmol m^{-2} s^{-1} and 70 % relative humidity. The daytime maximum temperature/nighttime minimum temperature was maintained for 8 h with a transition period between daytime and night time temperatures of 4 h to imitate the diurnal temperature fluctuation of outside atmospheric condition and vice versa. Both growth chambers were divided into three sets each set consist of 5 trays representing five replications. At the onset of flowering stages (Feekes growth stage 10.0), one set of plants were irrigated with distilled water and served as control and the other two served as salinity treatment. Two levels of salinity (60 and 120 mM NaCl solution, EC value of 7.5 and 14.5 dSm^{-1}) was used to irrigate the plants. Salinity treatments were applied by irrigating each plant with 250 mL of NaCl solution to all treated plants and as mentioned above in both growth chambers for 10 d. Also, at the same time plants grown at high temperature were exposed to high temperature (HT; 35/25 °C d/ n) for 10 d. After that, the plants were returned to optimum temperature (OT; 25/15 °C d/ n) and irrigated with normal water till plants attained physiological maturity. Similar management practices were followed in both experiments.

Data Collection

At flowering stages, the main stem of all plants was tagged for the measurements of chlorophyll content, chlorophyll *a* fluorescence and gas exchange. Measurements were taken on three plants of each genotype in each treatment at 2, 5, and 10 d after stress imposition Leaf samples were collected for biochemical analysis on 2, 5, and 10 d after stress imposition. Leaf samples were collected for biochemical analysis on 2, 5, and 10 d after stress imposition and at maturity, plant

height, tiller number per plant[-1], spike number per plant[-1], spike length, spikelet number per spike[-1], and grain number per spike[-1] were measured. All the above physiological traits were measured on attached fully expanded flag leaves of the main stems of three plants per genotype from each treatment during 10:00 and 14:30 hours. The leaf chlorophyll was measured using a self-calibrating chlorophyll meter (SPAD-502, Spectrum Technologies, Plainfield, IL, USA) on the fully expanded flag leaf of the main stem. Each time, data were taken four times from the middle portion of the leaf and the readings were averaged to get a single value for a plant. The Chlorophyll a fluorescence parameters were measured using a modulated fluorometer (OS30p; OptiSciences, Hudson, NH, USA). The minimum fluorescence (Fo) and maximum fluorescence (Fm) measurements were taken after the flag leaf was dark adapted for 1 h. The maximum quantum yield of PS II is the ratio of variable fluorescence (difference between maximum and minimum fluorescence (Fv) to maximum fluorescence (Fm), which decreases with stress (Rohacek, 2002). The leaf level photosynthesis was measured using the LI-COR 6400 portable photosynthesis system (LI-COR, Lincoln, NE, USA). Measurements were taken at daytime growth temperature and ambient CO_2 conditions (390 mol^{-1}). The internal light emitting diode (LED) light source in the LI-COR 6400 was set at 1600 mol m^{-2} s^{-1}. For all the biochemical analysis, the flag leaf and second leaf from the top were collected at 2, 5, and 10 d during the stress period. Samples placed in aluminum paper and immediately frozen in liquid nitrogen and transported to the laboratory where samples were stored at -80 °C until processing.

Total carbohydrate content (g/kgdry weight; dw) : A known weight of (0.2 g) frozen leaf samples from each treatment was ground in liquid nitrogen to a fine powder using a pestle and mortar followed by the addition of 10 mL of 80 % ethanol and kept in a preheated (70 °C) water bath for 30 min. After the expiry of time, the homogenate was filtered through Whatman No. 1

filter paper and then re-extracted using 80 % ethanol (10 mL) and dried in a water bath to evaporate the ethanol and then 10 mL of distilled water was added and vortexed for 2 min. These extractswere used to determine soluble sugars, reducing sugar and non-reducing sugars.

Soluble sugars (g/kg dw) contents were determined based on the method of phenol sulphuric acid as described by Dubois et al. (1956). Briefly, 0.2 ml of sample exact was mixed with 0.8 ml of distilled water. To the diluted extract, 1 mL of phenol reagent and 5 mL of 96 % sulphuric acid were added and incubated for 30 min at 30 °C. The optical density reading was taken at 490 nm using a UV- spectrophotometer.

The reducing sugars (g/kg dw) content were quantitatively estimated in the obtained extract following the method of Somogyi (1952). Briefly, 0.2 ml of sample exact was taken and 0.8 mL of distilled water and 1 mL of alkaline copper tartrate was added and the reaction mixture was heated for ten min in a boiling water bath and cooled rapidly in an ice bath. Then 1 mL of arsenomolybdate reagent and 10 mL of distilled water were added and mixed well. The reaction mixture was incubated for ten min at room temperature. The optical density reading was measured at 620 nm using UV- spectrophotometer. The difference between total sugar and reducing sugar corresponds to the non-reducing sugar (g/kg dw).

Starch content (g/kg dw) was determined using anthrone method (Hedge and Hofreiter, 1962). A known weight of 0.2 g of frozen leaf samples from each treatment were ground in liquid nitrogen to a fine powder and homogenized in a pestle and mortar using 10 mL of 80 % ethanol and kept in preheated (70 °C) water bath for 30 min. The homogenate was filtered through Whatman No. 1 filter paper and then re-extracted using 10 mL of 80 % ethanol for removing the soluble sugars. The residue was retained and was washed with hot 20 % ethanol till the washings did not give color with anthrone reagent. Sample residue was dried in oven at 70 °C. To the dry

sample residue, 5 ml of distilled water and 6.5 ml of 52 % perchloric acid were added. Starch was extracted at 0 °C for 20 min. The extract was retained after centrifugation. The extraction was repeated with fresh perchloric acid. The extracts were pooled after centrifugation and the volume was made up to 50 mL with distilled water. To 0.2 ml of the extract, 0.8 ml of distilled water and 4 ml of anthrone reagent were added. The reaction mixture was heated for 8 min in a boiling water bath and cooled rapidly in ice bath. The optical intensity was read at 630 nm using a UV-spectrophotometer.

Free proline content was quantified according to the method of Bates et al. (1973). Briefly, 0.5 g of frozen leaf samples from each treatment was ground in liquid nitrogen to a fine powder and homogenized in a pestle and mortar in 3% (w/v) sulfosalicylic acid, and the residue was removed by centrifugation. From the supernatant, 2 mL was mixed with 2 mL of glacial acetic acid and with 2 mL of acid ninhydrin (1.25 g of ninhydrin was warmed in a mixture of 30 mL of glacial acetic acid and 20 mL of 6 mol/L phosphoric acid until dissolved) for 1 h at 100 °C; the reaction was terminated in an ice bath. The reaction mixture was extracted with 4 mL of toluene. The chromophore-containing toluene was warmed to room temperature and its optical density was measured at 520 nm using UV- spectrophotometer. Proline content was calculated according to Bates et al. (1973).

Lipid peroxidation was measured in terms of content of malondialdehyde (MDA, $\varepsilon = 155$ mmol^{-1} cm^{-1} a product of lipid peroxidation, following the method of Heath and Packer (1968). Briefly, 0.5 g of frozen leaf samples from each treatment were ground in liquid nitrogen to a fine powder and homogenized in a pestle and mortar with 10 mL of extraction buffer (0.1% trichloro acetic acid (TCA). The homogenate was centrifuged for 10 min at 10,000 rpm. For every 1 mL of the aliquot, 4 mL of 20 % TCA containing 0.5 % thio barbituric acid (TBA) was added. The

mixture was kept in water bath at 95 °C for 30 min and cooled rapidly in an ice bath to stop the reaction. The optical density reading of the mixture was immediately taken at 532 nm using UV-visible spectrophotometer, and the value for the non-specific absorption at 600 nm was subtracted. The concentration of malondialdehyde (MDA) was calculated using coefficient of absorbance of 155 mM^{-1}cm^{-1}. MDA content expressed as mmol/g fresh weight; fw. The MDA content was calculated as follows: MDA concentration = (Abs532-Abs600) xVx1000/($\mathcal{E}$ x W). Where: V = extraction volume, $\mathcal{E}$ = extinction coefficient and W = sample weight.

Total soluble protein content was determined as by Bradford (1976). Briefly, 0.5 g of frozen leaf samples from each treatment was ground in liquid nitrogen to a fine powder and homogenized in a pestle and mortar with 15 mL of extraction buffer (0.1M Tris buffer 8 pH) and then centrifuged at 12000 rpm at 4 °C for 15 min. Then 5 ml of Coomasie brilliant blue reagent (CBB) and 0.5 ml of distilled water were added to 0.5 ml of the supernatants. Spectrophotometer cuvettes and absorbance were measured using a UV- visible spectrophotometer at 595 nm.

At maturity, plants were hand-harvested by cutting them at the soil level. Data on plant height, number of tillers plant^{-1}, spike number per plant, spike length were recorded at the day of harvesting on five plants per genotype from all the temperature and salinity levels. Plant height was determined as the distance between base of the plant and the spike. For vegetative dry weight measurements, plant parts - leaves, stems, and spikes (main spike and other spikes separately) were collected and dried at 40 °C for 10 d. Vegetative dry weight was determined as the weight of leaves, stems, and spikes per plant. After drying for 5 d, spikelet number was counted for main spike, then main spikes were hand threshed to separate grains, and grain number per spike was counted manually. Grain yield for main spike and per plant were calculated and individual grain

weight was calculated by dividing grain yield per spike by grains number per spike. Harvest index was calculated as the ratio of grain yield to the total vegetative dry weight for each plant.

Experiment Design and Data Analysis

The experimental design was a randomized complete block with a split split-plot treatment structure in five replications. Temperature was the main plot factor, salinity was assigned to sub-plots and genotypes to sub-sub-plots. For the treatments, temperature had two levels (optimum and high temperature), salinity had three levels (0, 60, 120 mM NaCl), and genotype had twelve levels (GAGE, MTS0531, TASCOSA, GUYMON, AVALANCHE, OK05108, TX86A5606, ONAGA, CO04W320, 2174-05, CARSON AND TX04M410211). Data were analyzed using MIXED procedure in statistical software SAS 9.4 for mean and standard error estimation. Separation of means was carried out using the LSD test ($P < 0.05$). The PROC MIXED procedures were used with block, temperature, salinity, and genotypes as class variables.

Result

The P-values for physiological, biochemical, growth and yield traits obtained with SAS PROC MIXED are presented in Tables 4.1, 4.2 and 4.3. The independent effects of temperature, was significant ($P < 0.0001$) for maximum quantum yield of PS II, thylakoid membrane damage, leaf photosynthetic rate, soluble sugars, reducing and non-reducing sugars, starch, proline, soluble proteins contents, MDA content, spike length, spikelet number, dry weight, grain number, grain yield, individual grain weight, and harvest index. The independent effect of salinity stress was significant ($P < 0.0001$) for maximum quantum yield of PS II, thylakoid membrane damage, leaf photosynthesis, stomatal conductance, soluble sugars, reducing sugars, starch, proline, soluble

proteins contents, MDA content, plant height, spikelet number, dry weight, grain number, grain yield, and harvest index. The independent effect of genotype was significant ($P < 0.0001$) for maximum quantum yield of PS II, thylakoid membrane damage, leaf photosynthetic rate, chlorophyll content, reducing sugars, starch, soluble proteins, MDA contents, plant height, spike length, spikelet number, grain number, grain yield, and harvest index. Interaction effects of temperature x salinity were significant ($P < 0.05$) maximum quantum yield of PS II, thylakoid membrane damage, leaf photosynthetic rate, stomatal conductance, soluble sugars, reducing and non-reducing sugars, starch, proline, soluble proteins, MDA content, plant height, tiller number, spikelet number, dry weight, grain number, grain yield, and harvest index. Interaction effect of temperature x genotypes were significant ($P < 0.05$) for thylakoid membrane damage, leaf photosynthetic rate, chlorophyll content, soluble sugars, reducing and non-reducing sugars, starch, proline, soluble proteins, MDA content, spikelet number, grain number, grain yield and harvest index. Interaction effects of salinity x genotype were significant ($P < 0.05$) for leaf photosynthetic rate, chlorophyll content, soluble sugars, reducing and non-reducing sugars, starch, proline content, spikelet number, dry weight, and grain number. The temperature x salinity x genotypes interactions, was significant ($P < 0.05$) on soluble sugars, reducing and non-reducing sugars, starch, proline content, spikelet number, grain yield, and harvest index.

Physiological Traits

Results of the main effect of high temperature, salinity and combined stresses on leaf level photosynthesis was presented in table 4.1. The mean value of photosynthesis was 19 μmol m^{-2} s^{-1}. Values of photosynthesis were significantly decreased by high temperature 27 %, salinity 16 % and combined high temperature and salinity stress 39 % (Figures 4.1a, 4.2a, 4.4a), which indicates

decreased leaf level photosynthesis due to high temperatures, salinity and their interaction. Also genotypes showed different response to these stresses, the value of photosynthesis ranged between 18 and 20 µmol m^{-2} s^{-1}. Figure 4.3a show that genotypes GUYMON, CARSON, TX04M410211 and TASCOSA had the highest level of leaf photosynthesis. Temperature and genotype interaction also significantly affected leaf photosynthesis (P < 0.001). Fig. 4.5a shows a percent reduction over the control in all genotypes due to high temperature the result showed that genotypes GUYMON, CARSON, TX04M410211 and TASCOSA had the lowest reduction of leaf photosynthesis which was about 24 %, whereas other genotypes had reduction of 29 %. Salinity and genotype interaction also reduced leaf photosynthesis by 17 %. The interactions of high temperature, salinity and genotype had no effect of leaf level photosynthesis.

Stomatal conductance was significantly (P < 0.001) affected by high temperature, salinity and combined stresses (Table 4.1). Results of the effect of high temperature, salinity and combined stresses on stomatal conductance were presented in table 1 and Figures 4.1b, 4.2b, and 4.4b. The mean value of stomatal conductance was 0.86 mmol m^{-2} s^{-1}. The values of stomatal conductance were significantly decreased by high temperature 67 %, high salinity level 31 % and combined stresses 78 % (Figures 4.1b, 4.2b, 4.4b), which indicates decreased stomatal conductance due to high temperatures, salinity and their interaction. Besides, genotypes were significantly different for stomatal conductance. The values of stomatal conductance ranged between 0.82 and 0.90 mmol m^{-2} s^{-1}. The result showed that genotypes GUYMON, TX04M410211 and TASCOSA had the lowest reduction for stomatal conductance (Fig. 4.3b). High temperature x genotype interaction; salinity x genotype interaction; as well as high temperature x salinity x genotypes interaction had no significant effect on stomata conductance.

Maximum quantum yield of PS II (Fv/Fm ratio; unitless) were significantly (P < 0.0001) affected by high temperature, salinity and genotype (Table 4.1). Values of Fv/Fm ratio were significantly decreased by high temperature 10 %, salinity 7 % and combined stresses 18 % (Figures 4.1c, 4.2c and 4.4c), which indicates decreased photochemical efficiency of PS II due to high temperatures, salinity and their interaction. The values of Fv/Fm ranged between 0.74 and 0.76 so genotypes showed different response to the stresses in term of maximum quantum yield of PS II. The result showed that genotypes CARSON, TX04M410211 and TASCOSA had the lowest reduction (Fig. 4.3c). Temperature x genotype interaction; salinity x genotype interaction; as well as high temperature x salinity x genotype interactions had no significant effect on maximum quantum yield of PS II.

Thylakoid membrane damage (Fo/Fm ratio; unitless) were significantly (P < 0.0001) affected by high temperature, salinity, genotype and combined stresses (Table 4.1). The mean value of Fo/Fm ratio was 0.199. Values of Fo/Fm ratio were significantly increased by high temperature 24 %, salinity 6 % and combined stresses 29 % (Figures 4.1d, 4.2d, 4.4d.), which indicates increased thylakoid membrane damage due to high temperatures, salinity and their interaction. Genotypes responded differently to the stresses in term of Fo/Fm ratio. Figure 4.4c showed that genotypes CARSON, TX04M410211 and TASCOSA had the lowest value of thylakoid membrane damage, whereas genotype Ok05108 had the highest membrane damage. In addition, thylakoid membrane damage was significantly (P < 0.0001) affected by temperature x genotype interaction (Fig. 4.5b). The result indicated that genotypes had diverse response to high temperature. The per cent increase in membrane damage was 17 % in genotype TASCOSA and by 27 % in genotype Ok05108. Salinity x genotype interaction as well as high temperature x

salinity x genotype interactions had no significant effect on thylakoid membrane damage (Fo/Fm ratio; unitless).

Chlorophyll concentration was significantly (P < 0.001) affected by high temperature and salinity stress (Table 4.1). The mean value of SPAD was 50 SPAD units, the values of SPAD were significantly decreased by high temperature by 10 %, salinity 7 % which indicates decreased chlorophyll concentration due to high temperatures and salinity respectively. Also, the result indicated that genotypes had diverse response to high temperature. The per cent decrease in chlorophyll concentration were by 7 % in genotypes TX04M410211 and TASCOSA and by 12 % in genotype GAGE (Fig 4.5c). High temperature x salinity interaction; salinity x genotype interaction; and high temperature x salinity x genotype interaction had no significant effect on chlorophyll concentration.

Biochemical Traits

Analysis of variance for biochemical traits obtained with SAS PROC MIXED are presented in table 4. 2. The independent effects of temperature, salinity, and genotypes; and interaction effects of temperature x genotypes, salinity x genotype, temperature x salinity, and temperature, x salinity x genotypes were significant (P < 0.001) for total soluble sugar, reducing sugar, non-reducing sugar, starch, proline, soluble protein, and MDA contents unless indicated otherwise (Table 4. 2). However, there were no significant effect of salinity on non-reducing sugar. Also no significant effects were found as a result of the interaction of salinity x genotype; and high temperature x salinity x genotype interaction on total soluble protein and MDA content.

Total soluble sugars, reducing sugars, non-reducing sugar, and starch contents

The mean value of starch, soluble sugars, reducing sugars, nonreducing sugars were, 70, 63, 21, and 81 g/kg, respectively. The main effect of temperature reduced starch content by 18 % and increased soluble sugar, reducing sugar, and non-reducing sugar, by 27, 49 and 10 %, respectively (Fig 4.6). Whereas, main effect of salinity stress reduced starch content by 11 % and increased soluble sugar and reducing sugar by 16, and 23 %, respectively (Fig. 4.8a-c). The combination of salinity stress and high temperature also resulted in a significant decrease in starch content with about 28 % reduction over control and increase in soluble sugar and reducing sugar which were about 50, and 86 % respectively (Fig. 4.12a-c). The value of total soluble sugar accumulation ranged between 67 and 72 g/ kg in genotypes CARSON, TX04M410211 and TASCOSA (Fig 4.10a). High temperature x genotype interaction had significant (P < 0.001) effect on soluble sugar accumulation. Figure 4.14a shows the percent increase in soluble sugars accumulation in each genotypes due to high temperature effect. The result showed that genotypes 2174-05 had the highest quantity of soluble sugar with percent increase of 38 %. Whereas, genotype GAGE had the least increase in soluble sugar accumulation of about 20 %. Salinity x genotype interaction also significantly (P < 0.0001) affected soluble sugar accumulation. The interaction effect increased soluble sugars by 8-30 % in all genotypes, with genotype GUYMON accumulated the highest amount of soluble sugars and genotypes MTS0531 accumulated the lowest amount (Fig 4.16a). In addition, high temperature x salinity x genotypes interactions significantly (P < 0.0001) affected soluble sugar accumulation in all genotypes tested (Fig. 4.17a). In respect to reducing sugars, the values of reducing sugars ranged between 46 and 50 g/kg and the result showed that genotypes CARSON, TX04M410211 and TASCOSA had the highest value in reducing sugar accumulations (Fig. 4.10b). High temperature x genotype interaction had significant (P < 0.001)

effect on reducing sugar accumulation. Figure 4.14b showed the increase in reducing sugars accumulation in each genotypes due to high temperature effect. The result showed that in genotype TASCOSA the reducing sugars increased by 60 %, whereas it increased by 42 % in GAGE genotype (Fig 4. 14b). Reducing sugar accumulation also increased significantly ($P < 0.01$) due to salinity x genotype interaction. The interaction effect increased reducing sugar by 16-36 %, with genotype GUYMON accumulated the highest quantity of reducing sugars and genotypes AVALANCHE accumulated the lowest quantity (Fig. 4.16b). Reducing sugars significantly ($P < 0.001$) affected by temperature x salinity x genotypes interaction (Fig. 3.17b). The genotype TASCOSA showed the best performance under combined stresses condition. Non- reducing sugars significantly ($P < 0.0001$) affected by high temperature and salinity x temperature interaction. High temperature x genotype interaction had significant ($P < 0.0001$) effect on non-reducing sugar accumulation. The result showed the increase in reducing sugars accumulation in each genotypes due to high temperature effect and that in genotype TASCOSA the non-reducing sugars increased by 34 and only by 2 % in ONAGA and OK05108 genotypes (data not shown). Salinity x genotype interaction; and high temperature x salinity x genotypes interactions had significant ($P < 0.0001$) effect on non-educing sugars accumulation (data not shown). The amount of starch in wheat leave were significantly ($P < 0.0001$) decreased by high temperature salinity and combined high temperature and salinity stress. Genotypes responded differentially to the stresses. The value of starch accumulated ranged between 80 and 84 g/kg. Figure 4. 10c, showed the starch content in all genotypes and that genotypes include TX04M410211, CARSON and TASCOSA had the highest amount of starch as compared to other genotypes. Interaction effect of high temperature x genotypes was significant ($P < 0.0001$) and in some genotypes such as genotype CO04W320 the starch contend decreased by 23 % and in genotypes TX04M410211 and TASCOSA the starch

content was reduced by 15 % (Fig 4.14c). In addition, salinity x genotype interaction and high temperature x salinity x genotype interactions significantly (P < 0.0001) decreased starch content in all wheat genotypes (data not shown).

Proline, Soluble protein, and MDA contents

The mean value of proline, soluble protein and MDA were, 3 µmoles/ g, 13 g/ kg and 2.4 (µmol/g), respectively. The main effect of high temperature resulted in a significant (P < 0.0001) increase proline content in all genotypes tested. High temperature increased proline by 239 % (Fig. 4.7a). While, salinity stress (P < 0.0001) increased proline content by 66 % (Fig. 4.9a). The combination of salinity and high temperature stress also resulted in a significant (P < 0.0001) increase in proline, which was 567 % increase of proline content (Fig. 4.13a) and genotypes responded differently to the stress where the value of proline accumulation ranged between 3.2 and 3.7 µmoles/g some genotype include CARSON, TX04M410211 and TASCOSA accumulated maximum values for proline content as compared to the other genotypes (Fig. 4.11a). Temperature x genotypes interaction had significant (P < 0.0001) effect on proline accumulation. Figure 4. 15a showed that accumulation of proline increased in all genotypes with percent increase between 159 -213 % in genotype CARSON and TX04M410211, respectively. Salinity x genotype interaction had significant (P < 0.05) effect on accumulation of proline. A per cent increase between 76 and 113 % were reported in CARSON and GUYMON genotypes respectively (Fig. 4.16c). In addition, an increase of proline accumulation was significant (P < 0.05) due to temperature x salinity x genotype interactions (Fig 4.17c).

The main effect of high temperature, salinity and genotypes resulted in a significant (P < 0.0001) increase soluble protein content. High temperature increased soluble protein by 56 % (Fig.

4. 7b). While, salinity stress increased soluble protein 14 % (Fig. 4.9b). The combination of salinity stress and high temperature also resulted in a significant ($P < 0.001$) increase in soluble protein with percent increase of 80 % (Fig. 4.13b). Genotypes act differently in response to the stress, where genotypes TX04M410211 and MTS0531 had the highest accumulation of soluble proteins and genotype GUYMON had the least protein accumulation (Fig. 4.11b). High temperature x genotype interaction effect was significant ($P < 0.01$), all genotypes showed increase in soluble protein accumulation due to high temperature as compared to optimum temperature. Genotype CARSON showed percent increase of about 64 %, and genotype ONAGA showed 47 % per cent increase in protein accumulation. (Fig. 4.15b). Salinity x genotype interaction and temperature x salinity x genotype interactions had no significant effect on soluble protein accumulation.

The main effect of high temperature, salinity and genotypes resulted in a significant ($P < 0.0001$) increase in MDA content. High temperature increased MDA by 190 % (Fig. 4.7c). While, salinity stress increased MDA content by 68 % (Fig. 4.9c). The combination of salinity stress and high temperature also resulted in a significant ($P < 0.001$) increase in MDA content with percent increase of 427 % over the control (Fig. 4.13c) and genotype acted differently as the value of MDA ranged between 2.1 and 2.9 µmol/g. Figure 4.11c showed that genotypes CARSON and TX04M410211 accumulated less MDA and genotype CO04W320 accumulated high amount of MDA. High temperature x genotype interaction significantly ($P < 0.0001$) increased MDA content in wheat leaves. A per cent increase of 217 % in MDA content was seen in genotype ONAGA due to high temperature, whereas genotypes CARSON accumulated less MDA (157 %) under the same condition (Fig. 4.15c). Salinity x genotype interaction as well as high temperature x salinity x genotypes interactions had no significant effect on MDA.

Growth and Yield Traits

Plant Height, Tiller Numbers, Spike Numbers, Spike Length and Vegetative Dry Biomass

The main effect of high temperature was significant (P < 0.001) on plant height, spike length, and biomass dry weight (Tables 4.3, 4.4, and 4.5), but there was no effect of high temperature on tiller number and spike number per plant. The main effect of salinity was significant (P < 0.0001) on plant height and biomass dry weight, but not significant on tiller number, spike number per plant and spike length (Tables 4.3, 4. 4, and 4.5). Also genotype effect was significant (P < 0.0001) on plant height and spike length, but not significant on tiller number, spike number per plant, and biomass dry weight. Combined stresses of high temperature and salinity was significant (P < 0.05) on plant height, tiller number, and dry weight but not significant on spike number per plant and spike length. However, high temperature x genotype interaction, salinity x genotype interaction and high temperature x salinity x genotype interactions had no significant effect on all parameters mentioned above.

Spikelet Numbers, Grain Numbers, Grain Yield, Individual Grain Weight, and Harvest Index

The main effect of high temperature stresses was significant (P < 0.0001) on spikelet number; grain number, grain yield, individual grain weight and harvest index. The results showed that high temperature significantly decreased spikelet number by 19 %; grain number by 53 %; grain yield by 59 % and harvest index by 58 % (Figures 4. 18). The main effect of salinity stress (120 mM) was significant (P < 0.0001) on spikelet number, grain number, grain yield; and harvest index. The results reported that salinity significantly decreased spikelet number by 14 %; grain number by 34 %; grain yield by 37 % and harvest index by 35 % (Figures 4. 19). The interaction effect of high

temperature x salinity was significant (P < 0.0001) on spikelet number, grain number, grain yield, and harvest index. The results showed significant decrease in spikelet number by 31 %; grain number by 72 %; grain yield by 77 % and harvest index by 75 % (Figures 4.21a-d). Genotype responded differently to the stresses in term of spikelet number, grain number, grain yield, individual grain weight, and harvest index. Figure 4.20 a-d showed that genotypes such as GUYMON, TX04M410211 and TASCOSA had the highest value in term of spikelet number per spike and genotypes TX04M410211, CARSON and TASCOSA had the highest value in term of grain number per plant, grain yield per plant and harvest index (Fig. 4.20a-c). High temperature x genotype interaction had significant (P < 0.05) effect on spikelet number, grain number, grain yield, individual grain weight and harvest index (Table 4. 3). Figure. 4.22aand b showed the per cent reduction, for all genotypes tested. The reduction in grain yield was between 48 % in genotypes CARSON and TX04M410211 and 64 % in genotypes GUYMON, OK05108 and 2174-05 (Fig. 4.22a). Also Fig 4.22b shows the per cent decrease in harvest index. It showed that genotype TX04M410211 had per cent reduction of 47 % and genotypes GUYMON had per cent reduction of 64 %. In addition, salinity x genotype interaction had significant (P < 0.05) effect on some yield traits include spikelet number and grain number, but it had no significant effect of grain yield and harvest index. The reduction of spikelet number ranged between 9 and 18 % (Fig. 4. 23a); ad the reduction of grain number ranged between 27 and 41 % (Fig. 4.23b). High temperature x salinity x genotypes also significantly (P < 0.05) affected most of yield traits. Figure 4.24a and b shows the reduction on grain yield and harvest index due to salinity x high temperature x genotype and their interactions genotypes include CARSON, TX04M410211 and TASCOSA showed good performance under combined stresses.

Discussion

High temperature and salinity stresses affect plant growth and development at all growth stages. However, wheat plants are more sensitive to high temperature stress during reproductive stages than at vegetative stages. Plants growing under high temperature and saline condition are subjected to suffer from drought stress, ion toxicity, and nutrient imbalance which may lead to reduced growth and productivity. Exposure to high temperatures and salinity stress may vary with the stage of plant development, but all vegetative and reproductive stages are affected by high temperature stress (Wahid et al., 2007; Farooq et al., 2011; Sultan et al., 2012) and salinity stress (Munns and Termaat, 1986; Maas and Grattan, 1999). Flowering stage in wheat is the transition between two growth stages, which are the vegetative stages and the grain filling stages. During vegetative the reproductive initiation, and reproductive development occur and determine the final yield potential and provide the photosynthetic factory essential for maximum yield. At the flowering stages, fertilization has been shown to be highly sensitive to high temperatures in various plants. Therefore stress in this stage mostly result in yield decline. Though, there are limited studies on the combined and independent effects of high temperature and salinity during this stage on winter wheat. Under high temperature and salinity stress plants are encounter to water stress, which results in reduced leaf photosynthesis, stomata conductance, caused thylakoid membrane damage, reduced seed set, spikelet number per spike, grain number per plant, harvest index and ultimate yield per plant. In such situations many plants accumulate some osmo-protective compounds such as proline, glycine-betaine, and carbohydrates (Poustin et al., 2007; Sultan et al., 2012; Ghafiyehsanj et al., 2013; Sabbagh et al., 2014; Yu et al., 2015; Tavakoli1 et al., 2016).

This study has been done to evaluate the response of different winter wheat genotypes to an individual and combination of salinity and high temperature stress. This study reported that

high temperature and salinity stresses had significant effect on physiological, biochemical, and yield traits of winter wheat genotypes. The study also reported that, while the negative impact of high temperature stress was higher than the impact of salinity stress, the combined stresses of high temperature and salinity was much greater than each individual stress.

The study found that high temperature and salinity stresses directly influences photosynthetic process and influences gas exchange and causes thylakoid membrane damage. Also stomatal conductance become more negative under high temperature and salinity stress, which led to stomata closing and reduce CO_2 concentration in leave. These results are in agreement with other studies that have been done on the effect of high temperature on wheat (Wahid et al., 2007; Djanaguiraman et al., 2010; Farooq et al., 2011; Sabbagh et al., 2014), and on the effect of salinity on photosynthesis and gas exchange in wheat (Kingsbury et al., 1984; Sharma et al., 2005; Dadkhah and Rassam, 2016). This study also in agreement with a study on the effect of combined stresses on gas exchange and photosynthesis process under combined stresses than individual stress (Anjum et al., 2008; Dadkhah and Rassam, 2016). These results suggest that salt-stressed plants led to enhanced sensitivity of plants to high temperature. These results indicated that the combination of salinity stress and high temperature led to closing of stomata, which may cause reduction in CO_2 uptake by wheat leaves. In this study, salinity, high temperature and the combination of salinity and high temperature decreased leaf chlorophyll content. In addition, high temperature induces lipid peroxidation of chloroplast membranes that decreases leaf chlorophyll, which is in agreement with previous research in sorghum and wheat (Esfandiari et al., 2007; Djanaguiraman et al., 2010; Narayanan et al., 2015). This study also found that under combined stresses environments, damage of photosystem II was greater than the damage caused by high temperature or salinity alone. The study herein reported that the interaction effect was additive or

synergistic (positive interaction) the combined effect (high temperature and salinity) was higher than the sum of the individual effect (high temperature or salinity) on leaf photosynthesis and thylakoid membrane damage (Fig. 4.4a and d). On the other hand the interaction effect was hypo-additive (negative interaction) on stomata conductance and maximum quantum yield of PS II (Fig. 4.4b and c. Moreover, the present study found that genotypes responded differently to the individual and combine stress and that some genotypes such as CARSON, TX04M410211 and TASCOSA had performed well under individual and combined stresses as compared to other genotypes (Fig. 4.3-c). The tolerance of photosynthetic system to salinity stress may be related to the capacity of some plant species to successfully compartmentalize the salts in the vacuole (Sabbagh et al., 2014). Also the tolerance of photosynthetic system to high temperature and salinity could be due to the production of some antioxidant enzymes which may cause ROS detoxification (Esfandiari et al., 2007; Khan et al., 2015; Narayanan et al., 2015).

Under stress condition many plants accumulate some osmoprotective compounds such as proline, glycine-betaine, and carbohydrates (Hamada and Khulaef. 1995; Poustin et al., 2007; Sultan et al., 2012; Ghafiyehsanj et al., 2013; Sabbagh et al., 2014; Yu et al., 2015; Tavakoli1 et al., 2016). Soluble sugars, reducing sugars and non-reducing sugars have significant role in plant metabolism such as products of hydrolytic processes, substrates in biosynthetic processes, and energy production. The present study indicates that salinity and high temperature stress individually and in combination increased sugar compounds. The increase of these substances may play an important role in osmotic regulation. Some plants are able to stand salinity by reducing the cellular osmotic potential as a result of a net increase in inorganic and solute accumulation (Yang et al., 2009; Sabbagh et al., 2014). Numerous studies have tried to linke the increase of soluble carbohydrate to temperature stress tolerance (Radi et al., 2013) and salinity stress tolerance (Ashraf

and Tufail, 1995). The present result is in agreement with other result which reported that high temperature and salinity stress resulted in a significant increase, in the total of soluble sugar, reducing sugar and non-reducing sugar in some wheat genotypes (Hamada and Khulaef, 1995). This study indicated that high temperature and salinity treatments resulted in a significant increase, in the total of soluble sugar, reducing and non-reducing sugar in all genotypes, however there was a trend that some genotypes accumulated high amount of these carbohydrates. The genotype CARSON, TX04M410211 and TASCOSA showed to be more tolerant to stress as compared to other genotypes (Fig. 4.10a-c). In addition the result of this study found decrease in starch content in all wheat genotypes tested, which agree with previous study on the effect of water stress on wheat plant (Saeedipour and Morad, 2011). This reduction in starch content is due to decreased photosynthetic rate, the main source of starch, under stress condition.

Proline accumulation has been demonstrated to be correlated with stress tolerance in plants (Hare and Cress, 1997; Ashraf and Foolad, 2007; Tatar and Gevrek 2008). The proline accumulation observed in this study provides other evidence that increased proline levels create an adaptive response for plants during water stress. This result is in agreement with previous studies about high temperature stress on wheat (Sultan et al., 2012) and salinity stress on wheat (Ashraf and Foolad 2007; Poustin et al., 2007; Ghafiyehsanj et al., 2013; Yu et al., 2015; Tavakoli1 et al., 2016). In the present study, high temperature and salinity stress at flowering stages, increased significantly the proline accumulation in all the wheat genotypes tested. And the increase was greater in CARSON and TASCOSA and lowest in GUYMON and MTS0531 (Fig. 4.11a).

One of the most common responses of many plant species exposed to abiotic stresses is the accumulation stress related proteins (Farooq et al., 2011; Kosová et al., 2013; Kumar et al., 2013; Radi et al., 2013). In the present study, increase in total leaf soluble protein under high temperature

and salinity stress was perceived at flowering stages. This increase in total soluble proteins under stress condition is due to the production of stress proteins such as heat chock proteins and other related stress proteins. These proteins are shown to be one adaptive strategy for many plants. Variability was also found among different wheat genotypes for soluble proteins accumulation under salt and high temperature stress where the accumulation of soluble proteins was grater in TX04M410211 and lower in GUYMONR (Fig. 4.11b).

MDA has been considered an indicator of stress induced oxidation in cell membranes and a tool for determining stress tolerance in plants (Dhyani et al., 2013; Ghafiyehsanj et al., 2013; Radi et al., 2013). In this study, MDA content was significantly increased due to high temperature, salinity and combined stresses. However, the accumulation of MDA content was higher in some genotypes than in other genotypes, this suggest that within the genotypes tested there were some susceptible genotypes that accumulated more MDA such as CO04W320; and some were tolerant genotypes include CARSON and TX04M410211 (Fig 4.11c). Many studies agree that increasing in MDA content is linked with increasing of the degree of stress in wheat plants (Tatar and Gevrek, 2008; Dhyani et al., 2013; Mansoor and Naqvi, 2013) and that plant that accumulate less MDA are more tolerant.

Improvement of grain yield in wheat is an important objective in breeding program. Therefore, the assessment of final grain yield and other yield related parameters determining grain yield is an important feature of breeding programs. This study showed that high temperature and salinity at the flowering period decreased almost all yield traits of winter wheat. This research reported that decrease in yield was due to a decrease in spikelet number per spike and grain number per spike (Fig. 4.21a and b), which agree with (El-Hendawy et al., 2005). In the present study, at flowering stages high temperature, salinity and combined stresses significantly decreased grain set

185

per plant in all the tested wheat genotypes. This is in agreement with previous studies on high temperature (Owen, 1971; Saini and Aspinall, 1983; Prasad et al., 2008; Pradhan et al., 2012; Reynolds et al., 2012; Prasad et al., 2014; Narayanan et al., 2015), where they conclude that high temperature stress during reproductive stages of crop development resulted in a significant yield losses in wheat. That's because the stress led to morphological abnormalities in pollen, stigma and style and caused florets sterility which lead to decreased grain numbers and high temperature stress during meiosis in wheat can reduce yield by causing abnormal ovary development, which results in reduced pollen tube growth and seed set (Saini and Aspinall, 1983). Also a study on salinity agreed that salinity stress result in reduced gain number (Maas and Grieve, 1990; Sairam et al., 2002; El-Hendawy et al., 2005). This can be due to the fact that spikelet number and grain number are determined during the period of spike emergence to flowering, which in this experiment was the stress period. This study reported that the interaction effect was hypo-additive (negative interaction) the combined effect (high temperature and salinity) was less than the sum of the individual effect (high temperature or salinity) on grain yield and harvest index (Fig. 4.21c and d). In addition, the result herein reported that the highest number grains per plant counted were in CARSON, TX04M410211 and TASCOSA, and the lowest were in 2174-05, OK05108, and AVALANCHE (Fig 4.20b), which indicate that CARSON, TX04M410211 and TASCOSA are tolerance to stress. Combined stresses also caused great reduction on grain number, however, to my knowledge, no previous studies was done to evaluate the impact of combined stresses of high temperature and salinity on wheat at flowering stage. Therefore this observation needs to be confirmed with further studies. There was no effect of combined stresses on individual grain weight, this may be due to fact that grain weight depends on the environmental condition post flowering and at gain filling period, which in our study for these stages the condition was set back

to optimum condition. Therefore the study reported that at flowering stage of the wheat growth, grain number was the main determinant of grain yield under high temperature and salinity stress. In this study and based on grain yield reduction genotype TX04M410211 was the most tolerant to high temperature stress (48 % decline) and to salinity stress (24 % decline) at flowering stage. This genotype is from Texas and is expected to be well adapted to high temperature environment. This genotype was also tolerant to salinity which mean that selection in hot environments may allow for selection of better tolerance to salinity stress. However, genotype OK05108 was highly susceptible to high temperature stress (65 % decline) and genotype MTS0531 was highly susceptible to salinity stress (41 % decline) at flowering stage.

Conclusions

In wheat, flowering stage is the most sensitive stage to abiotic stresses such as high temperature and salinity. High temperature 35 °C and salinity 120 mM NaCl and their combined effects at flowering stage were negatively affects wheat growth and yield. The stress decreased physiological function and resulted in yield reduction. This study conclude that combined stresses was more damaging to wheat development than the individual effect of each stress, which indicated that the interaction effect was additive. High temperatures, salinity and their interaction at flowering stages had undesirable effects on wheat physiology, biochemical, yield and yield component as indicated by the reduced leaf level photosynthesis, reduced chlorophyll content, starch content, increased MDA level, and reduced grain yield and harvest index. Also the study concludes that winter wheat genotypes varied in their response to individual and combination stress of high temperature and salinity stress. Genotype TX04M410211 was the most tolerant ones. This study conclude that there are some traits that can be selected for breeding programs such as

photosynthesis rate, leaf chlorophyll content, grain number and grain yield. However, the screening for wheat genotypes can be based on characteristics related to high yields under stress condition. These criteria better be stable and easy to evaluate specially with high number of genotypes screening. Still, further research is needed to endorse these interaction effects with other wheat genotypes and under field condition.

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Figure 4-1 The main effect of high temperature on (A) leaf photosynthetic rate (μmol m^{-2} s^{-1}), (B) stomata conductance (mmol m^{-2} s^{-1}), (C) maximum quantum yield of PS II (Fv/Fm ratio; unitless), and (D) thylakoid membrane damage (Fo/Fm ratio; unitless) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, three replications of each genotype and three measurements taken on each plant on d 2, 5 and 10 during the stress period. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase or decrease in each trait due to high temperature as compared to optimum temperature is indicated.

Figure 4-2 The main effect of salinity on (A) leaf photosynthetic rate (μmol m^{-2} s^{-1}), (B) stomata conductance (mmol m^{-2} s^{-1}), (C) maximum quantum yield of PS II (Fv/Fm ratio; unitless), and (D) thylakoid membrane damage (Fo/Fm ratio; unitless) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, three replications of each genotype and three measurements taken on each plant on d 2, 5 and 10 during the stress period. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase or decrease in each trait due to salinity as compared to the control is indicated.

Figure 4-3 The main effect of genotype on (A) leaf photosynthetic rate (μmol m^{-2} s^{-1}), (B) stomata conductance (mmol m^{-2} s^{-1}), (C) maximum quantum yield of PS II (Fv/Fm ratio; unitless), and (D) thylakoid membrane damage (Fo/Fm ratio; unitless) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means.. Separation of means was carried out using the LSD test (P < 0.05). Means with different letters are significantly different according to the LSD test at P < 0.05.

Figure 4-4 The effect of combined stresses of high temperature and salinity on (A) leaf photosynthetic rate (µmol m^{-2} s^{-1}), (B) stomata conductance (mmol m^{-2} s^{-1}), (C) maximum quantum yield of PS II (Fv/Fm ratio; unitless), and (D) thylakoid membrane damage (Fo/Fm ratio; unitless) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, three replications of each genotype and three measurements taken on each plant on d 2, 5 and 10 during the stress period. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase or decrease in each treatment as compared to control is indicated.

Figure 4-5 The effect of high temperature and genotype interactions on (A) leaf photosynthetic rate (μmol m^{-2} s^{-1}), (B) thylakoid membrane damage (Fo/Fm ratio; unitless) and (C) chlorophyll index (SPAD unit) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, three replications of each genotype and three measurements taken on each plant on d 2, 5 and 10 during the stress period. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase or decrease due to high temperature as compared to optimum temperature is indicated.
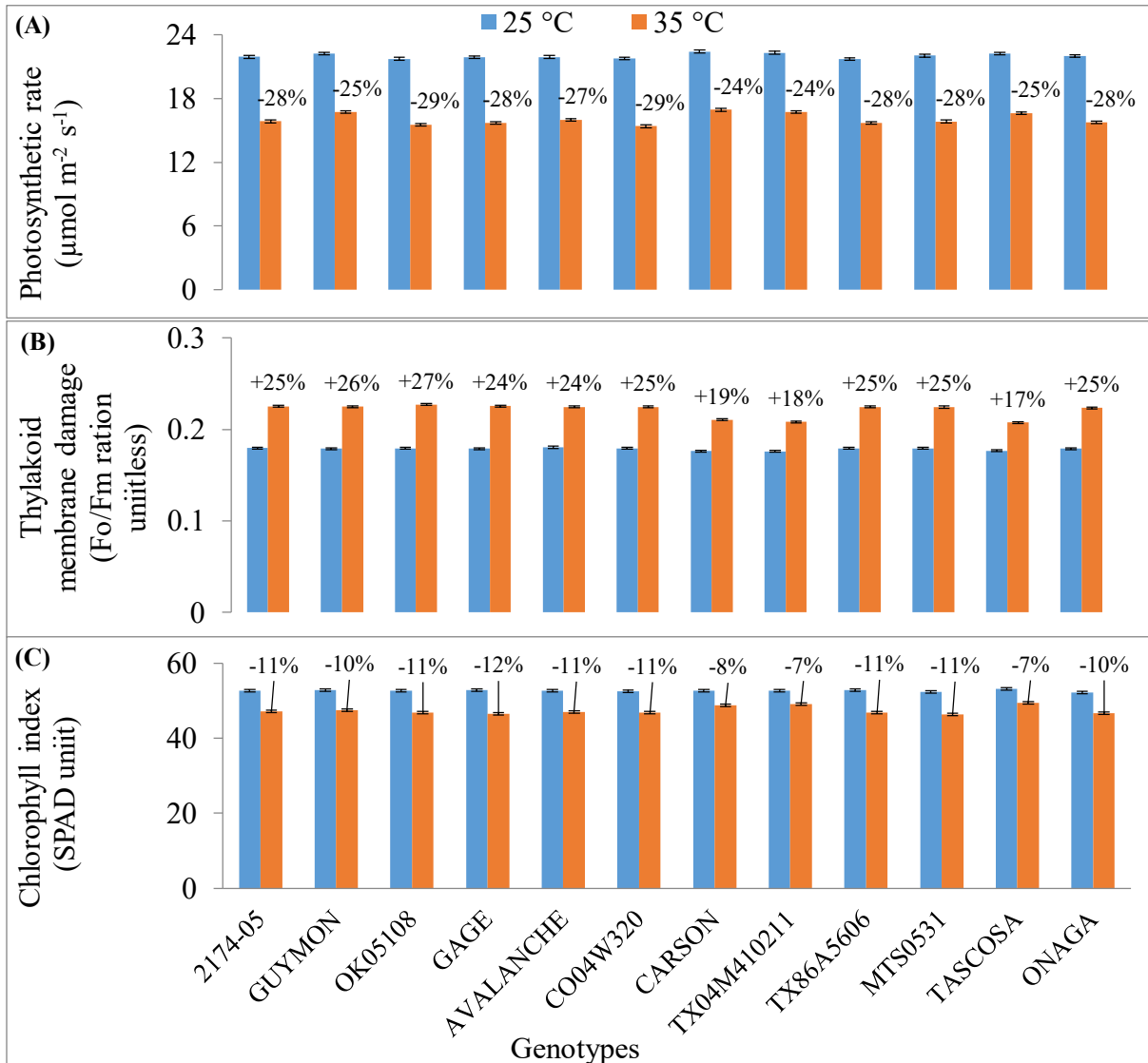
Figure 4-6 The main effect of high temperature on (A) total soluble sugar g/kg, (B) reducing sugar g/kg, (C) non-reducing sugar g/kg, and (D) starch content g/kg of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase or decrease in each trait due to high temperature as compared to optimum temperature is indicated.
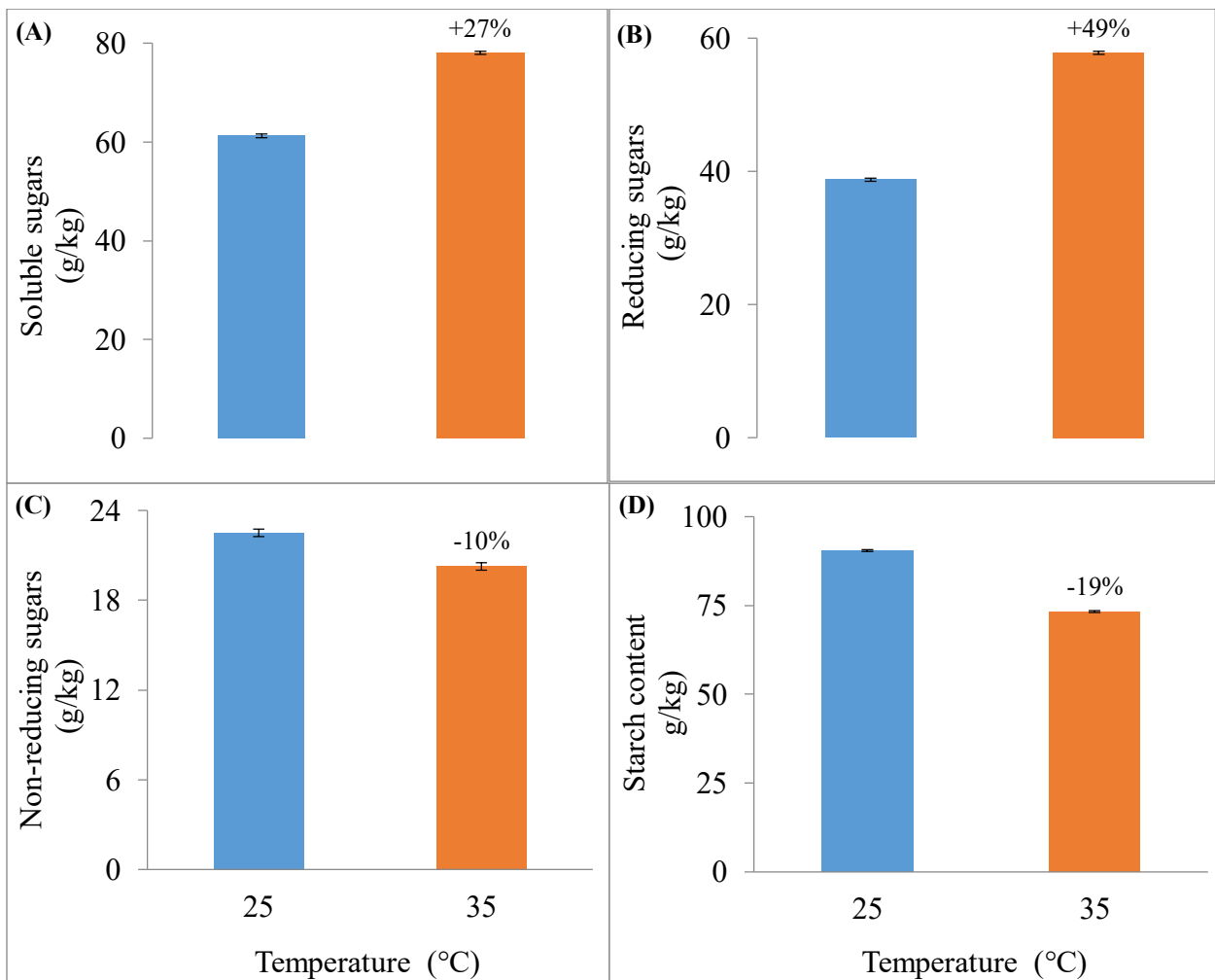
Figure 4-7 The main effect of high temperature on (A) proline content (μmol/g), (B) soluble protein content (g/kg), and (C) MDA content (μmol/g) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase in each trait due to high temperature as compared to optimum temperature is indicated.
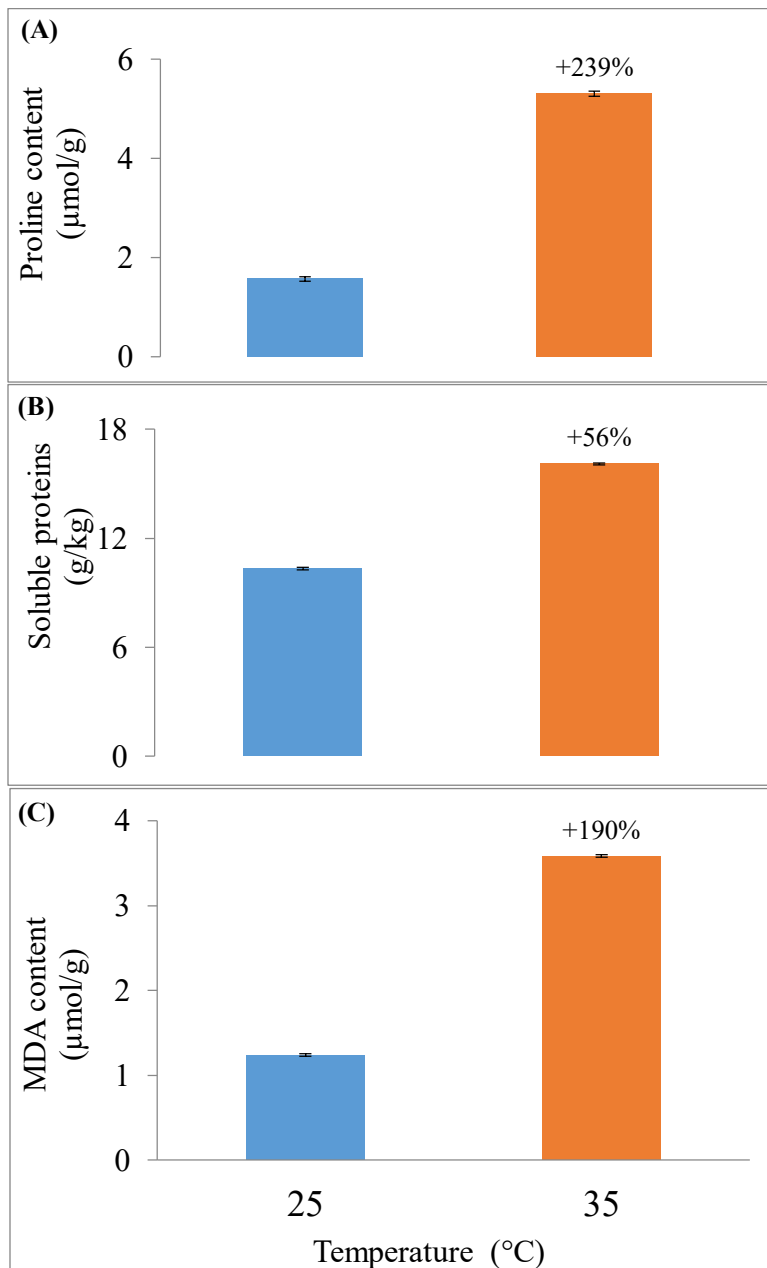
Figure 4-8 The main effect of salinity on (A) total soluble sugar (g/kg), (B) reducing sugar (g/kg), and (C) starch content (g/kg), of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase or decrease in each trait due to salinity as compared to the control is indicated.
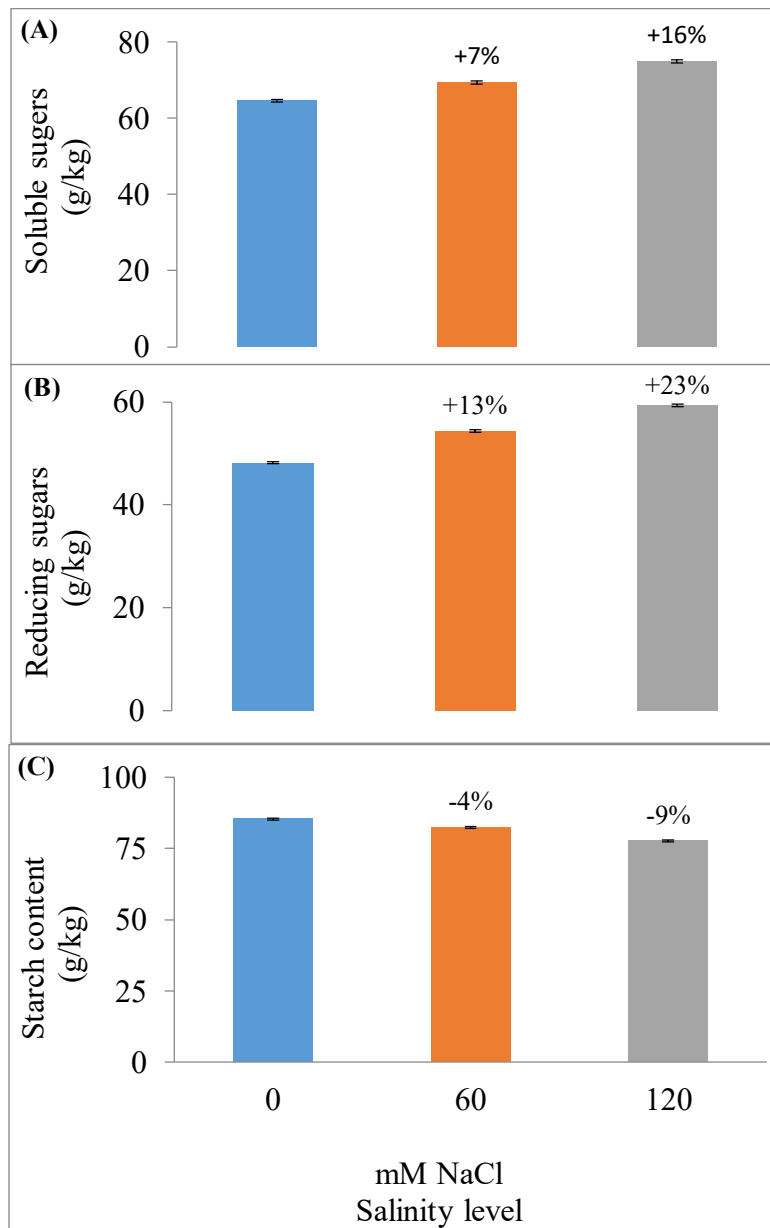
Figure 4-9 The main effect of salinity on (A) proline content (μmol/g), (B) soluble protein content (g/kg), and (C) MDA content (μmol/g) of twelve winter wheat genotypes Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase in each trait due to salinity as compared to the control is indicated.
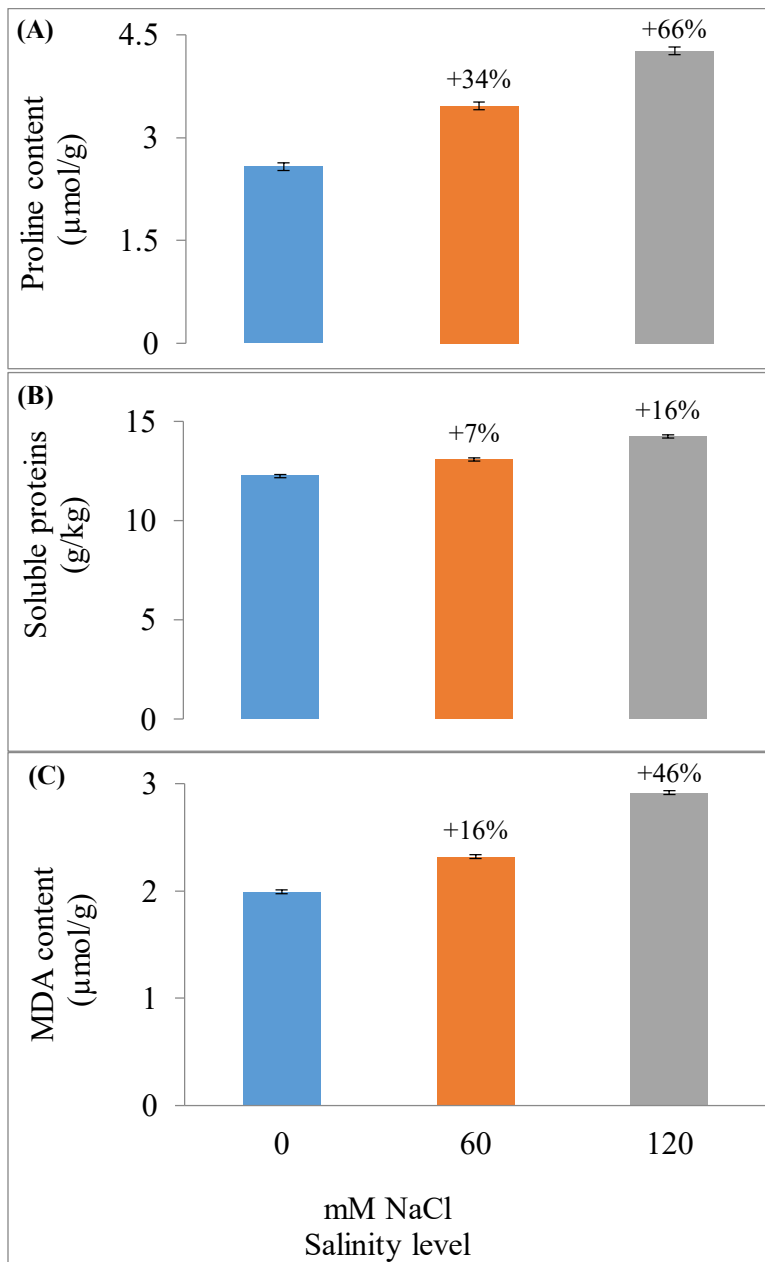
Figure 4-10 The main effect of genotype on (A) total soluble sugar (g/kg), (B) reducing sugar (g/kg) and (C) starch content (g/kg) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Separation of means was carried out using the LSD test (P < 0.05). Means with different letters are significantly different according to the LSD test at P < 0.05.
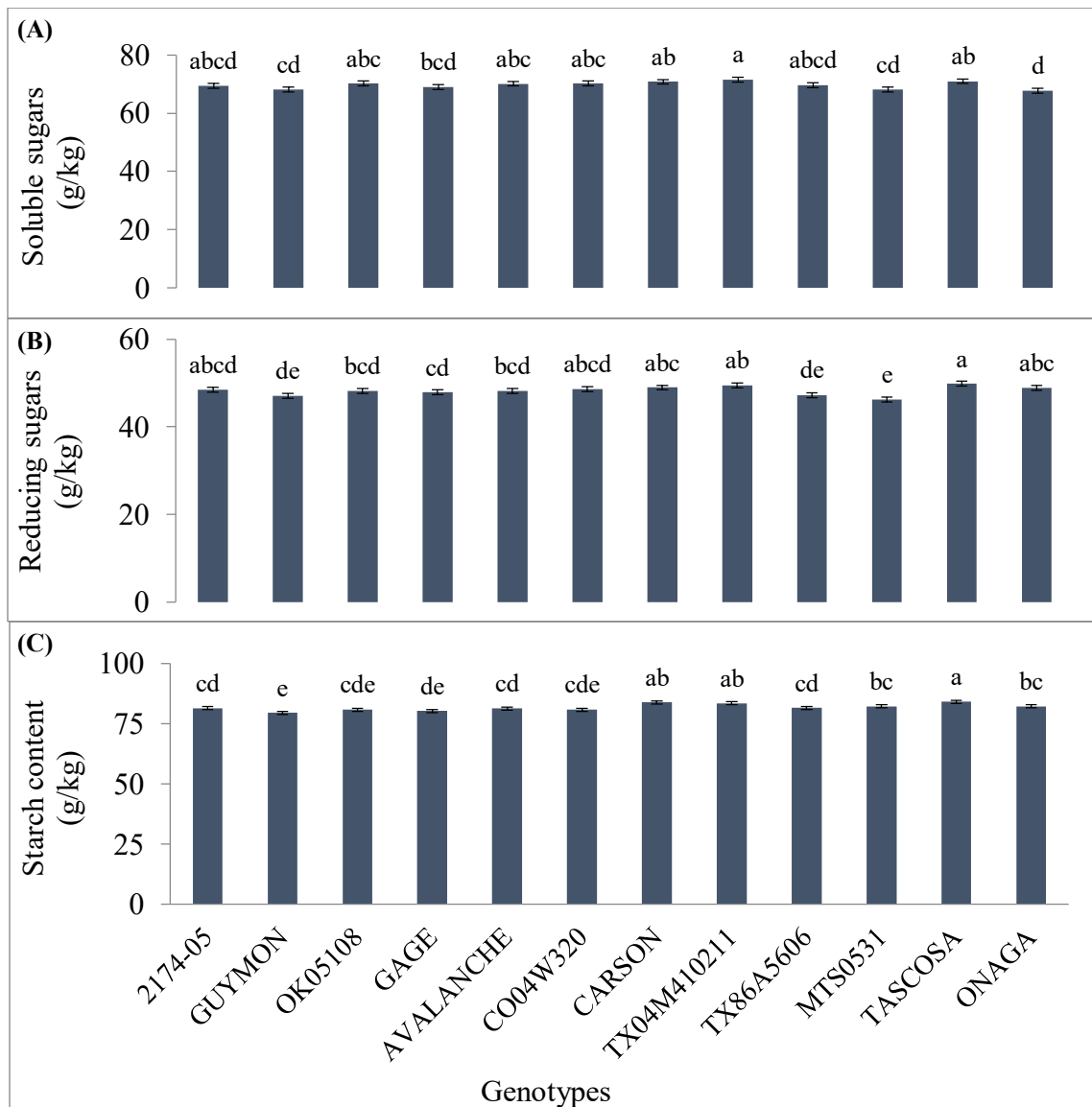
Figure 4-11 The main effect of genotype on (A) proline content (μmol/g), (B) soluble protein content (g/kg), and (C) MDA content (μmol/g) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Separation of means was carried out using the LSD test ($P < 0.05$). Means with different letters are significantly different according to the LSD test at $P < 0.05$.
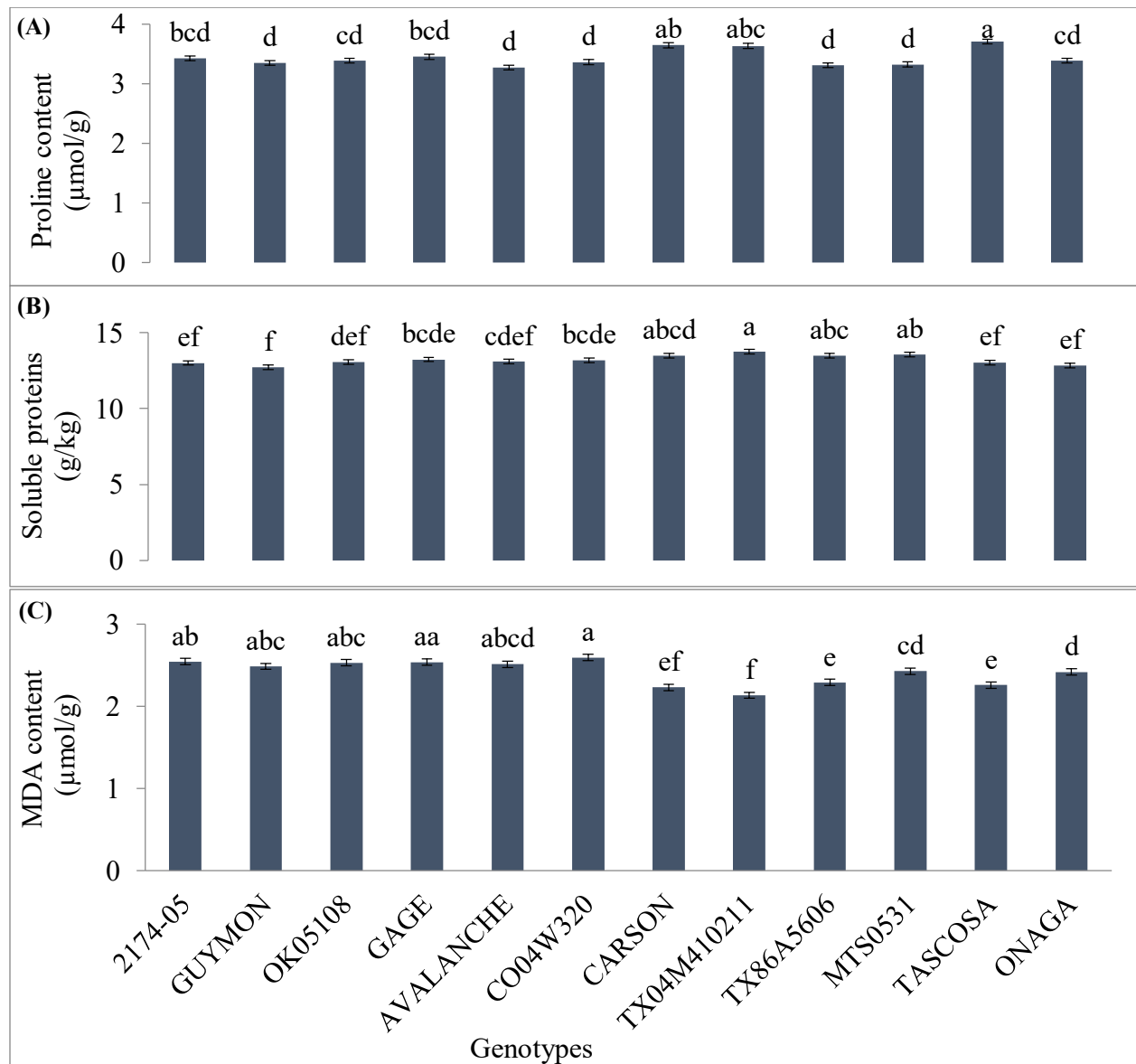
Figure 4-12 The effect of combined stresses of high temperature and salinity on (A) total soluble sugar (g/kg), (B) reducing sugar (g/kg) and (C) starch content (g/kg) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase or decrease in each treatment as compared to control is indicated.
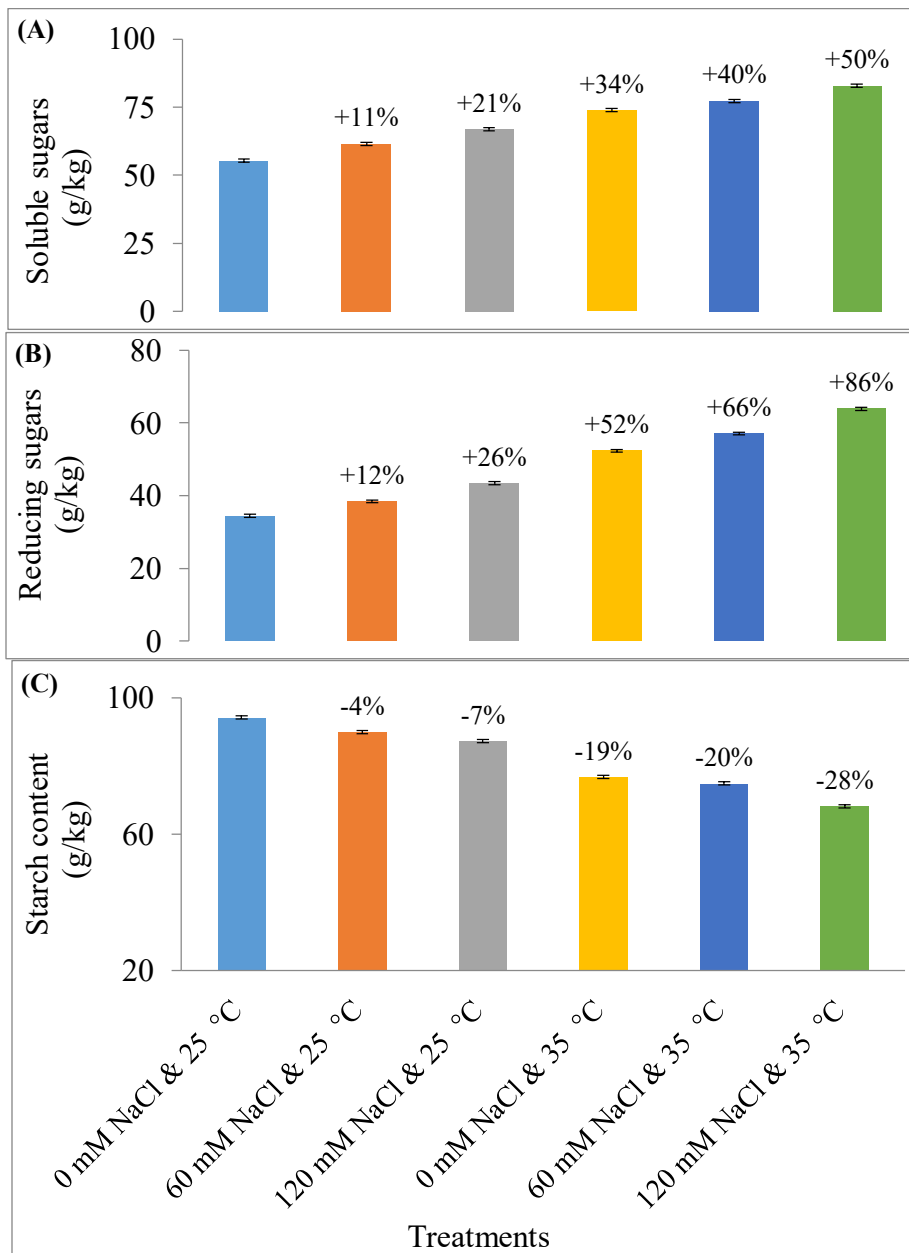
Figure 4-13 The effect of combined stresses of high temperature and salinity on (A) proline content (μmol/g), (B) soluble protein content (g/kg), and (C) MDA content (μmol/g) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase in each treatment as compared to control is indicated.
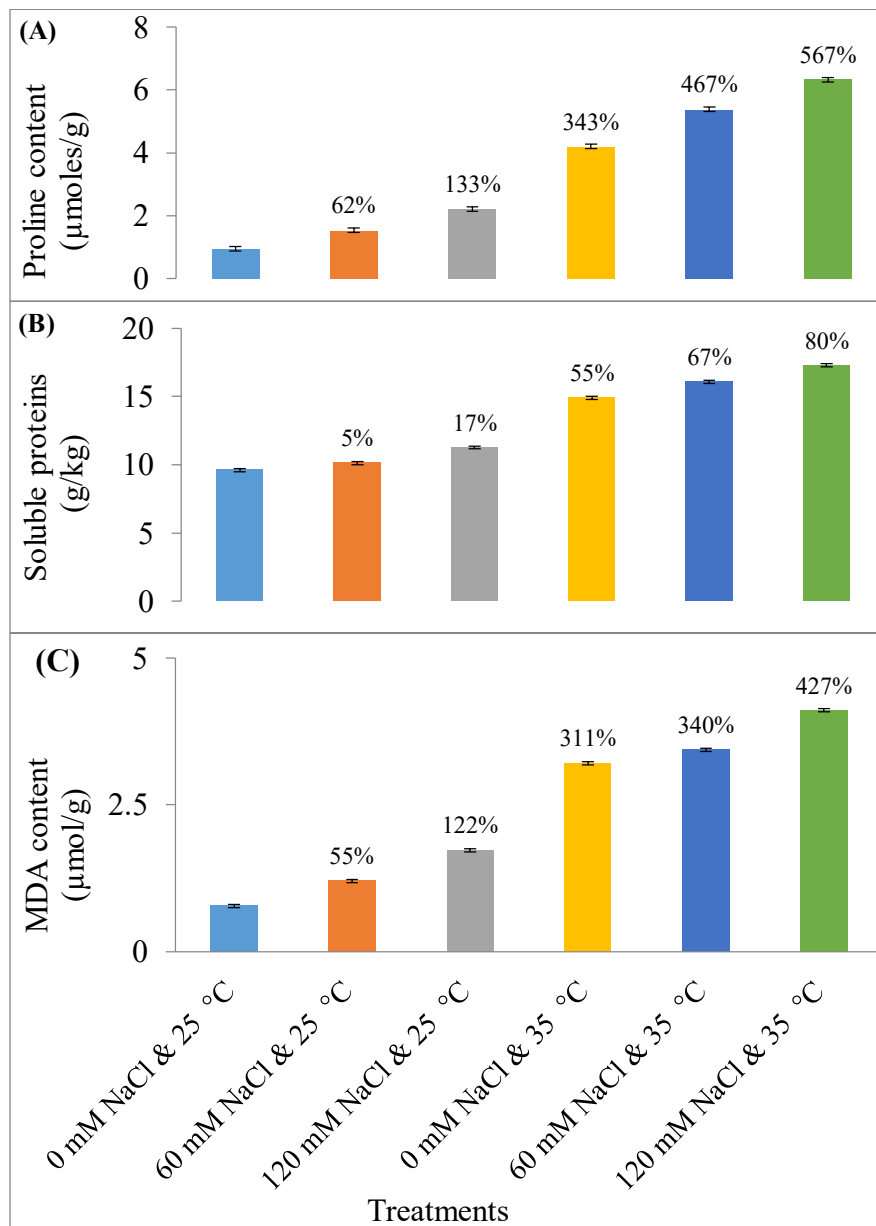
Figure 4-14 The effect of high temperature and genotype interactions on (A) total soluble sugar (g/kg), (B) reducing sugar (g/kg) and (C) starch content (g/kg) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase or decrease in each trait due to high temperature as compared to optimum temperature is indicated on each genotype.
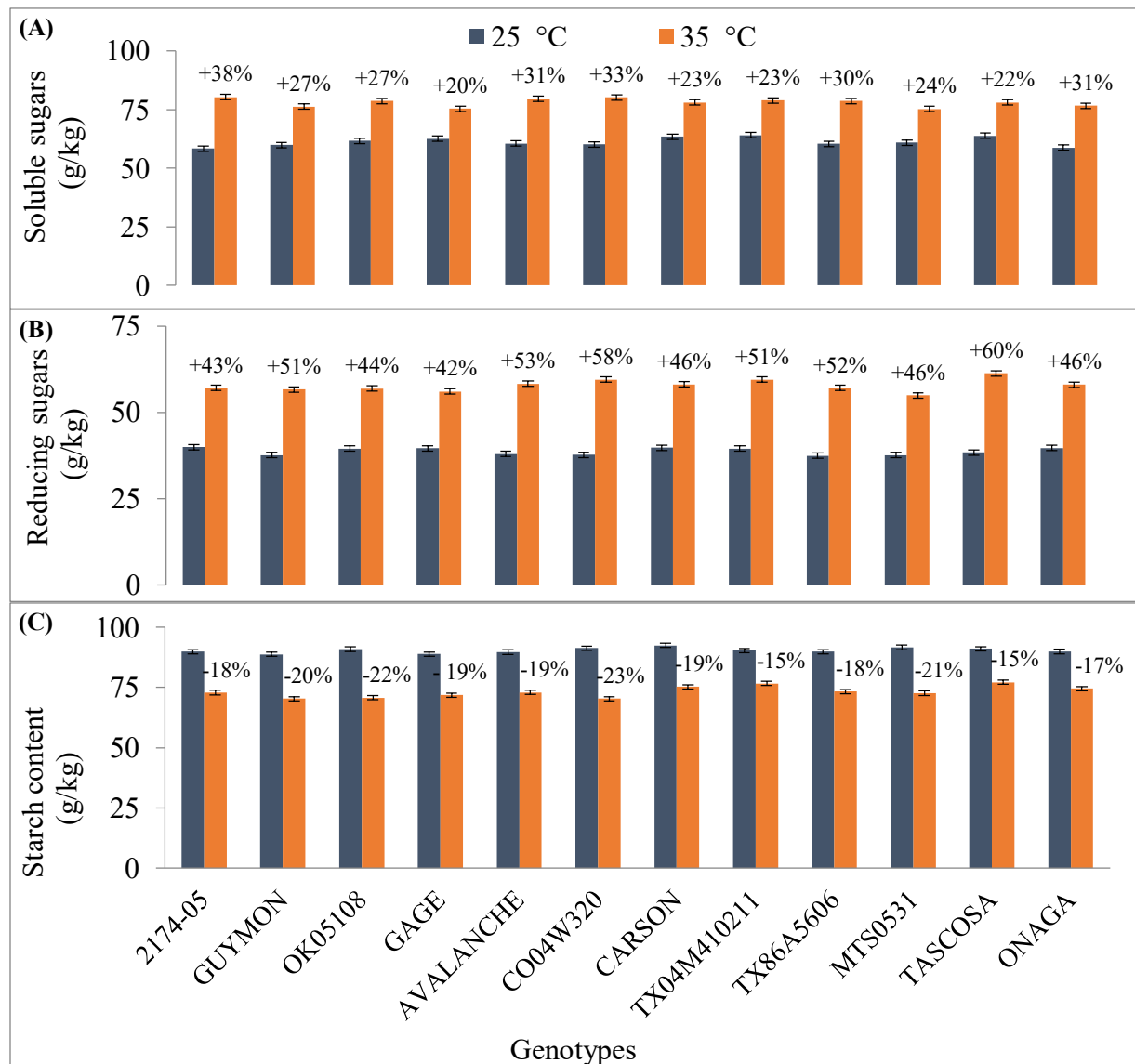
Figure 4-15 The effect of high temperature and genotype interactions on (A) proline content (μmol/g), (B) soluble protein content (g/kg), and (C) MDA content (μmol/g) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase in each trait due to high temperature as compared to optimum temperature is indicated on each genotype.
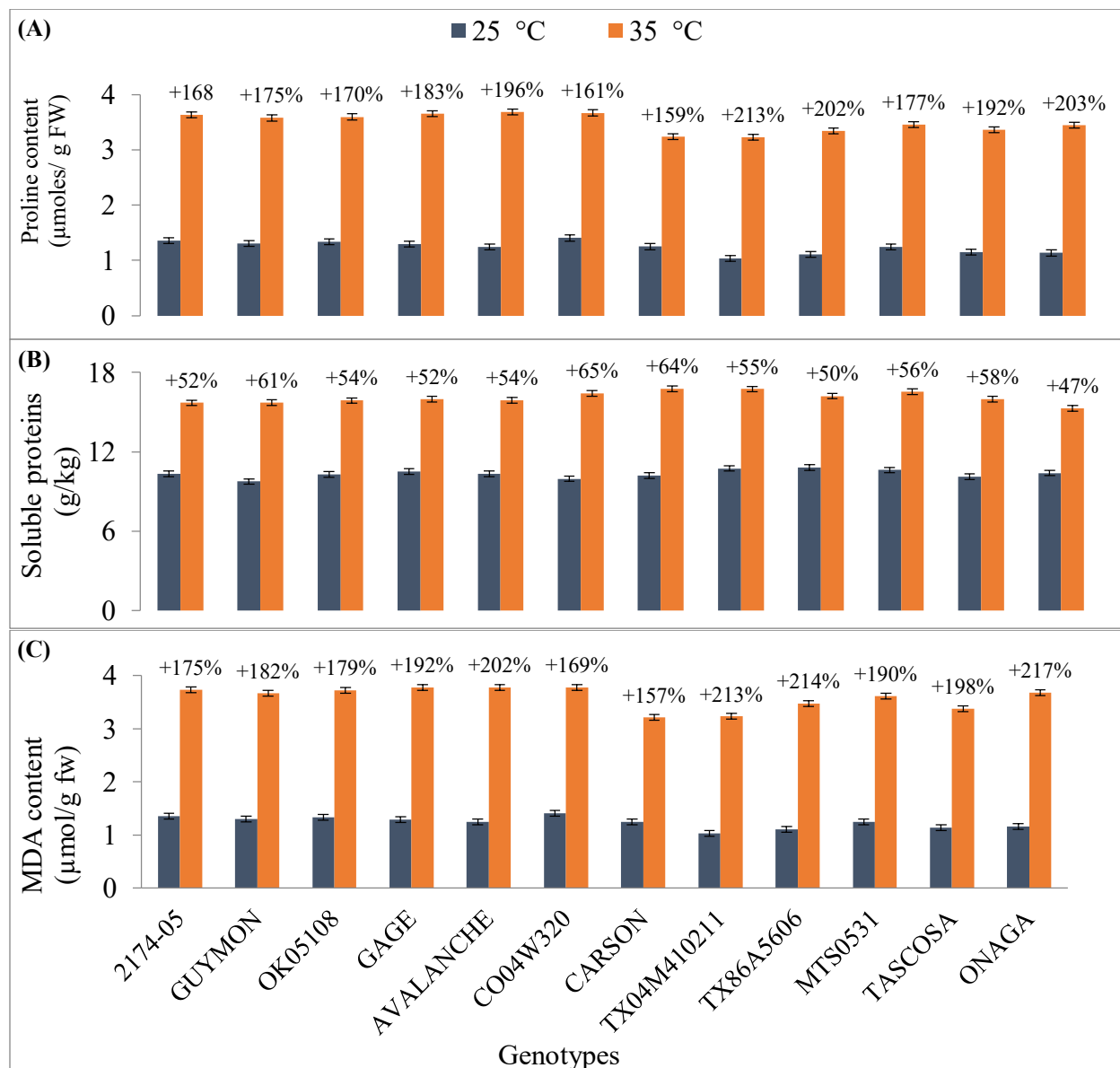
Figure 4-16 The effect of salinity and genotype interaction on (A) total soluble sugar (g/kg), (B) reducing sugar (g/kg) and (C) proline content of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent increase in each trait due to high salinity as compared to the control is indicated.
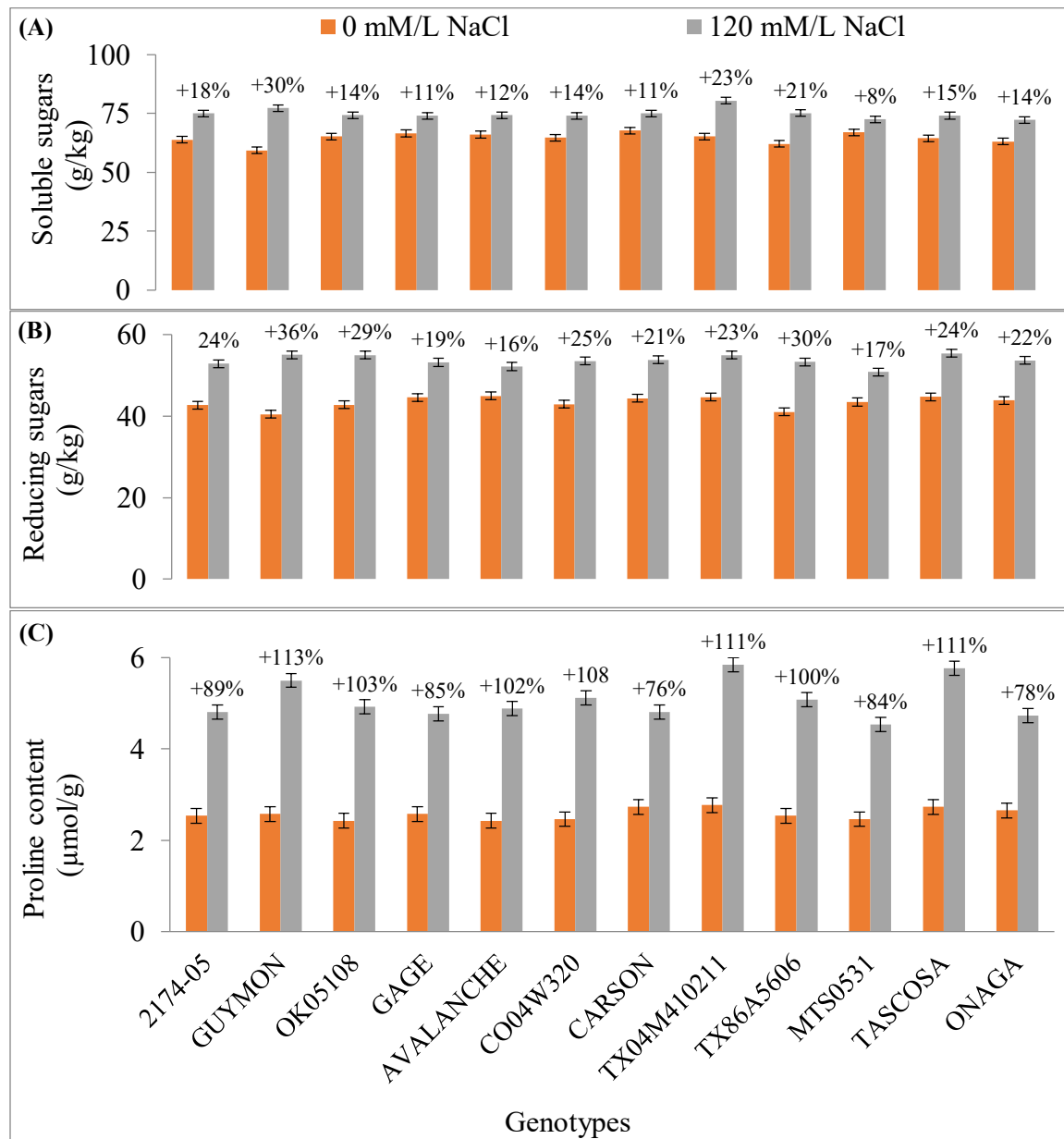
Figure 4-17 The effect of high temperature, salinity and genotype interaction on (A) total soluble sugar (g/kg), (B) reducing sugar(g/kg), and (C) proline content (µmol/g) of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS.
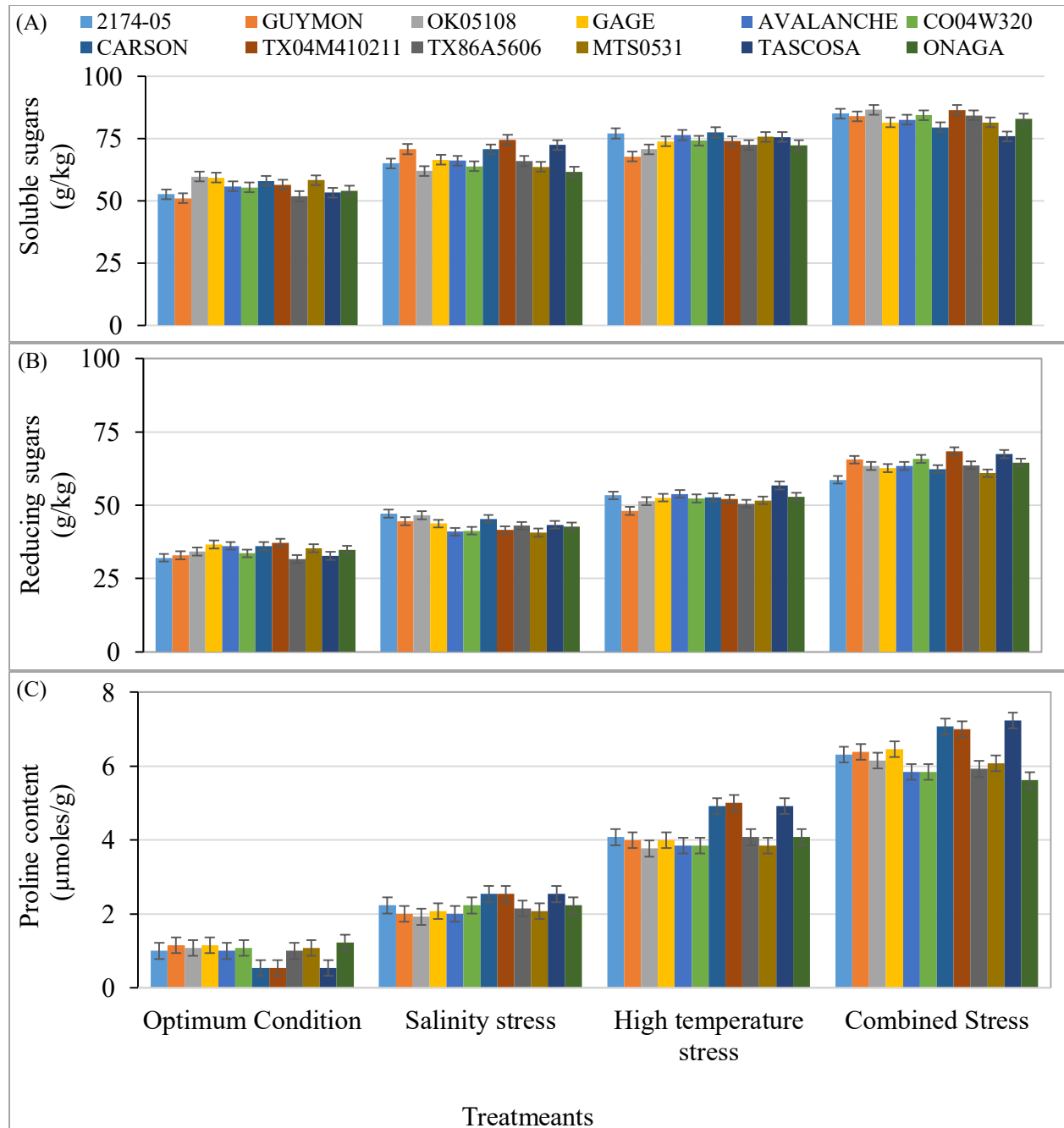
Figure 4-18 The main effect of high temperature on (A) spikelet number per spike, (B) grain number per plant, (C) grain yield per plant (g), and (D) harvest index of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent decrease in each trait due to high temperature as compared to optimum temperature is indicated.
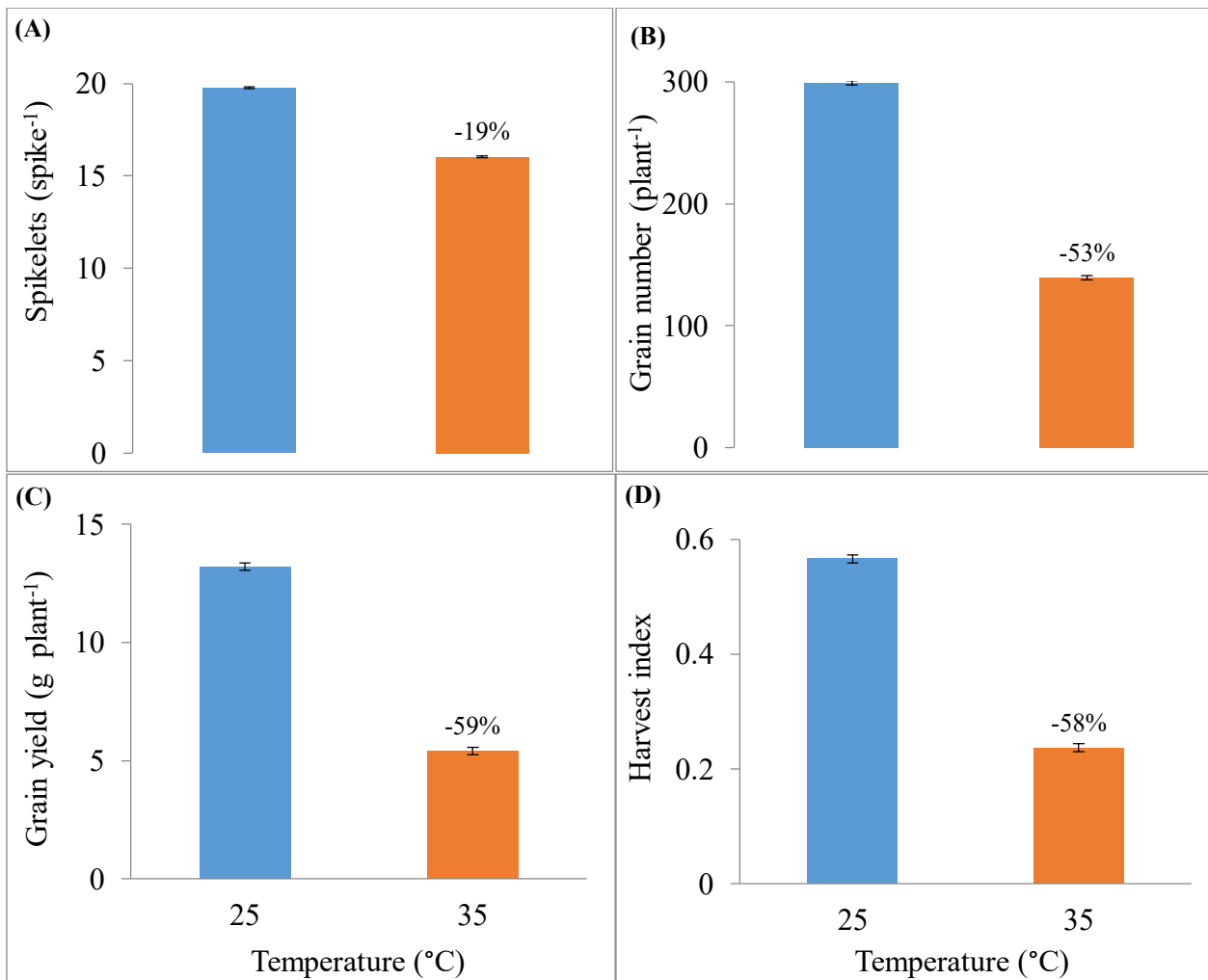
Figure 4-19 The main effect of salinity on (A) spikelet number per spike, (B) grain number per plant, (C) grain yield per plant (g), and (D) harvest index of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent decrease in each trait due to salinity as compared to the control is indicated.
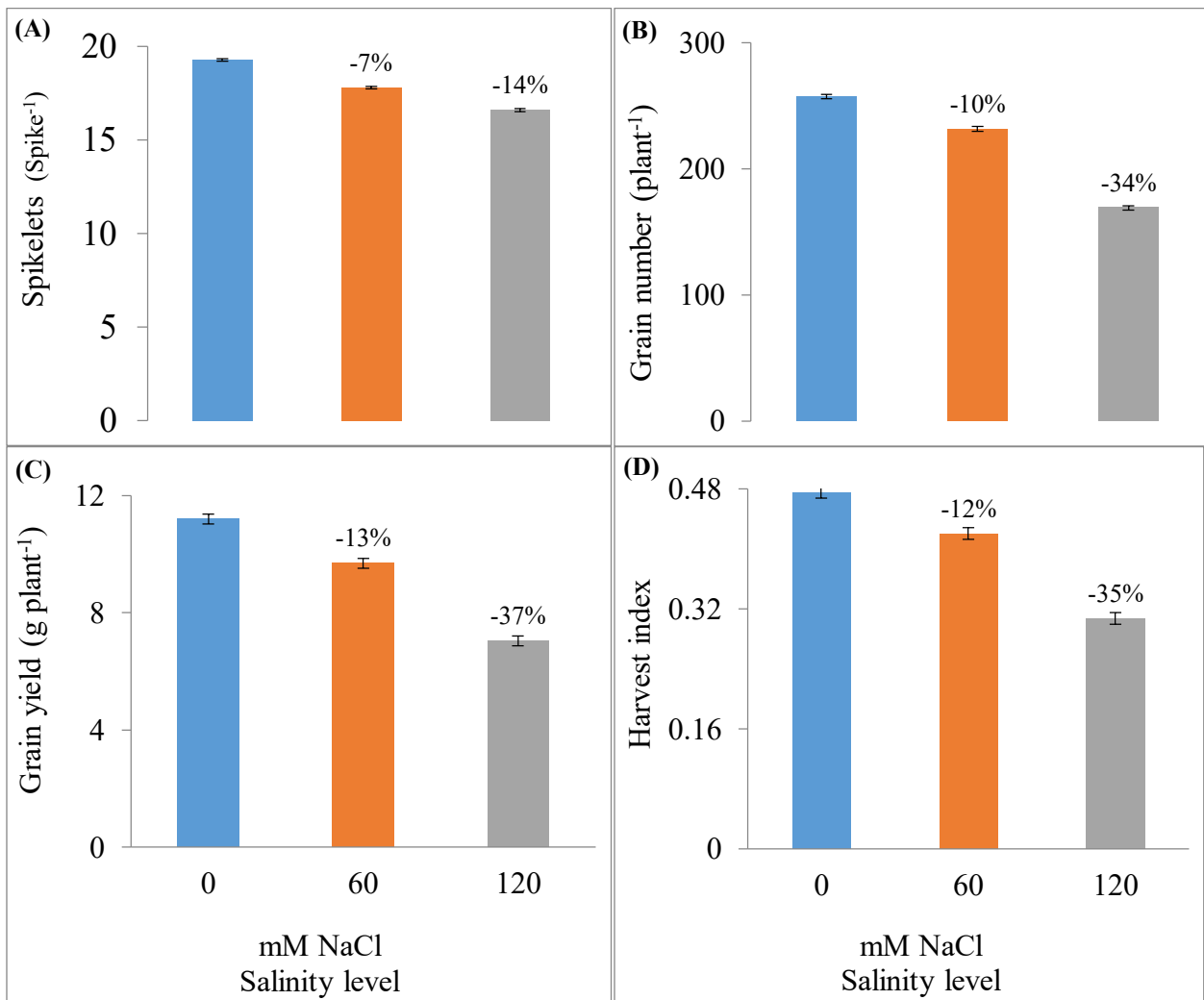
Figure 4-20 The effect of genotype on (A) spikelet number per spike, (B) grain number per plant, (C) grain yield per plant (g), and (D) harvest index of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Separation of means was carried out using the LSD test (P < 0.05). Means with different letters are significantly different according to the LSD test at P < 0.05.
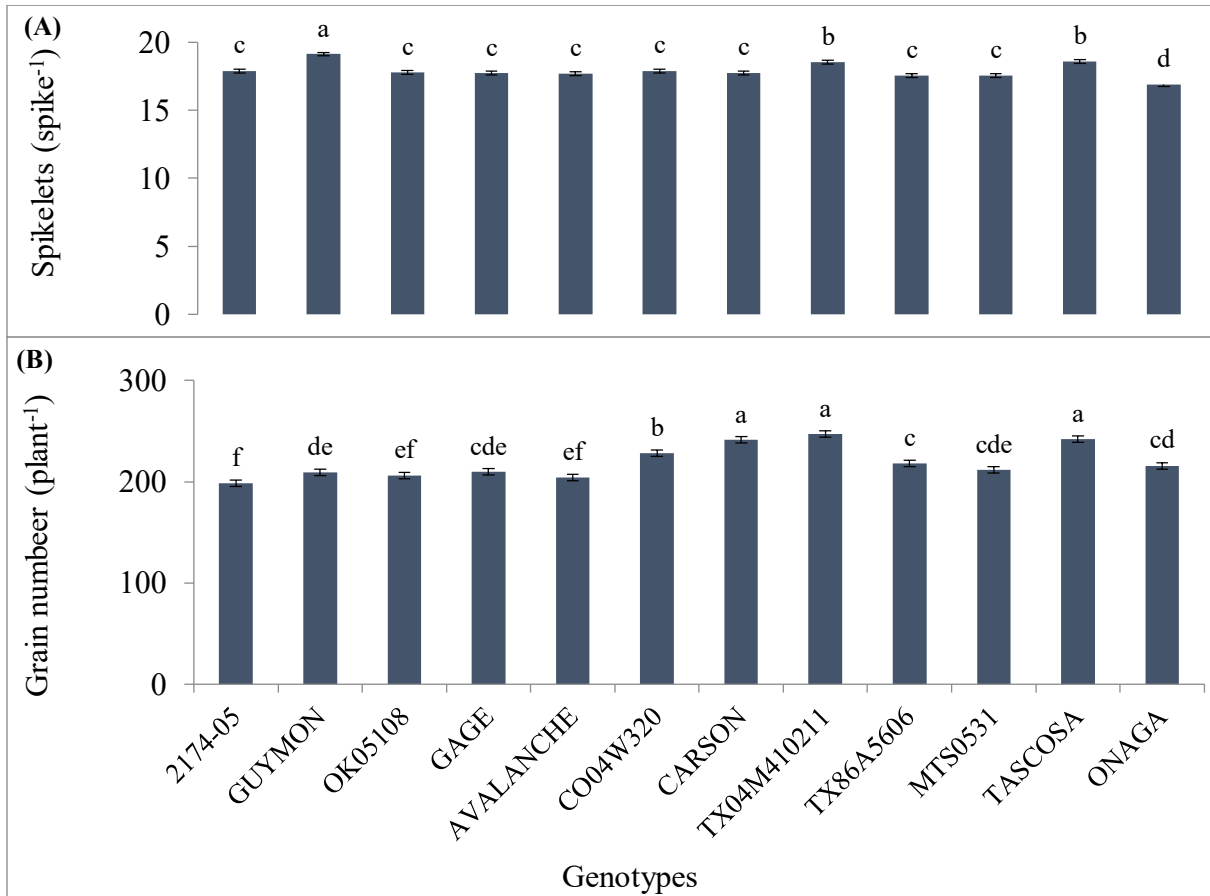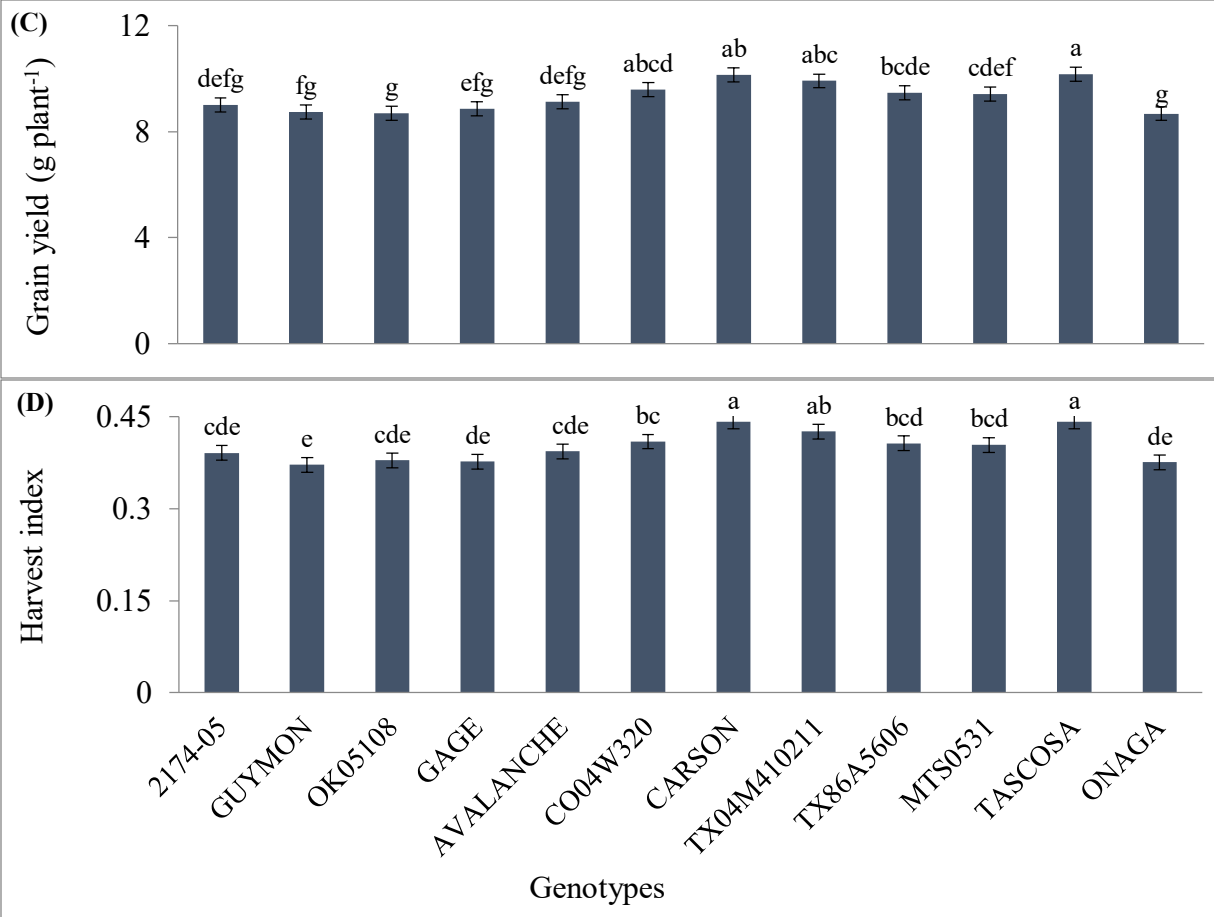
Figure 4-21 The effect of combined stresses of high temperature and salinity on (A) spikelet number per spike, (B) grain number per plant, (C) grain yield per plant (g), and (D) harvest index of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent decrease in each treatment as compared to control is indicated.
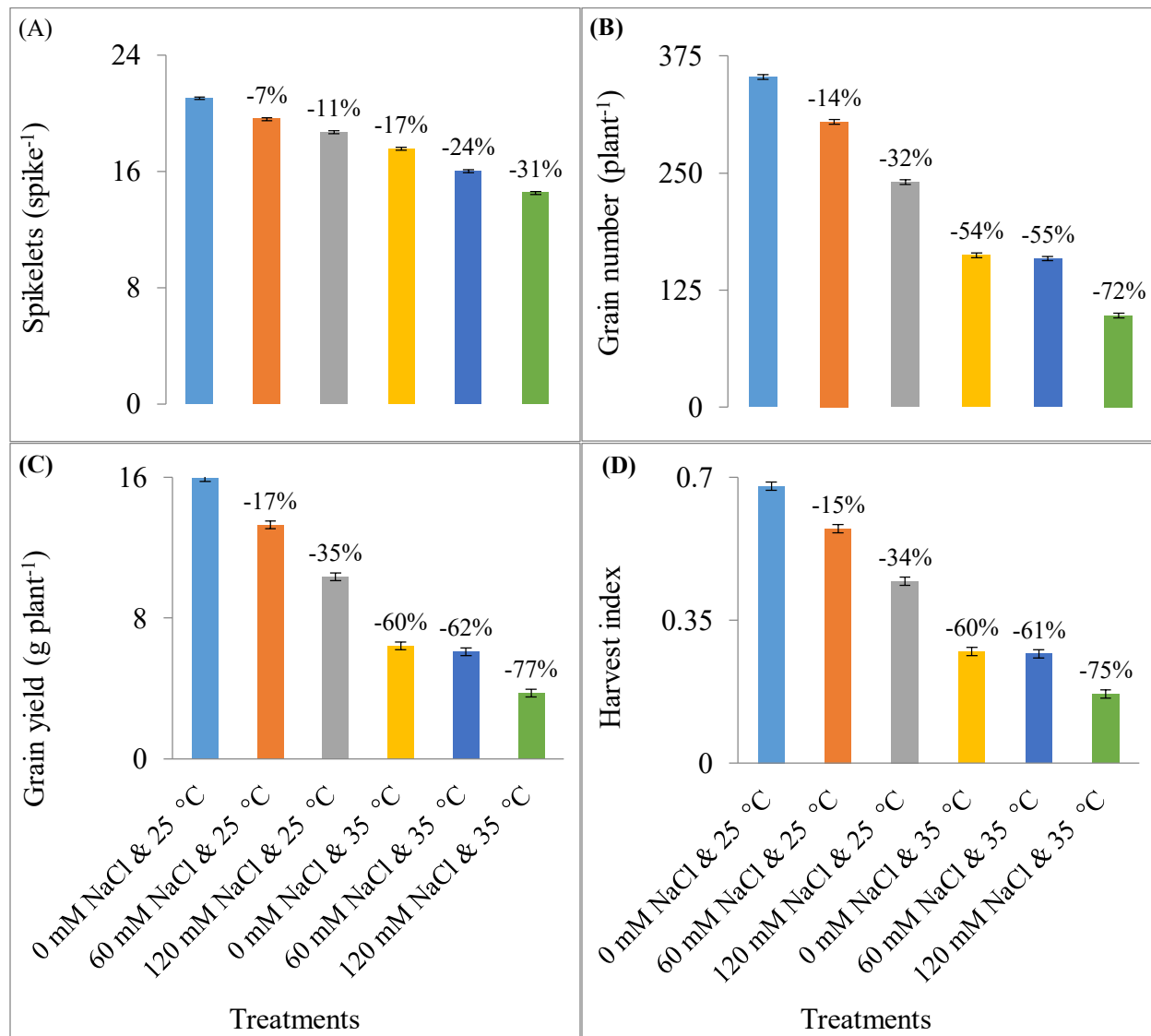
Figure 4-22 The effect of high temperature and genotype interactions on (A) grain yield per plant (g) and (B) harvest ibdex of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent decrease in each trait due to high temperature as compared to optimum temperature is indicated on each genotype.
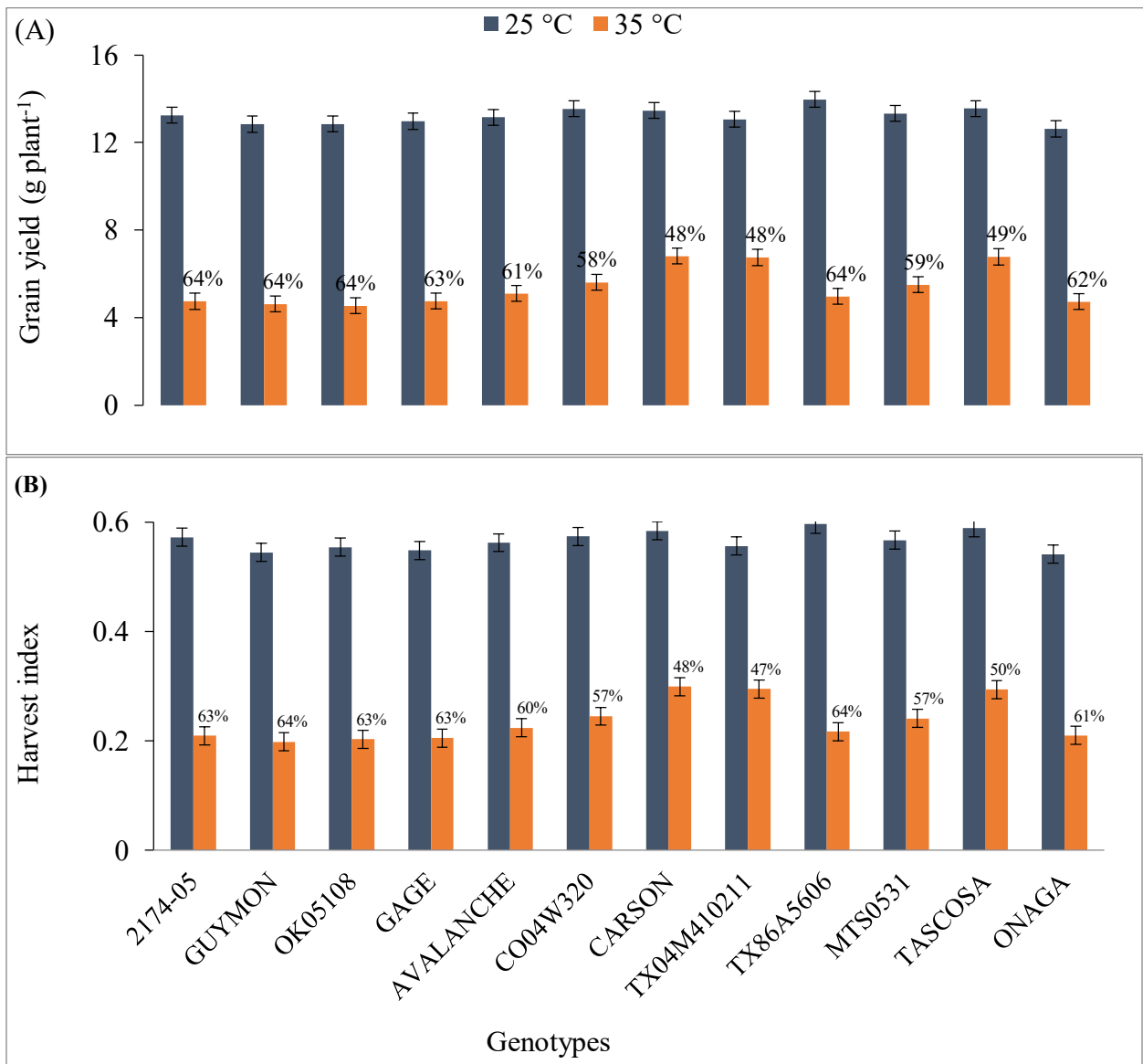
Figure 4-23 The effect of salinity and genotype interactions on (A) spikelet number per spike and (B) grain number per plant of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS. Percent decrease in each trait due to high salinity level as compared to control is indicated on each genotype.
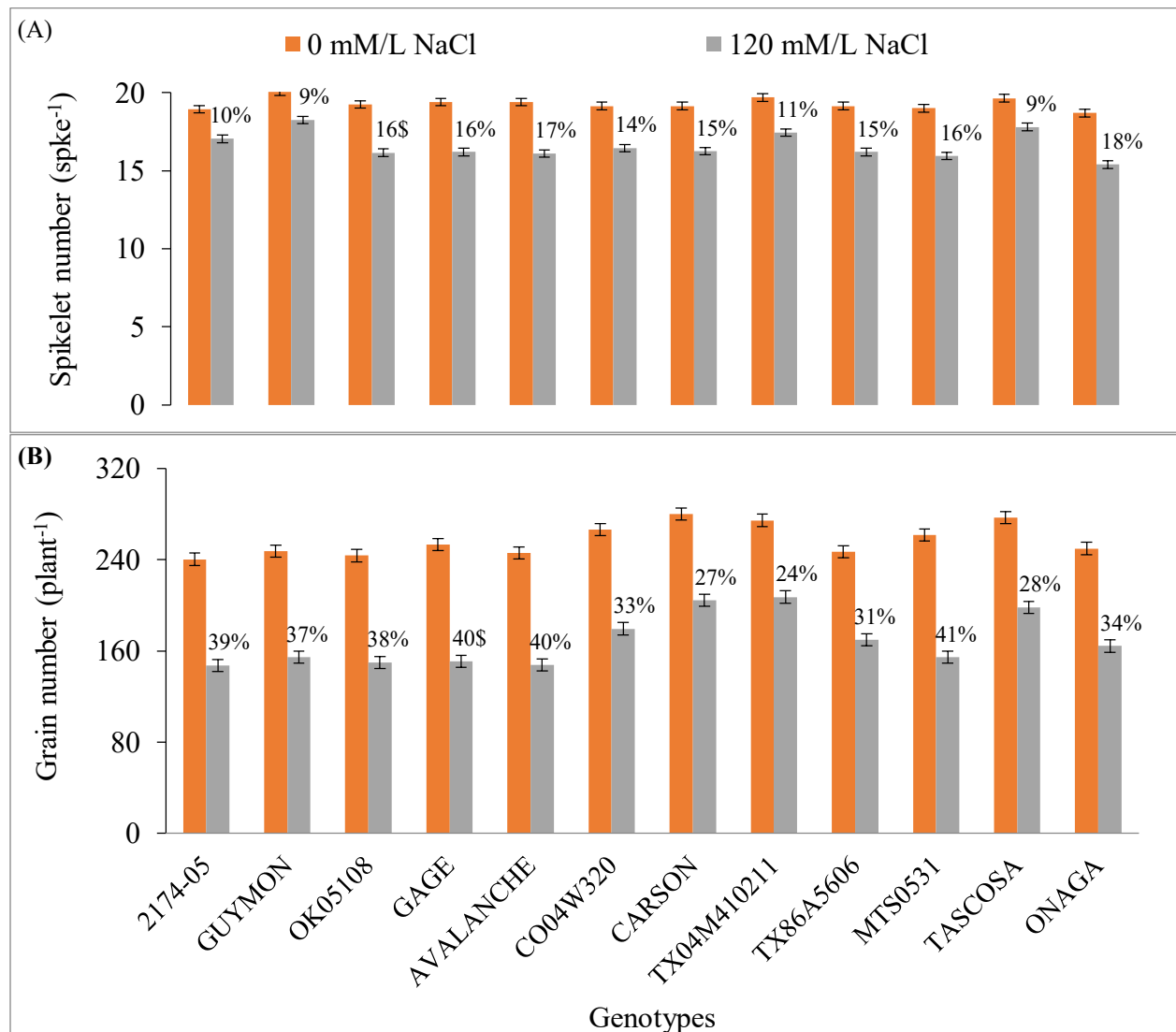
Figure 4-24 The effect of high temperature, salinity and genotype interaction on (A) grain yield per plant and (B) harvest index of twelve winter wheat genotypes. Data are averaged across two experiments, twelve genotypes, and five replications of each genotype. Each datum indicates mean value and vertical lines on top of bars indicate standard error of means. Means and standard errors were estimated using the MIXED procedure in SAS.
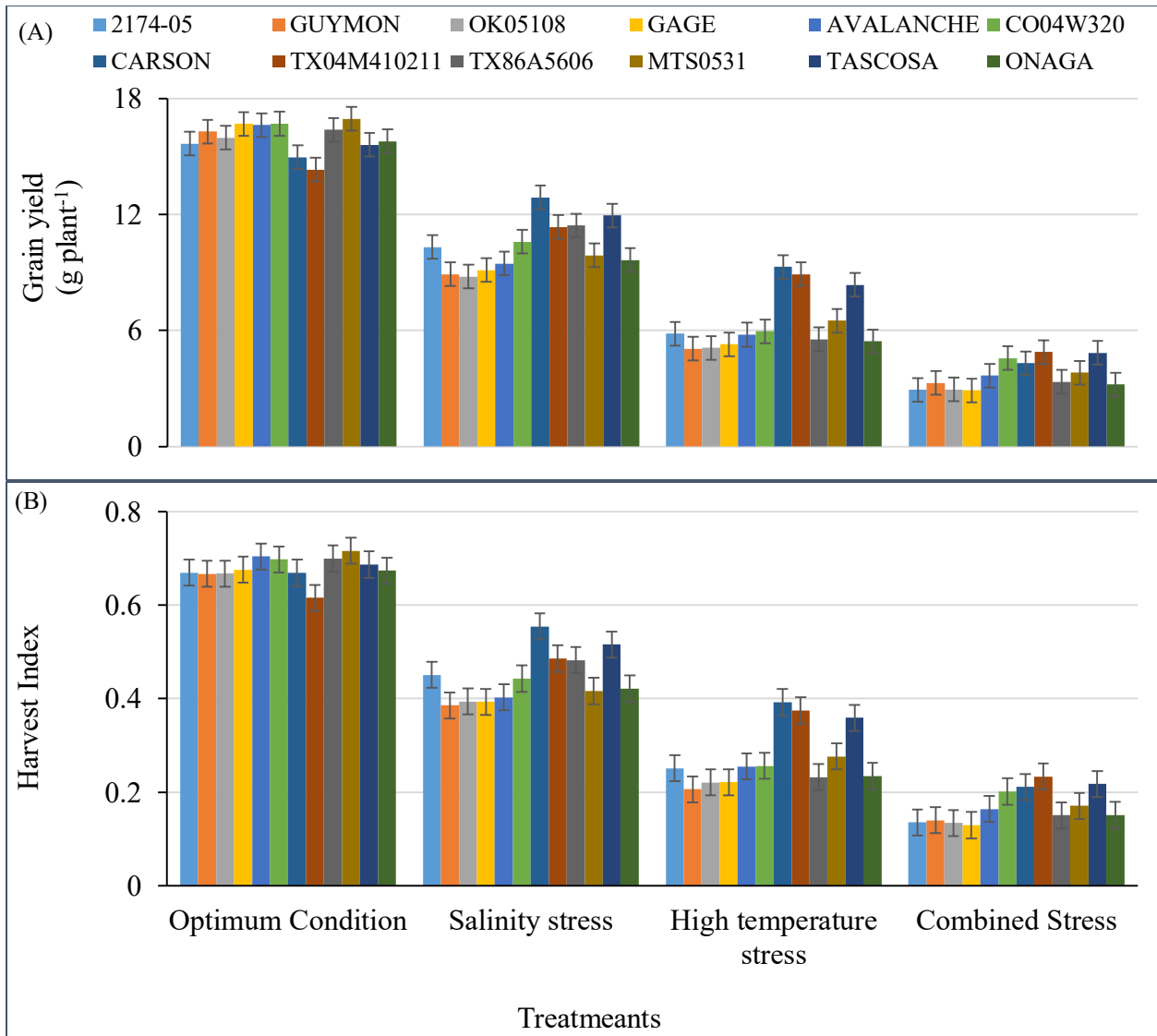
Table 4-1 Probability values of effects of temperature (T), salinity (S), genotype (G),T x S interaction, T x G interaction, S x G interaction and T x G x S interaction on various physiological traits.

Traits	Temperature (T)	Salinity (S)	Genotype (G)	T x S	T x G	S x G	T x G x S
Maximum quantum yields of PS II (Fv/Fm ratio; unitless)	<0.0001	<0.0001	<0.0001	0.0003	0.3678	0.9043	0.9959
Thylakoid membrane damage (Fo/Fm ratio; unitless)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.1204	0.4414
Leaf photosynthesis (μmol m^{-2} s^{-1})	<0.0001	<0.0001	<0.0001	0.0004	0.0005	0.0114	0.7861
Stomatal Conductance (m^2 s^1)	0.0003	<0.0001	0.0008	0.0005	0.7393	0.1077	0.0986
Chlorophyll index (SPAD units)	0.0008	0.0002	<0.0001	0.2035	<0.0001	0.2670	0.4021

Table 4-2 Probability values of effects of temperature (T), salinity (S), genotype (G),T x S interaction, T x G interaction, S x G interaction and T x G x S interaction on various biochemical traits.

Traits	Temperature (T)	Salinity (S)	Genotype (G)	T x S	T x G	S x G	T x G x S
Soluble sugars content (g/kg)	<0.0001	<0.0001	0.0104	0.0216	0.0008	<0.0001	<0.0001
Reducing sugars content (g/kg)	<0.0001	<0.0001	0.0001	0.0036	0.0004	0.0027	0.0001
Non reducing sugars content (g/kg)	<0.0001	0.5887	0.0174	<0.0001	<0.0001	<0.0001	<0.0001
Starch content (g/kg)	<0.0001	<0.0001	<0.0001	0.0004	<0.0001	<0.0001	<0.0001
Proline content (µmol/g)	<0.0001	<0.0001	0.0049	<0.0001	<0.0001	0.0144	0.0299
Soluble proteins content (g/k)	<0.0001	<0.0001	<0.0001	0.0010	0.0045	0.7893	0.1918
MDA content (µmol/g)	<0.0001	<0.0001	<0.0001	0.0006	<0.0001	0.7371	0.5532

Table 4-3 Probability values of effects of temperature (T), salinity (S), genotype (G),T x S interaction, T x G interaction, S x G interaction and T x G x S interaction on various yield traits.

Traits	Temperature (T)	Salinity (S)	Genotype (G)	T x S	T x G	S x G	T x G x S
Plant height (cm)	0.0003	<.0001	<.0001	<.0001	0.1231	0.1207	0.7424
Tiller number (plant^{-1})	1000	0.6690	0.1780	0.0124	0.5618	0.5092	0.4416
Spike number (plant^{-1})	0.1076	0.9186	0.2523	0.2738	0.9161	0.7042	0.3715
Spike length (cm)	< 0.0001	0.9626	< 0.0001	0.1137	04705	0.8192	0.1940
Spikelet number (spike^{-1})	< 0.0001	< 0.0001	< 0.0001	0.0006	0.0204	0.0111	0.0387
Dry weight (g plant^{-1})	< 0.0001	< 0.0001	0.0945	0.0003	0.9016	0.0084	0.1783
Grain number (spike^{-1})	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Grain number (plant^{-1})	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0015	< 0.0001
Grain yield (g spike^{-1})	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0003	0.1898	< 0.0001
Individual grain weight (mg)	< 0.0001	0.3934	0.0288	0.7907	0.7105	0.9860	0.4022
Grain yield (plant^{-1})	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0020	0.3512	< 0.0001
Harvest index	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0108	0.1154	0.0171

Table 4-4 Mean growth and morphological parameters for twelve winter wheat genotypes. Separation of means was carried out using the LSD test (P < 0.05). Means with different letters are significantly different according to the LSD test at P < 0.05.

Genotypes	Plant height (cm)	Number of tillers plant[-1]	Spike number plant[-1]	Vegetative biomass (g plant[-1])
2174-05	67.2cd	8.4c	6.5b	23.0bcd
GUYMON	70.0a	8.5abc	6.7ab	23.5a
OK05108	69.1ab	8.4bc	6.5b	22.8d
GAGE	69.8abc	8.7ab	6.8a	23.4ab
AVALANCHE	68.6abc	8.6abc	6.6ab	23.2abcd
CO04W320	67.8bc	8.7ab	6.7ab	23.3abc
CARSON	68.7abc	8.5abc	6.6ab	22.8cd
TX04M410211	68.9abc	8.5abc	6.6ab	23.1abcd
TX86A5606	64.9e	8.7a	6.6ab	23.3abc
MTS0531	68.5abc	8.6ab	6.7ab	23.3abc
TASCOSA	68.1abc	8.5abc	6.6ab	23.1abcd
ONAGA	65.6de	8.5abc	6.6ab	23.0bcd

Table 4-5 Mean growth and yield parameters for twelve winter wheat genotypes. Separation of means was carried out using the LSD test (P < 0.05). Means with different letters are significantly different according to the LSD test at P < 0.05.

Genotypes	Spikelet number (spike^{-1})	Grain yield (g plant^{-1})	Grain number plant^{-1}	Harvest index
2174-05	17.9c	9.0defg	198.5f	0.39cde
GUYMON	19.1a	8.7fg	209.0de	0.37e
OK05108	17.8c	8.7g	206.2ef	0.38cde
GAGE	17.7c	8.9efg	209.7cde	0.38de
AVALANCHE	17.7c	9.1defg	204.4ef	0.39cde
CO04W320	17.9c	9.6abcd	228.3b	0.41bc
CARSON	17.7c	10.1ab	241.3a	0.44a
TX04M410211	18.5b	9.9abc	247.2a	0.43ab
TX86A5606	17.5c	9.5bcde	217.9c	0.41bcd
MTS0531	17.5c	9.4cdef	211.7cde	0.40bcd
TASCOSA	18.6b	10.2a	242.4a	0.44a
ONAGA	16.9c	8.7g	215.8cd	0.38de

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Chapter 5 - General Conclusions and Future Direction

In this research three experiments were conducted under the controlled environment conditions. The objectives of this research were (i) to screen winter wheat genotypes for salinity tolerance at the germination stages and to determine seedling growth traits associated with salinity tolerance. (ii) to evaluate the independent and combined effects of high temperature and salinity on winter wheat genotypes at the booting stages through growth, physiological, biochemical, and yield traits; and (iii) to evaluate the independent and combined effects of high temperature and salinity on winter wheat genotypes at the flowering stages through growth, physiological, biochemical, and yield traits. Important conclusions from each experiment are as follows:

Experiment 1: Screening of 292 winter wheat genotypes for salinity tolerance at the germination and seedling stage.

This research indicated that genotypic variability for salt tolerance was found among different winter wheat genotypes and the variation was best explained by mean daily germination percentage and vigor index. The genotypes were ranked based on the seedling vigor index, such that those with the smallest and largest percent reduction over the control were ranked respectively as the most and least tolerant germplasm at 120 mM NaCl. According to that genotypes were divided into three categories (1) tolerant to salinity at germination stage (genotypes like GAGE, OK04507, MTS0531, TASCOSA, ENDURANCE and GUYMON), (2) moderately tolerant to salinity at germination stage genotypes like AVALANCHE, NE05496, ENHANCER, OK05108, TX86A5606 and ONAGA) and (3) susceptible to salinity at germination stage (CO04W320, 2174-05, CARSON, OK1070275, TX02A0252 and TX04M410211). Wheat genotypes showed

differential response to higher levels (120 mM NaCl) of salinity. Yet, salinity reduced all seed germination and seedling attributes of wheat genotypes. The salinity tolerant genotypes identified herein may be used in salininty breeding program.

Experiment 2: Assessing the independent and combined effects of high temperature and salinity on winter wheat genotypes at the booting stage

The experiment indicated that high temperature 35/20º C (daytime maximum and nighttime minimum temperature) and salinity level of 120 mM NaCl and their combined effects at booting stage negatively influenced wheat growth and yield. Combined stresses was more damaging to wheat development than the individual effect of each stress. High temperatures, salinity and their interactions at booting stage, had negatively influence the leaf level photosynthesis, chlorophyll content, photosystem II efficiency, and starch content. However, it increased the damaged thylakoid membrane damage, and the contents of total carbohydrates, proline and soluble proteins, MDA. The changes in the above physiological traits have resulted in decreased grain yield and harvest index. Also the study concludes that winter wheat genotypes diverse in their response to combined high temperature and salinity stress. Genotype GUYMON, TX04M410211 and TASCOSA were the most tolerant ones. The traits like photosynthetic rate, leaf chlorophyll content, grain number and grain yield can be used for breeding salinity and high temperature stress tolerant wheat breeding program...

Experiment 3: Assessing the independent and combined effects of high temperature and salinity on winter wheat genotypes at flowering stage

High temperature 35/20 ºC (daytime maximum and nighttime minimum temperature) and salinity level of 120 mM NaCl and their combined effects at flowering stages negatively influenced wheat growth and yield. The study showed that combined effects of high temperature and salinity stress was more detrimental than the individual effect of each stress. High temperatures, salinity and their interaction at flowering stages had undesirable effects on yield and yield component. The study showed that genotypes varied in their response to combined effects of high temperature and salinity stress, and genotype CARSON, TX04M410211 and TASCOSA were the most tolerant as indicated by increased leaf level photosynthesis, photosystem II efficiency, chlorophyll content, starch content, and decreased MDA level resulting in increased grain yield and harvest index. In conclusion there are some traits that can be used for breeding programs such as photosynthesis efficiency, leaf chlorophyll content, grain number and grain yield. However, the screening for wheat genotypes can be based on characteristics related to high yields under stress condition. These criteria should be stable and easy to evaluate specially with high number of genotypes screening.

From second and third experiments we conclude that spikelet number and grain number were the yield component associated with the stress tolerance at the booting and flowering stages. In addition, from these experiments we conclude that high temperature and salinity stress at both stages of wheat growth and development severely reduced the performance of all tested wheat genotypes. Yet, severity being higher at flowering stage than booting stages. In this study and based on grain yield reduction, genotype TASCOSA was the most tolerant to high temperature stress (46 % decline) and genotype GUYMON was the most tolerant to salinity stress (32 % decline) at booting stage. These genotypes are best adapted to the High Plains, which expected to have better drought tolerance, therefore these genotypes were high temperature and salinity tolerance. Whereas, genotypes CARSON was highly susceptible to high temperature stress (52 %

decline) and AVALANCHE was highly susceptible to salinity stress (42 % decline) at booting stage. In addition, genotype TX04M410211 was the most tolerant to high temperature stress (48 % decline) and to salinity stress (24 % decline) at flowering stage. This genotype is from Texas and is well adapted to high temperature environment, and may have salinity tolerance, which mean that selection in hot environments may allow for selection of tolerance to salinity stress. However, genotype OK05108 was highly susceptible to high temperature stress (65 % decline) and genotype MTS0531 was highly susceptible to salinity stress (41 % decline) at flowering stage. However genotype GUYMON flipped from tolerant at germination and booting stages and susceptible at flowering stage and genotypes TX04M410211 flipped from susceptible at germination and booting stages and tolerant at flowering stage This may due to the fact that plants respond to the stress is highly depend on the growth stage of plant development and that response is different at different developmental stages. However, further studies are needed to validate these interactions under filed conditions and future studies should give more attention to physiological parameters such as leaf water potential, and osmotic potential as well as some biochemical analysis such as Na^+ and Cl^- content in plant tissue and antioxidant enzymes.

Overall Outputs

- Mean daily germination and seedling vigor index was the best germination traits that canbe used as a selection criterion for salinity tolerance in wheat. Based on those genotypes GUYMON, MTS0531, TASCOSA, GAGE, and ENDURANCE were identified as tolerant genotypes to salinity stress at germination stages.

- The combined effects of salininty and high temperature stress during booting and flowering stages was greater than the individual effects of salinity and high temperature stress as evidenced by seed number and grain yield.

- Grain yield and harvest index are the key traits responsible for high temperature and salinity stress tolerance. Therefore, genotype TASCOSA was the most tolerant genotype to combined high temperature and salinity stress at the booting stages; and genotype TX04M410211 was the most tolerant genotype to combined high temperature and salinity stress at flowering stages.

Future Research Opportunities

These investigations showed existence of significant genetic variability in winter wheat lines for salinity stress at germination stages as well as for the combined stresses of high temperature and salinity at booting and flowering stage. Therefore, additional research might be directed towards following:

1) There is need to develop new screening technique to identify large germplasm collection for salinity tolerance during germination and seedling stages of development.

2) Studies comparing the genotypes identified as tolerant from this study with other known salt tolerant genotypes (check) will increase our knowledge on mechanism of tolerance and novel traits conferring tolerance to these stresses.

3) Investigate the effects of high temperature and salinity stress at the booting and flowering stages of these tolerant and susceptible genotypes under field conditions to validate the results of study.

4) To validate the cross-tolerance for salininty and high temperature in the available genotypes, so that it can ne used for breeding salinity and high temperature stress

5) This study focused on the effect of high temperature and salinity stress at booting and flowering stages, therefore further research on the effects of high temperature and salinity stress during the post-flowering stages, (grain filling and seed development) is needed to evaluate the effect of these stress at later stages of wheat growth and development.

Appendix A - List of entries in the hard winter wheat association mapping panel (HWWAMP) used in this study with their names, year of release, type (C, cultivar; L, landrace; B, breeding line), origin, NSGC accession number, and pedigree.

ENTRY	NAME	Year	Type†	Origin	NSGC Accession	Pedigree
142	CO03064	.	B	CO	.	CO970547/Prowers 99
125	CO03W043	.	B	CO	.	KS96HW94/CO980352
126	CO03W054	.	B	CO	.	Arlin/KS89H20 (KS96HW94)/6/Trego/5/(CO960293) PI 222668 / TAM 107 /4/(CO0850034) Novi Sad 14 / Novi Sad 603 // Newton /3/ Probrand 835
128	CO04025	.	B	CO	.	CO940610/CO960293//CO99W189
129	CO04393	.	B	CO	.	Stanton/CO950043
130	CO04499	.	B	CO	.	Above/Stanton
131	CO04W320	.	B	CO	.	CO950635/CO99W1126
283	CO050337-2	.	B	CO	.	CO980829/TAM 111
120	CO940610	.	B	CO	GSTR10702	H15A13333 /5* Larned // Eagle / Sage /3/ TAM 105 (KS87H22) /4/ (MW09) Clark's Cream/5*KS75216 (Newton Sib)
84	TAM107-R7	.	B	CO	GSTR11601	CO850034 / PI372129 //5* TAM107
141	ABOVE	2001	C	CO	PI631449	TAM 110*4/FS2
146	AKRON	1994	C	CO	PI584504	TAM 107 / Hail
285	ANTERO	2013	C	CO	PI 667743	Trego/Betty sib (KS01HW152-1)//TAM 111
121	AVALANCHE	2001	C	CO	PI620766	RL6005 / RL6008 // Larned /3/ Cheney / Larned /4/ Bennett sib /5/ TAM107 (KS87H325) /6/ Rio Blanco
143	BILL BROWN	2007	C	CO	PI653260	Yumar/Arlin
122	BOND CL	2004	C	CO	PI639924	Yumar//TXGH12588-120*4/FS2
284	BYRD	2011	C	CO	PI 664257	TAM112//(CO970547-7) Ike/Halt
133	CARSON	1986	C	CO	PI501534	Anza / Scout // Centurk

100	DAWN	1982	C	CO	CItr17801	II 21031 / Trapper /4/(CO 652363) Warrior // Kenya 58 / Newthatch /2*(Cheyenne / Tenmarq / Mediterranean)/ Hope /3/ Parker
282	DENALI	2011	C	CO	PI 664256	Yuma/T-57//CO850034/3/4*Yuma/4/NEWS12 (CO980829)/5/Tam 111
136	DUKE	1981	C	CO	CItr17856	3* Sonora 64 / Warrior // Selkirk /2* Cheyenne /5/ Scout /4/ Quivera /3/ Tenmark // Marquis 1 / Oro
134	HAIL	1982	C	CO	PI470927	Mexican / USA // Scout /3/ Mara /4/ Scout /5/ Ciano /6/ Trapper /7/ Parker
137	HALT	1994	C	CO	PI584505	Sumner / CO820026 // PI372129 /3/ TAM 107
138	HATCHER	2004	C	CO	PI638512	Yuma / PI 372129 // TAM 200 /3/4* Yuma /4/ KS91H184 / Vista
147	JULES	1993	C	CO	PI564851	Warrior *5/ Agent // Agate sib (NE76667)/3/ Hawk
132	LAMAR	1988	C	CO	PI559719	74 F878 (Mexican dwarf)/ Wings // Vona
124	LINDON	1975	C	CO	CItr17440	Andes 64A / Sonora 64 // Tacuari (II21183)/4/(CO 652363) Warrior 2 / Kenya 58 / Newthatch // Cheyenne / Tenmark / Mediterranean / Hope /3/ Parker/5/ Lancer /3/(KS 62136) Norin 16 / CI 12500 // Kaw
234	OGALLALA	1993	C	CO	PI573037	TX81V6187 / Abilene
139	PRAIRIE RED	2000	C	CO	PI605390	CO850034 / PI 372129 //5* TAM 107
145	PROWERS	1997	C	CO	PI605389	CO850060 / PI 372129 //5* Lamar
144	RIPPER	2006	C	CO	PI644222	PI 220127/P5//TAM-200/KS87H66 (CO940606)/3/(TAM107R-2) CO850034/PI 372129//5*TAM 107
135	SANDY	1981	C	CO	CItr17857	Sonora 64A / Tezanos Pintos Precoz / Yaqui 54 //(Frontana / Kenya 58 / Newthatch)/ Norin 10 / Brevor / Gabo 55B / Trapper // Centurk
127	THUNDER CL	2008	C	CO	PI655528	FS2/KS97HW150//KS97HW349 (KS01-5539)/3/(CO99W165) KS92WGRC25/Halt
119	VONA	1976	C	CO	CItr17441	Andes 64A / Sonora 64 // Tacuari (II 21183) /4/ (CO 652363) Warrior // Kenya 58 / Newthatch /2*(Cheyenne / Tenmarq / Mediterranean / Hope /3/ Parker /5/ Lancer /4/ KS 62136
148	YUMA	1992	C	CO	PI559720	NS14 / NS25 //2* Vona
140	YUMAR	2000	C	CO	PI605388	Yuma / PI 372129 , F1 // CO850034 /3/4* Yuma

115	HV906-865	.	B	KS	.	G980039/Onaga
110	HV9W03-1379R	.	B	KS	.	B1127/3/B1551W//ROWDY/RWA 671 MONT
108	HV9W03-1551WP	.	B	KS	.	B1043/PL2180
111	HV9W03-1596R	.	B	KS	.	B1397-1/WGRC33
112	HV9W05-1280R	.	B	KS	.	SPARTANKA/G980761
113	HV9W06-504	.	B	KS	.	G982231/G982159//KS920709W
244	KS00F5-20-3	.	B	KS	.	0
237	W04-417	.	B	KS	.	BULK POPULATION
251	WB411W	.	B	KS	.	G3006/ARLIN
242	2145	2002	C	KS	PI 631087	HBA142A/HBZ621A//Abilene
183	2180	1989	C	KS	PI532912	TAM W-101 / Pioneer W603 // Pioneer W558
85	ARLIN	1992	C	KS	PI564246	Selection from population of intercrossed hard red winter wheat and hard red spring wheat genotypes
226	BAKER'S WHITE	2004	C	KS	PI 633865	Ponderosa/Jagger
222	BISON	1956	C	KS	CItr12518	Chiefkan // Oro / Tenmarq
227	BURCHETT	2004	C	KS	PI 633863	W91-126/WI88-052-05
210	CHENEY	1978	C	KS	CItr17765	Scout / Tascosa
225	COMANCHE	1942	C	KS	CItr11673	Oro / Tenmarq
247	COSSACK	1998	C	KS	PI 606780	BCD1828/83
228	CUTTER	2002	C	KS	PI 631389	JAGGER//(WI89-189-14)Tam200/Stallion sib
280	DANBY	2007	C	KS	PI 648010	Trego/Jagger 'S'
208	DODGE	1986	C	KS	PI506344	KS73H530 (Newton sib)/ KS76HN1978-1 (Arkan sib)
229	DUMAS	2001	C	KS	PI 619199	WI90-425/WI89-483
217	EAGLE	1970	C	KS	CItr15068	Selection from Scout
248	ENHANCER	1998	C	KS	PI606779	1992 Nebraska bulk selection

246	FULLER	2007	C	KS	PI 653521	Ogallala/KS95WGRC33//Jagger
109	G1878	1995	C	KS	PI 591622	Hawk/Sturdy//Plainsman V
243	HEYNE	2001	C	KS	PI612577	KS82W422 / SWM754308 / KS831182 / KS82W422
230	HONDO	1999	C	KS	PI 603958	W84-179/W81-171/5/Sturdy/Hawk/4/Vona/3/NDD63/CO652643//Centurk
231	JAGALENE	2002	C	KS	PI 631376	JAGGER/ABILENE
78	JAGGER	1994	C	KS	PI593688	KS82W418 / Stephens
207	KARL 92	1992	C	KS	PI564245	Selection from Karl = Plainsman V /3/ Kaw / Atlas 50 // Parker *5/ Agent
220	KAW61	1960	C	KS	CItr12871	purification and re - release of Kaw = Oro // Mediterranean / Hope /3/ Early Blackhull / Tenmarq
252	KEOTA	2007	C	KS	PI 648007	CUSTER/JAGGER
223	KIOWA	1950	C	KS	CItr12133	Chiefkan // Oro / Tenmarq
214	KIRWIN	1973	C	KS	CItr17275	Parker *3/ Bison
204	LAKIN	2002	C	KS	PI617032	KS89H130 / Arlin
212	LARNED	1976	C	KS	CItr17650	Ottawa /5* Scout
232	LONGHORN	1991	C	KS	PI552813	NS2630-1 / Thunderbird
233	NEOSHO	2006	C	KS	PI 639739	W91-376-20/W95-084
211	NEWTON	1978	C	KS	CItr17715	Pitic 62 / Chris sib //2* Sonora 64 /3/ Klein Rendidor /4/ Scout
209	NORKAN	1986	C	KS	PI506345	Plainsman V /3/2*(KS76H3705) Larned / Eagle // Sage
238	NUFRONTIER	2002	C	KS	PI 619089	2180/HBZ356A//Mesa
239	NUHORIZON	2001	C	KS	PI 619198	WI89-282/Arlin
240	ONAGA	1998	C	KS	.	HT43-231-19 (Pioneer bulk)
245	OVERLEY	2004	C	KS	PI 634974	TAM-107 *3/TA 2460 (U1275-1-4-2-2)//Heyne 'S'/3/Jagger
219	PARKER	1966	C	KS	CItr13285	Quivira /3/ Kanred / Hard Federation // Prelude / Kanred /4/ Kawvale / Marquillo // Kawvale / Tenmarq
213	PARKER 76	1976	C	KS	CItr17685	Parker *5/ Agent
123	PLATTE	1997	C	KS	PI 596297	Tesia 79 / Chat'S' // Abilene

235	POSTROCK	2006	C	KS	PI 643093	Ogallala/KSU94U261//Jagger
241	RONL	2007	C	KS	PI 648020	Trego/3/(CO9600293) PI222668/TAM 107//CO850034
215	SAGE	1973	C	KS	CItr17277	Agent /4* Scout
249	SANTA FE	2006	C	KS	PI 641772	G1878/Jagger
218	SHAWNEE	1967	C	KS	CItr14157	Mediterranean / Hope // Pawnee /3/ Oro / Illinois No. 1// Comanche
118	SHOCKER	2006	C	KS	PI 646185	FREEDOM/TOMAHAWK//JAGGER
117	SMOKYHILL	2006	C	KS	PI 646184	97 8/64 MASA (Population developed by combining several crosses with a common female "G2500")
114	SPARTAN	2007	C	KS	.	RL8400193/PL2180
205	STANTON	2002	C	KS	PI617033	PI 220350 / KS87H57 // TAM200 / KS87H66 /3/ KS87H325
116	TARKIO	2006	C	KS	.	OK90604/KSSB-369-7//SnowWhite
236	THUNDER BOLT	2000	C	KS	PI 608000	ABILENE/KS90WGRC10
206	TREGO	1999	C	KS	PI612576	RL6005 / RL6008 // Larned /3/ Cheney / Larned /4/ Bennet sib /5/ TAM107 (KS87H325)/6/ Rio Blanco
216	TRISON	1973	C	KS	CItr17278	Triumph / Bison
250	VENANGO	2000	C	KS	.	HBE1066-105/HBF0551-137
76	WICHITA	1944	C	KS	CItr11952	Early Blackhull / Tenmarq
224	WICHITA	1944	C	KS	CItr11952	Early Blackhull / Tenmarq
281	E2041	.	B	MI	.	Pioneer Brand 2552/Pioneer Brand 2737W
199	MT0495	.	B	MT	.	MT9640/NB1133
202	MT06103	.	B	MT	.	Composite cross
191	MT85200	.	B	MT	.	Froid/Winoka/3/TX55-391-56-D8/Westmont//Trader
193	MT9513	.	B	MT	.	NuWest/MT8030
194	MT9904	.	B	MT	.	MT85200/Tiber
195	MT9982	.	B	MT	.	Promontory/Judith
200	MTS0531	.	B	MT	.	L'Govskaya167/Rampart//MT9409
279	BIG SKY	2001	C	MT	PI619166	NuWest / Tiber
188	CREST	1967	C	MT	CItr13880	Westmont *2/ PI 178383
201	DECADE	2010	C	MT	PI660291	Composite
196	GENOU	2004	C	MT	PI640424	Lew/Tiber//Redwin (MTS92015)/3/Vanguard/Norstar
203	JUDEE	2011	C	MT	PI 665227	Vanguard/Norstar//Judith/3/NuHorizon

190	JUDITH	1989	C	MT	PI584526	Lancota / Froid // NE69559 / Winoka
197	NORRIS	2005	C	MT	PI643430	BigSky//TAM110sib*4/FS2
192	NUSKY	2001	C	MT	PI619167	NuWest / Tiber
189	ROSEBUD	1981	C	MT	PI473570	Lancer /2* BWH 1376-8
198	YELLOWS TONE	2005	C	MT	PI643428	Selected from a composite of F2 seed from two closely related populations: Promontory/Judith and Judith-phenotypic dwarf selection/Promontory
83	JERRY	2001	C	ND	PI632433	Roughrider // Winoka / NB66425 /3/ Arapahoe
287	NE02558	.	B	NE	.	JAGGER/ALLIANCE
289	NE04490	.	B	NE	.	NE95589/3/(NE94632) ABILENE/NORKAN//RAWHIDE/4/(NE95510)ABILENE/ARAPAHOE
290	NE05430	.	B	NE	.	IN92823A1-1-4-5/NE92458
291	NE05496	.	B	NE	.	KS87H325/RIO BLANCO (KS95HW62-6)//HALLAM
294	NE06607	.	B	NE	.	KS89H50-4/3/(NE90518)BRL//SXL/BENN (NE98466)/4/WESLEY
63	NE99495	.	B	NE	.	ALLIANCE/KARL 92
296	NI06736	.	B	NE	.	KM602-90/NE89657//ARLIN (NW97S312)/3/(KS96HW10-3) KS91HW29// RIO BLANCO/KS91H184
297	NI06737	.	B	NE	.	KM602-90/NE89657//ARLIN (NW97S312)/3/(KS96HW10-3) KS91HW29// RIO BLANCO/KS91H184
298	NI07703	.	B	NE	.	919021/B725//K92 (G97343, R-148)/5/(NI00436) BEZ 1/CTK78//ARTHUR/CTK78/3/BENNET/4/NORKAN
299	NI08707	.	B	NE	.	Yuma/T-57//CO850034/3/4*Yuma/4/NEWS1 (CO980829)/5/Wesley
300	NI08708	.	B	NE	.	Yuma/T-57//CO850034/3/4*Yuma/4/NEWS1 (CO980829)/5/Wesley
288	NW03666	.	B	NE	.	N94S097KS/NE93459
41	AGATE	1979	C	NE	CI17463	Ponca /3* Cheyenne // Kenya 58 / Newthatch //2*(Cheyenne / Tenmarq / Mediterranean / Hope)/3/ Scout
42	ALLIANCE	1993	C	NE	PI573096	Arkan/Colt//Chisholm (sib)
43	ANTELOPE	2005	C	NE	PI633910	Pronghorn / Arlin
81	ANTON	2007	C	NE	PI651044	WA691213-27 / PI 559717 // Platte

44	ARAPAHO E	1988	C	NE	PI518591	Brule /3/ Parker *4/ Agent // Belocerkovskaja 198 / Lancer
45	BENNETT	1978	C	NE	CI17723	Scout /3/ Quivira / Tenmarq // Marquillo / Oro /4/ Homestead
46	BUCKSKIN	1973	C	NE	CI17263	Scout/3/Quivera/Tenmarq//Marquillo/Oro
61	CAMELOT	2008	C	NE	PI653832	KS91H184/ARLIN SIB//KS91HW29/3/NE82761/REDLAND (NE91631)//VBFO168
47	CENTURA	1983	C	NE	PI476974	Warrior*5/Agent/NE68457/3/Centurk78
48	CENTURK 78	1978	C	NE	CItr17724	Selection from Centurk
50	COLT	1983	C	NE	PI476975	Agate sib (NE69441)// (Tx65A1503-1) 391-56-D8 / Kaw
51	COUGAR	2000	C	NE	PI613098	Warrior *5/ Agent // Kavkaz /4/ NE63218 / Kenya 58 /3/ Newthatch /2* CTMH // Ponca /* 2 Cheyenne (NE85707)/5/ Thunderbird (CTMH = Cheyenne / Tenmarq / Mediterranean / Hope)
52	CULVER	1999	C	NE	PI606726	NE82419/Arapahoe
293	FREEMAN	2013	C	NE	PI 667038	ABI86*3414/Jagger//Karl 92 (KS92-946-B-15-1)/3/ALLIANCE
53	GAGE	1963	C	NE	CItr13532	Ponca /3/ Mediterranean / Hope // Pawnee
54	GOODSTR EAK	2002	C	NE	PI632434	Len // Butte / ND526 (ND604) /6/ (SD2971) Agent /3/ ND441 // Waldron / Bluebird /4/ Butte /5/ Len (SD3055) /7/ KS88H164 /8/ NE89646
55	HALLAM	2006	C	NE	PI638790	Brule / Bennett // Niobrara
56	HARRY	2002	C	NE	PI632435	Brule /4/ Parker *4/ Agent // Beloterkovskaia 198 / Lancer /3/ Newton / Brule (NE90614) /5/ (NE87612) Newton // Warrior *5/ Agent /3/ Agate sib
57	HOMESTE AD	1973	C	NE	CI17264	Scout /4/ Kenya / Newthatch // Cheyenne / Tenmarq / Mediterranean / Hope /3/ Pawnee / Cheyenne
58	INFINITY CL	2006	C	NE	PI639922	Windstar//Millennium sib/Above sib
79	LANCER	1963	C	NE	CItr13547	Turkey Red / Cheyenne // Hope /2* Cheyenne
82	MACE	2007	C	NE	PI651043	Yuma//PI 372129/3/CO850034/4/4*Yuma/5/KS91H184/Arlin S//KS91HW29/3/NE89526

286	MCGILL	2010	C	NE	PI659689	Vona // Chisholm / PlainsmanV (OK83201)/3/Redland (NE92458)/4/ Ike
60	MILLENNI UM	2000	C	NE	PI613099	Arapahoe / Abilene /4/ Colt /3/ Warrior *5/ Agent // Kavkaz
96	NEKOTA	1994	C	NE	PI584997	Bennett/TAM 107
64	NIOBRAR A	1994	C	NE	PI584996	TAM 105*5/AMIGO//Brule
65	NUPLAINS	1998	C	NE	PI605741	Abilene / KS831872 = Abilene /3/ Plainsman V // Newton / Arthur 71
62	OVERLAN D	2007	C	NE	PI647959	Millennium sib//(ND8974) Seward/Archer
292	PANHAND LE	2014	C	NE	.	BRIGANTINA/2*ARAPAHOE (NE97426)//NE98574
66	PRONGHO RN	1996	C	NE	PI593047	Centura/Dawn//Colt
67	RAWHIDE	1990	C	NE	PI543893	Warrior *5/ Agent // Kavkaz /4/ Parker *4/ Agent // Belocerkovskaja 198 / Lancer /3/ Vona
68	REDLAND	1986	C	NE	PI502907	Selection from Brule
295	ROBIDOU X	2010	C	NE	PI659690	Odesskaya P / Cody // Pavon 76 /3* Scout 66 (NE96644)/3/ Wahoo sib
69	SCOUT 66	1967	C	NE	CI13996	composite of 85 selections from Scout, CItr 13546 (Scout = Nebred // Hope / Turkey /3/ Cheyenne / Ponca)
80	SETTLER CL	2009	C	NE	PI653833	Wesley sib // Millennium sib / Above sib
70	SIOUXLAN D	1984	C	NE	PI483469	Warrior*5/Agent*2//Kavkaz
72	VISTA	1992	C	NE	PI562653	Warrior // Atlas 66 / Comanche /3/ Comanche / Ottawa (NE68513)/5/(NE68457) Ponca /2* Cheyenne /3/ Illinois No. 1//2* Chinese Spring /T. timopheevii /4/ Cheyenne / Tenmarq // Mediterranean / Hope /3/ Sando 60 /6/ Centurk / Brule
73	WAHOO	2000	C	NE	PI619098	Arapahoe *2/ Abilene
74	WARRIOR	1960	C	NE	CItr13190	Pawnee / Cheyenne
75	WESLEY	1998	C	NE	PI605742	KS831936-3 / NE86501 = Sumner sib (Plainsman V / Odesskaya 51)// Colt / Cody

77	WINDSTAR	1996	C	NE	PI597379	TAM103 / Newton sib (TX79A2729)// Caldwell / Brule field sel .6/3/ Siouxland
49	CHEYENNE	1933	L	NE	CI8885	selection from Crimean, CI 1435
71	TURKEY	1874	L	NE	CI 12137	The original Turkey (Nebr. No. 1) grown at Lincoln since 1897. From it were selected Nebr. 6, 60, etc.
16	OK02405	.	B	OK	.	Tonkawa/GK50
23	OK04111	.	B	OK	.	2174*2/Jagger
24	OK04415	.	B	OK	.	N563/OK98G508W
19	OK04505	.	B	OK	.	OK91724/2*Jagger
21	OK04507	.	B	OK	.	OK95593/Jagger//2174
20	OK04525	.	B	OK	.	FFR525W/Hickok//Coronado
27	OK05108	.	B	OK	.	Lut 13686/2174//Jagger
28	OK05122	.	B	OK	.	KS94U337/NE93427
30	OK05134	.	B	OK	.	OK97411/TX91D6825
34	OK05204	.	B	OK	.	SWM866442/OK95548
31	OK05303	.	B	OK	.	OK95548/TXHBG0358
32	OK05312	.	B	OK	.	TX93V5919/WGRC40//OK94P549/WGRC34
33	OK05511	.	B	OK	.	TAM 110/2174
25	OK05711W	.	B	OK	.	G1878/OK98G508W
26	OK05723W	.	B	OK	.	SWM866442/Betty
22	OK05830	.	B	OK	.	OK93617/Jagger
36	OK06114	.	B	OK	.	KS97P0630-4-5/CM95560//X920879-C15-1/3/X84WO63-9-18/U1324-25-1-4
37	OK06210	.	B	OK	.	KS90175-1-2/CMSW89Y271//K92/3/ABI 86*3414/X86035*-BB-34//HBC 302E
39	OK06318	.	B	OK	.	HBG0358/2174//2145
38	OK06319	.	B	OK	.	Enhancer/2174
40	OK06336	.	B	OK	.	Magvars/2174//Enhancer
276	OK07231	.	B	OK	.	OK92P577-RMH 3099/Duster
277	OK07S117	.	B	OK	.	[ALTAR84/AE.SQ//OPATA]/OK98G508W
278	OK08328	.	B	OK	.	GK Keve/Ok101//OK93P656-RMH3299
273	OK09634	.	B	OK	.	OK95616-98-6756/Overley
274	OK10119	.	B	OK	.	JEI 110/Overley
265	OK1067071	.	B	OK	.	TX98V9437/OK00316//Farmec
266	OK1067274	.	B	OK	.	GA961912-8-4-5/OK02129//Kristi-K.K

267	OK1068002	.	B	OK	.	EFECT/Jagalene//Deliver
268	OK1068009	.	B	OK	.	LADA/Jagalene//G980122
269	OK1068026	.	B	OK	.	ERYTHROSPERMUM 270/TAM 111//OK99212
270	OK1068112	.	B	OK	.	Farmec/Jagalene
272	OK1070267	.	B	OK	.	VI.9/Guymon//G980411W
271	OK1070275	.	B	OK	.	KNJAZHNA/KS00HW175-4//OK00611W
5	2174-05	1998	C	OK	PI602595	IL71-5662/PL145(Newton sib)//2165
18	BILLINGS	2009	C	OK	PI656843	N566/OK94P597
12	CENTERFIELD	2006	C	OK	PI644017	TXGH12588-105*4/FS4//2*2174
3	CENTURY	1986	C	OK	PI502912	Payne // TAM W-101 / Amigo
2	CHISHOLM	1983	C	OK	PI486219	Sturdy sib / Nicoma
4	CUSTER	1994	C	OK	.	F-29-76/TAM-105//Chisholm
10	DELIVER	2004	C	OK	PI639232	Yantar/2*Chisholm (OK91724)//Karl
14	DUSTER	2006	C	OK	PI644016	W0405D/NE78488//W7469C/TX81V6187
9	ENDURANCE	2004	C	OK	PI639233	HBY756A/Siouxland//2180
275	GALLAGHER	2013	C	OK	PI 667569	OK99711/Duster
35	GARRISON	2011	C	OK	PI661992	OK95616-1/Hickok//Betty
13	GUYMON	2005	C	OK	PI643133	Intrada/Platte
6	INTRADA	2000	C	OK	PI631402	Rio Blanco / TAM 200
11	OK BULLET	2005	C	OK	PI642415	KS96WGRC39/Jagger
15	OK RISING	2009	C	OK	PI656382	KS96WGRC39/Jagger
7	OK101	2001	C	OK	PI631493	OK87W663/Mesa//2180
8	OK102	2002	C	OK	PI632635	2174/Cimarron
17	PETE	2009	C	OK	PI656844	N40/OK94P455
29	RUBY LEE	2011	C	OK	PI661991	KS94U275/OK94P549
1	TRIUMPH 64	1964	C	OK	CItr13679	Danne Beardless Blackhull /3/ Kanred / Blackhull // Florence /4/ Kanred / Blackhull // Triumph
92	SD01058	.	B	SD	.	XH1877/NE967430
91	SD01237	.	B	SD	.	UNKNOWN
93	SD05118	.	B	SD	.	Wesley/NE93613
94	SD05210	.	B	SD	.	SD98444/SD97060

95	SD05W018	.	B	SD	.	SD98W302/SD98W175
86	ALICE	2006	C	SD	PI644223	Abilene/Karl.
104	BRONZE	1974	C	SD	CItr14013	Hume / Gage /4/ Hume /3/ NE61943 , Mida / Kenya 117A //2* Hope /2* Turkey Red
98	CRIMSON	1997	C	SD	PI601818	TAM-105 / Winoka
87	DARRELL	2006	C	SD	PI644224	2076-W12-11/Karl92
88	EXPEDITI ON	2002	C	SD	PI629060	Tomahawk / Bennett
106	GENT	1974	C	SD	CItr17293	Agent /4* Scout
107	HARDING	1999	C	SD	PI608049	Brule // Bennett / Chisholm /3/ Arapahoe
105	HUME	1965	C	SD	CItr13526	crosses involving: Minter, Kharkof, Wichita, Nebred, Cheyenne, and others
90	LYMAN	2009	C	SD	PI 658067	KS93U134/Arapahoe
102	NELL	1981	C	SD	CItr17803	Scout selection / Capitan
103	RITA	1980	C	SD	CItr17799	Seu Seun / Denton 8 // Westmont /3/ (SD 6689) Ponca //3* Cheyenne / Kenya58 / Newthatch //2*(Cheyenne / Tenmarq // Mediterranean / Hope)
99	ROSE	1979	C	SD	CItr17795	Seu Seun / Denton 8 // Westmont /4/ Hume /3/ NE 63265
97	TANDEM	1997	C	SD	PI601817	Brule / Agate
89	WENDY	2004	C	SD	PI638521	Gent/Siouxland (SD89333) // Abilene
101	WINOKA	1969	C	SD	CItr14000	Selection from Winalta
180	TX00V1131	.	B	TX	.	TX87V1613/KS91WGRC11
168	TX01A5936	.	B	TX	.	JAGGER/3/PSN 'S'/BOW 'S'//T200
179	TX01M500 9-28	.	B	TX	.	MASON/JAGGER//PECOS
174	TX01V5134 RC-3	.	B	TX	.	TAM-200/JAGGER
171	TX03A0148	.	B	TX	.	TX89A7137/TIPACNA
172	TX03A0563	.	B	TX	.	X96V107/OGALLALA
173	TX04A0012 46	.	B	TX	.	TX95V4339/TX94VT938-6
175	TX04M410 164	.	B	TX	.	MIT/TX93V5722//W95-301
176	TX04M410 211	.	B	TX	.	MASON/JAGGER//OGALLALA

177	TX04V0750 80	.	B	TX	.	JAGGER/TX93V5722//TX95D8905
260	TX05A0011 88	.	B	TX	.	T107//TX98V3620/Ctk78/3/TX87V1233/4/N87V106//TX86V1540/T200
253	TX05A0018 22	.	B	TX	.	2145/X940786-6-7
258	TX05V7259	.	B	TX	.	T107//TX78V3620/Ctk78/3/TX87V1233/4/Arap//TX86V1540/T200
259	TX05V7269	.	B	TX	.	HBG0358/4/T107//TX78V3620/Ctk78/3/TX87V1233
255	TX06A0011 32	.	B	TX	.	HBG0358/4/T107//TX78V3620/Ctk78/3/TX87V1233
254	TX06A0012 63	.	B	TX	.	UNKNOWN
256	TX06A0012 81	.	B	TX	.	TX98VR8422/U3704A-7-7
257	TX06A0013 86	.	B	TX	.	TX99A6030/CUSTER
264	TX06V7266	.	B	TX	.	TX99U8617/TX97U2001
261	TX07A0012 79	.	B	TX	.	X930332-4-1/TX97V2838
262	TX07A0013 18	.	B	TX	.	TX98VR8431/TX95A3091
263	TX07A0014 20	.	B	TX	.	U1254-1-5-2-1/TX81V6582//DESCONOCIDO
185	TX86A5606	.	B	TX	.	TAM 105*4/AMI*4//LGO
186	TX86A6880	.	B	TX	.	TAM 105*4/AMI*4//LGO
187	TX86A8072	.	B	TX	.	TAM 105*4/AMI*4//LGO
182	TX96D1073	.	B	TX	.	TX86D1310/Kavkaz//TX86D1308 (=WX87D144-10-99-12-18)
178	TX99A0153 -1	.	B	TX	.	OGALLALA/TAM-202
181	TX99U8618	.	B	TX	.	TX84V1237/TX71C8130R
167	CAPROCK	1969	C	TX	CItr14516	Sinvalocho / Wichita // Hope / Cheyenne /3/ Wichita /4/ Seu Seun 27
184	HG-9	2000	C	TX	PI614118	TAM 200 outcross selection
163	LOCKETT	2001	C	TX	PI604245	TX86V1540 / TX78V2430-4

166	MIT	1980	C	TX	CItr17896	Sinvalocho / Wichita // Hope / Cheyenne /3/ Wichita /4/ Seu Seun 27 (TX391-56-D1 - 24)/6/T. dicoccoides / Aeg. speltoides , amphiploid //2* Austin /3/ Supremo (TX55C907)/4/ Bison /5/ Caddo/7/ Frontana / Westar
164	STURDY	1966	C	TX	CItr13684	Sinvalocho / Wichita // Hope / Cheyenne /3/2* Wichita /4/ Seu Seun 27
165	STURDY 2K	2005	C	TX	PI636307	Sturdy Resel.
150	TAM 105	1979	C	TX	CItr17826	' short wheat' / Sturdy composite bulk selection
151	TAM 107	1984	C	TX	PI495594	TAM 105 *4/ Amigo
152	TAM 109	1991	C	TX	PI554606	TAMW-101 *5/ CI9321
153	TAM 110	1996	C	TX	PI595757	TAM 107*5/Largo
154	TAM 111	2002	C	TX	PI631352	TAM 107 // TX78V3630 / Centurk 78 /3/ TX87V1233 = TAM 107 /4/ Sturdy sib / Kaw // Centurk /3/ Centurk 78 /5/ Sturdy sub / Kaw // Centurk /3/ Jupetaco / Bluejay
155	TAM 112	2007	C	TX	PI643143	TAM 200/TA2460 (U1254-7-9-2-1)//(TXGH10440) TAM 107*5/Largo
170	TAM 113	2013	C	TX	PI 666125	TX90V6313/TX94V3724
156	TAM 200	1986	C	TX	PI578255	Sturdy sib / Tascosa // Centurk *3/3/ Amigo
157	TAM 202	1992	C	TX	PI561933	Siouxland outcross
158	TAM 203	2009	C	TX	PI655960	TX89V4132/704 L I-2221
159	TAM 302	1998	C	TX	PI605910	Probrand 812 / Caldwell // (TX86D1310) TAM300 sib
160	TAM 303	2006	C	TX	.	TX89D1253*2/TTCC404 (=WX93D208-9-1-2)
161	TAM 304	2009	C	TX	PI655234	TX92U3060/TX91D6564
162	TAM 400	2001	C	TX	PI614876	TAM-200//(TX82D5668) Era/TAMW-101
169	TAM 401	2010	C	TX	PI658500	Mason/Jagger
149	TAM W-101	1971	C	TX	CItr15324	Norin 10 /3/ Nebraska 60 // Mediterranean / Hope /4/ Bison
221	TASCOSA	1959	C	TX	CItr13023	Kanred / Hard Federation // Tenmarq /3/ Mediterranean / Hope /4/ Cimarron
59	KHARKOF	1900	L	Ukraine	PI5641	KHARKOF

Appendix B - The mean values for germination %, germination index, mean daily germination and germination rate of 292 winter wheat genotypes treated with three level of salinity (0, 60 and 120 mM/L^{-1}).

Genotype name	Salinity level	Germination %	Std Dev	Germination index	Std Dev	Mean daily germination	Std Dev	Germination Rate	Std Dev
TRIUMPH64	0	98.8	2.5	100	0	6.6	0.17	2.2	0.01
CHISHOLM	0	97.5	2.9	100	0	6.5	0.19	2.2	0.04
CUSTER	0	96.3	4.8	100	0	6.4	0.32	2.1	0.05
2174-05	0	98.8	2.5	100	0	7.4	1.42	2.1	0.05
INTRADA	0	98.8	2.5	100	0	6.6	0.17	2.2	0.03
OK101	0	97.5	2.9	100	0	6.5	0.19	2.2	0.04
OK102	0	98.8	2.5	100	0	6.6	0.17	2.2	0.04
ENDURANCE	0	96.3	4.8	100	0	6.4	0.32	2.1	0.03
DELIVER	0	97.5	5.0	100	0	6.5	0.33	2.1	0.03
OK_BULLET	0	100.0	0.0	100	0	6.7	0.00	2.1	0.04
CENTERFIELD	0	98.8	2.5	100	0	6.2	0.96	2.2	0.05
GUYMON	0	98.8	2.5	100	0	8.2	1.79	2.0	0.03
DUSTER	0	97.5	5.0	100	0	6.5	0.33	2.2	0.03
OK_RISING	0	100.0	0.0	100	0	6.7	0.00	2.1	0.03
OK02405	0	98.8	2.5	100	0	6.6	0.17	2.2	0.05
PETE	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
BILLINGS	0	96.3	7.5	100	0	6.4	0.50	2.1	0.04
OK04505	0	100.0	0.0	100	0	6.7	0.00	2.2	0.04
OK04525	0	100.0	0.0	100	0	6.7	0.00	2.1	0.03
OK04507	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
OK05830	0	97.5	5.0	100	0	6.5	0.33	2.1	0.03
OK04111	0	98.8	2.5	100	0	6.6	0.17	2.1	0.05
OK04415	0	100.0	0.0	100	0	6.7	0.00	2.1	0.03
OK05711W	0	97.5	5.0	100	0	6.5	0.33	2.2	0.06
OK05723W	0	100.0	0.0	100	0	6.7	0.00	2.1	0.03
OK05108	0	98.8	2.5	100	0	7.4	1.42	2.1	0.06
OK05122	0	97.5	5.0	100	0	6.5	0.33	2.1	0.02
OK05526	0	100.0	0.0	100	0	6.7	0.00	2.2	0.04
OK05134	0	98.8	2.5	100	0	6.2	0.79	2.2	0.06
OK05303	0	98.8	2.5	100	0	6.2	0.79	2.2	0.03
OK05312	0	98.8	2.5	100	0	6.2	0.79	2.2	0.05
OK05511	0	98.8	2.5	100	0	6.2	0.79	2.2	0.04
OK05204	0	98.8	2.5	100	0	6.2	0.79	2.2	0.04
GARRISON	0	97.5	5.0	100	0	6.5	0.33	2.1	0.03

OK06114	0	96.3	7.5	100	0	6.4	0.50	2.2	0.04
OK06210	0	100.0	0.0	100	0	6.3	0.83	2.2	0.06
OK06319	0	98.8	2.5	100	0	6.6	0.17	2.2	0.06
OK06318	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
OK06336	0	97.5	5.0	100	0	6.5	0.33	2.2	0.02
AGATE	0	98.8	2.5	100	0	6.6	0.17	2.2	0.00
ALLIANCE	0	98.8	2.5	100	0	6.2	0.79	2.2	0.04
ANTELOPE	0	98.8	2.5	100	0	6.2	0.79	2.2	0.05
ARAPAHOE	0	98.8	2.5	100	0	6.2	0.79	2.2	0.07
BENNETT	0	100.0	0.0	100	0	6.7	0.00	2.1	0.03
BUCKSKIN	0	100.0	0.0	100	0	6.7	0.00	2.2	0.05
CENTURK78	0	98.8	2.5	100	0	6.6	0.17	2.2	0.05
CHEYENNE	0	97.5	5.0	100	0	7.3	1.17	2.1	0.04
COLT	0	100.0	0.0	100	0	6.3	0.83	2.2	0.04
COUGAR	0	98.8	2.5	100	0	7.4	1.73	2.1	0.05
CULVER	0	98.8	2.5	100	0	6.6	0.17	2.1	0.02
GAGE	0	98.8	2.5	100	0	8.2	1.79	2.0	0.03
GOODSTREAK	0	100.0	0.0	100	0	7.5	1.67	2.1	0.06
HALLAM	0	97.5	5.0	100	0	7.3	1.81	2.1	0.05
HARRY	0	98.8	2.5	100	0	6.2	0.79	2.2	0.04
HOMESTEAD	0	100.0	0.0	100	0	7.5	1.67	2.1	0.06
INFINITY_CL	0	98.8	2.5	100	0	6.6	0.17	2.1	0.06
KHARKOF	0	100.0	0.0	100	0	6.7	0.00	2.1	0.03
MILLENNIUM	0	100.0	0.0	100	0	7.5	1.67	2.1	0.06
CAMELOT	0	98.8	2.5	100	0	6.6	0.17	2.1	0.02
OVERLAND	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
NE99495	0	100.0	0.0	100	0	8.3	1.92	2.0	0.05
NIOBRARA	0	98.8	2.5	100	0	6.6	0.17	2.1	0.04
NUPLAINS	0	98.8	2.5	100	0	6.6	0.17	2.2	0.02
PRONGHORN	0	98.8	2.5	100	0	6.6	0.17	2.2	0.03
RAWHIDE	0	98.8	2.5	100	0	6.6	0.17	2.1	0.02
REDLAND	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
SCOUT66	0	100.0	0.0	100	0	6.7	0.00	2.1	0.04
SIOUXLAND	0	97.5	2.9	100	0	6.1	0.92	2.2	0.03
TURKEY_NEBSEL	0	97.5	2.9	100	0	6.5	0.19	2.2	0.00
VISTA	0	97.5	2.9	100	0	6.1	0.74	2.1	0.07
WAHOO	0	100.0	0.0	100	0	6.7	0.00	2.2	0.04
WARRIOR	0	100.0	0.0	100	0	8.3	1.92	2.1	0.09
WESLEY	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
WICHITA	0	100.0	0.0	100	0	6.7	0.00	2.2	0.04
WINDSTAR	0	98.8	2.5	100	0	6.2	0.79	2.2	0.05

LANCER	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
ANTON	0	97.5	5.0	100	0	7.3	1.81	2.1	0.06
MACE	0	98.8	2.5	100	0	5.8	1.04	2.2	0.03
TAM107-R7	0	98.8	2.5	100	0	6.6	0.17	2.1	0.05
ARLIN	0	96.3	4.8	100	0	6.0	0.72	2.2	0.04
ALICE	0	100.0	0.0	100	0	6.3	0.83	2.2	0.07
DARRELL	0	98.8	2.5	100	0	6.6	0.17	2.2	0.03
EXPEDITION	0	97.5	2.9	100	0	6.5	0.19	2.1	0.00
WENDY	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
SD00111-9	0	97.5	2.9	100	0	6.5	0.19	2.1	0.03
SD01237	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
SD01058	0	98.8	2.5	100	0	6.6	0.17	2.2	0.04
SD05118	0	100.0	0.0	100	0	6.7	0.00	2.1	0.05
SD05210	0	96.3	2.5	100	0	6.4	0.17	2.2	0.05
SD05W018	0	97.5	2.9	100	0	6.5	0.19	2.1	0.02
NEKOTA	0	98.8	2.5	100	0	6.6	0.17	2.1	0.05
TANDEM	0	97.5	5.0	100	0	6.5	0.33	2.1	0.03
CRIMSON	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
ROSE	0	97.5	2.9	100	0	6.5	0.19	2.2	0.00
DAWN	0	97.5	5.0	100	0	6.5	0.33	2.1	0.06
WINOKA	0	97.5	2.9	100	0	6.5	0.19	2.3	0.02
NELL	0	98.8	2.5	100	0	6.6	0.17	2.2	0.02
RITA	0	98.8	2.5	100	0	6.6	0.17	2.2	0.02
BRONZE	0	98.8	2.5	100	0	6.6	0.17	2.3	0.02
HUME	0	97.5	5.0	100	0	6.5	0.33	2.2	0.03
GENT	0	96.3	4.8	100	0	6.4	0.32	2.1	0.05
HARDING	0	100.0	0.0	100	0	6.7	0.00	2.2	0.04
HV9W03-1551WP	0	100.0	0.0	100	0	6.7	0.00	2.2	0.05
G1878	0	100.0	0.0	100	0	6.7	0.00	2.1	0.03
HV9W03-1379R	0	98.8	2.5	100	0	6.6	0.17	2.3	0.01
HV9W03-1596R	0	98.8	2.5	100	0	6.6	0.17	2.2	0.04
HV9W05-1280R	0	97.5	5.0	100	0	6.5	0.33	2.1	0.02
HV9W06-504	0	98.8	2.5	100	0	6.6	0.17	2.2	0.02
SPARTAN	0	98.8	2.5	100	0	6.6	0.17	2.2	0.03
HV906-865	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
TARKIO	0	98.8	2.5	100	0	6.6	0.17	2.2	0.05
SMOKYHILL	0	93.8	2.5	100	0	6.3	0.17	2.2	0.03
SHOCKER	0	98.8	2.5	100	0	6.6	0.17	2.2	0.02
VONA	0	100.0	0.0	100	0	6.7	0.00	2.2	0.04
CO940610	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
AVALANCHE	0	98.8	2.5	100	0	7.4	1.42	2.1	0.05

BOND_CL	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
PLATTE	0	98.8	2.5	100	0	6.6	0.17	2.2	0.03
LINDON	0	98.8	2.5	100	0	6.6	0.17	2.2	0.03
CO03W043	0	100.0	0.0	100	0	6.7	0.00	2.2	0.05
SNOWMASS	0	96.3	4.8	100	0	6.4	0.32	2.1	0.03
THUNDER_CL	0	97.5	5.0	100	0	6.5	0.33	2.1	0.05
CO04025	0	97.5	2.9	100	0	6.1	0.74	2.3	0.04
CO04393	0	97.5	5.0	100	0	6.5	0.33	2.1	0.03
CO04499	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
CO04W320	0	98.8	2.5	100	0	7.4	1.42	2.1	0.04
LAMAR	0	100.0	0.0	100	0	6.7	0.00	2.1	0.03
CARSON	0	98.8	2.5	100	0	7.4	1.42	2.1	0.05
HAIL	0	97.5	2.9	100	0	6.5	0.19	2.3	0.01
SANDY	0	100.0	0.0	100	0	6.7	0.00	2.1	0.03
DUKE	0	96.3	4.8	100	0	6.4	0.32	2.2	0.02
HALT	0	100.0	0.0	100	0	6.7	0.00	2.2	0.05
HATCHER	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
PRAIRIE_RED	0	97.5	5.0	100	0	6.5	0.33	2.2	0.02
ABOVE	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
CO03064	0	97.5	2.9	100	0	6.5	0.19	2.2	0.03
BILL_BROWN	0	98.8	2.5	100	0	6.6	0.17	2.2	0.02
RIPPER	0	97.5	2.9	100	0	6.5	0.19	2.2	0.02
PROWERS	0	98.8	2.5	100	0	6.6	0.17	2.2	0.03
AKRON	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
JULES	0	100.0	0.0	100	0	6.7	0.00	2.1	0.04
YUMA	0	97.5	2.9	100	0	6.5	0.19	2.2	0.03
TAMW-101	0	97.5	5.0	100	0	6.5	0.33	2.1	0.03
TAM105	0	98.8	2.5	100	0	6.2	0.79	2.2	0.05
TAM107	0	98.8	2.5	100	0	6.6	0.17	2.1	0.05
TAM109	0	98.8	2.5	100	0	6.6	0.17	2.2	0.03
TAM110	0	98.8	2.5	100	0	6.2	0.96	2.2	0.03
TAM111	0	96.3	4.8	100	0	6.4	0.32	2.2	0.01
TAM112	0	98.8	2.5	100	0	6.6	0.17	2.2	0.03
TAM200	0	98.8	2.5	100	0	6.2	0.79	2.2	0.07
TAM202	0	96.3	4.8	100	0	6.4	0.32	2.2	0.02
TAM203	0	96.3	4.8	100	0	6.4	0.32	2.2	0.05
TAM302	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
TAM303	0	100.0	0.0	100	0	7.5	1.67	2.1	0.09
TAM304	0	98.8	2.5	100	0	6.6	0.17	2.1	0.05
TAM400	0	97.5	2.9	100	0	7.3	1.78	2.2	0.13
LOCKETT	0	100.0	0.0	100	0	7.5	1.67	2.1	0.06

STURDY	0	97.5	2.9	100	0	6.5	0.19	2.1	0.02
STURDY_2K	0	98.8	2.5	100	0	6.6	0.17	2.1	0.02
MIT	0	97.5	2.9	100	0	6.5	0.19	2.2	0.02
CAPROCK	0	97.5	5.0	100	0	6.5	0.33	2.1	0.05
TX01A5936	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
TAM401	0	100.0	0.0	100	0	6.3	0.83	2.1	0.07
TX02A0252	0	97.5	2.9	100	0	6.5	0.19	2.3	0.04
TX03A0148	0	100.0	0.0	100	0	6.7	0.00	2.1	0.03
TX03A0563	0	98.8	2.5	100	0	7.4	1.42	2.1	0.05
TX04A001246	0	95.0	4.1	100	0	6.3	0.27	2.1	0.03
TX01V5134RC-3	0	100.0	0.0	100	0	6.7	0.00	2.1	0.03
TX04M410164	0	98.8	2.5	100	0	6.6	0.17	2.2	0.05
TX04M410211	0	98.8	2.5	100	0	7.4	1.42	2.1	0.05
TX04V075080	0	97.5	2.9	100	0	6.5	0.19	2.1	0.03
TX99A0153-1	0	100.0	0.0	100	0	6.7	0.00	2.1	0.03
TX01M5009-28	0	98.8	2.5	100	0	6.2	0.79	2.2	0.07
TX00V1131	0	96.3	2.5	100	0	8.0	1.98	2.0	0.05
TX99U8618	0	100.0	0.0	100	0	7.5	1.67	2.1	0.04
TX96D1073	0	98.8	2.5	100	0	7.4	1.42	2.1	0.05
2180	0	95.0	7.1	100	0	6.3	0.47	2.1	0.01
HG-9	0	96.3	2.5	100	0	7.2	1.54	2.1	0.04
TX86A5606	0	98.8	2.5	100	0	7.4	1.42	2.1	0.04
TX86A8072	0	100.0	0.0	100	0	7.5	1.67	2.1	0.03
CREST	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
ROSEBUD	0	98.8	2.5	100	0	6.6	0.17	2.2	0.05
JUDITH	0	98.8	2.5	100	0	6.6	0.17	2.1	0.05
MT85200	0	100.0	0.0	100	0	7.5	1.67	2.0	0.03
NUSKY	0	97.5	2.9	100	0	5.7	0.95	2.2	0.07
MT9513	0	98.8	2.5	100	0	7.4	1.42	2.1	0.05
MT9904	0	97.5	5.0	100	0	7.3	1.81	2.1	0.05
NORRIS	0	98.8	2.5	100	0	6.6	0.17	2.1	0.00
YELLOWSTONE	0	100.0	0.0	100	0	6.7	0.00	2.1	0.04
MT0495	0	98.8	2.5	100	0	6.6	0.17	2.1	0.00
MTS0531	0	98.8	2.5	100	0	8.2	1.79	2.1	0.05
DECADE	0	97.5	2.9	100	0	6.5	0.19	2.1	0.05
MT06103	0	96.3	4.8	100	0	6.4	0.32	2.2	0.02
JUDEE	0	98.8	2.5	100	0	6.6	0.17	2.2	0.03
LAKIN	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
STANTON	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
TREGO	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
KARL_92	0	98.8	2.5	100	0	6.6	0.17	2.1	0.02

DODGE	0	96.3	4.8	100	0	6.4	0.32	2.2	0.02
NORKAN	0	98.8	2.5	100	0	6.6	0.17	2.2	0.03
CHENEY	0	98.8	2.5	100	0	6.6	0.17	2.1	0.00
NEWTON	0	98.8	2.5	100	0	6.6	0.17	2.2	0.04
LARNED	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
PARKER76	0	98.8	2.5	100	0	6.6	0.17	2.2	0.04
KIRWIN	0	98.8	2.5	100	0	6.6	0.17	2.1	0.02
SAGE	0	98.8	2.5	100	0	6.6	0.17	2.2	0.04
TRISON	0	96.3	4.8	100	0	6.4	0.32	2.1	0.04
EAGLE	0	97.5	2.9	100	0	6.5	0.19	2.2	0.04
SHAWNEE	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
PARKER	0	98.8	2.5	100	0	6.6	0.17	2.1	0.00
KAW61	0	96.3	7.5	100	0	6.4	0.50	2.1	0.02
TASCOSA	0	97.5	2.9	100	0	8.1	1.64	2.0	0.03
BISON	0	97.5	2.9	100	0	6.5	0.19	2.2	0.01
KIOWA	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
WICHITA	0	98.8	2.5	100	0	6.6	0.17	2.1	0.02
COMANCHE	0	97.5	2.9	100	0	7.3	1.48	2.0	0.03
BAKERS_WHITE	0	95.0	7.1	100	0	6.3	0.47	2.1	0.03
BURCHETT	0	98.8	2.5	100	0	6.6	0.17	2.2	0.03
CUTTER	0	98.8	2.5	100	0	6.6	0.17	2.1	0.02
DUMAS	0	96.3	4.8	100	0	6.4	0.32	2.2	0.02
HONDO	0	98.8	2.5	100	0	6.6	0.17	2.2	0.02
JAGALENE	0	98.8	2.5	100	0	6.6	0.17	2.2	0.02
LONGHORN	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
NEOSHO	0	98.8	2.5	100	0	6.6	0.17	2.1	0.02
OGALLALA	0	98.8	2.5	100	0	6.6	0.17	2.1	0.05
POSTROCK	0	96.3	4.8	100	0	6.4	0.32	2.1	0.03
THUNDERBOLT	0	97.5	2.9	100	0	6.5	0.19	2.2	0.05
W04-417	0	97.5	2.9	100	0	6.5	0.19	2.1	0.02
NUFRONTIER	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
NUHORIZON	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
ONAGA	0	98.8	2.5	100	0	7.4	1.42	2.1	0.04
RONL	0	98.8	2.5	100	0	6.6	0.17	2.2	0.00
2145	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
HEYNE	0	96.3	4.8	100	0	6.4	0.32	2.2	0.04
KS00F5-20-3	0	96.3	4.8	100	0	6.4	0.32	2.1	0.05
OVERLEY	0	98.8	2.5	100	0	6.6	0.17	2.2	0.01
FULLER	0	97.5	2.9	100	0	6.5	0.19	2.1	0.04
COSSACK	0	96.3	4.8	100	0	6.4	0.32	2.1	0.03
ENHANCER	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03

SANTA_FE	0	98.8	2.5	100	0	6.6	0.17	2.2	0.03
VENANGO	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
WB411W	0	100.0	0.0	100	0	6.7	0.00	2.1	0.05
KEOTA	0	97.5	2.9	100	0	6.5	0.19	2.2	0.05
TX05A001822	0	96.3	4.8	100	0	6.4	0.32	2.2	0.05
TX06A001263	0	98.8	2.5	100	0	6.6	0.17	2.2	0.01
TX06A001132	0	98.8	2.5	100	0	6.6	0.17	2.2	0.03
TX06A001281	0	97.5	5.0	100	0	6.5	0.33	2.2	0.04
TX06A001386	0	98.8	2.5	100	0	6.6	0.17	2.2	0.03
TX05V7259	0	98.8	2.5	100	0	6.6	0.17	2.2	0.05
TX05V7269	0	98.8	2.5	100	0	6.6	0.17	2.2	0.02
TX05A001188	0	98.8	2.5	100	0	6.6	0.17	2.2	0.05
TX07A001279	0	97.5	5.0	100	0	6.5	0.33	2.2	0.04
TX07A001318	0	98.8	2.5	100	0	6.6	0.17	2.1	0.05
TX07A001420	0	100.0	0.0	100	0	6.7	0.00	2.1	0.04
TX06V7266	0	98.8	2.5	100	0	6.6	0.17	2.2	0.00
OK1067071	0	96.3	4.8	100	0	6.4	0.32	2.1	0.04
OK1067274	0	100.0	0.0	100	0	6.7	0.00	2.2	0.04
OK1068002	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
OK1068009	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
OK1068026	0	98.8	2.5	100	0	6.6	0.17	2.2	0.04
OK1068112	0	98.8	2.5	100	0	6.6	0.17	2.2	0.04
OK1070275	0	100.0	0.0	100	0	6.7	0.00	2.2	0.00
OK1070267	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
OK09634	0	97.5	2.9	100	0	6.5	0.19	2.2	0.03
OK10119	0	97.5	2.9	100	0	6.5	0.19	2.2	0.04
GALLAGHER	0	100.0	0.0	100	0	6.7	0.00	2.1	0.03
OK07231	0	98.8	2.5	100	0	6.6	0.17	2.1	0.04
OK07S117	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
OK08328	0	98.8	2.5	100	0	6.6	0.17	2.1	0.00
BIG_SKY	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
DANBY	0	98.8	2.5	100	0	6.6	0.17	2.2	0.05
E2041	0	97.5	5.0	100	0	6.5	0.33	2.2	0.03
DENALI	0	96.3	4.8	100	0	6.4	0.32	2.1	0.02
CO050337-2	0	96.3	7.5	100	0	6.4	0.50	2.1	0.05
BYRD	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
CO07W245	0	100.0	0.0	100	0	6.7	0.00	2.2	0.03
MCGILL	0	96.3	4.8	100	0	6.4	0.32	2.2	0.05
NE02558	0	97.5	5.0	100	0	6.5	0.33	2.1	0.02
NW03666	0	98.8	2.5	100	0	6.6	0.17	2.2	0.00
NE04490	0	98.8	2.5	100	0	6.6	0.17	2.2	0.03

NE05430	0	100.0	0.0	100	0	6.3	0.83	2.2	0.08
NE05496	0	98.8	2.5	100	0	6.6	0.17	2.2	0.03
NE05548	0	98.8	2.5	100	0	6.6	0.17	2.1	0.05
NE06545	0	98.8	2.5	100	0	6.6	0.17	2.1	0.05
NE06607	0	98.8	2.5	100	0	6.6	0.17	2.1	0.03
ROBIDOUX	0	100.0	0.0	100	0	6.7	0.00	2.1	0.03
NI06736	0	98.8	2.5	100	0	6.6	0.17	2.1	0.05
NI06737	0	96.3	4.8	100	0	6.4	0.32	2.1	0.04
NI07703	0	97.5	5.0	100	0	7.3	1.81	2.1	0.05
NI08707	0	97.5	5.0	100	0	6.5	0.33	2.2	0.02
NI08708	0	96.3	4.8	100	0	6.4	0.32	2.2	0.04
EVEREST	0	97.5	5.0	100	0	6.5	0.33	2.1	0.03
TRIUMPH64	60	90.0	7.1	91.2	7.5	3.8	0.66	2.9	0.17
CHISHOLM	60	90.0	7.1	92.4	8.6	4.0	0.50	2.7	0.11
CUSTER	60	88.8	2.5	92.4	5.1	4.2	1.24	2.8	0.20
2174-05	60	87.5	6.5	88.6	5.0	3.9	0.46	2.7	0.18
INTRADA	60	91.3	2.5	92.4	2.8	3.9	0.43	2.9	0.13
OK101	60	91.3	2.5	93.6	2.4	3.7	0.10	3.0	0.12
OK102	60	92.5	5.0	93.6	2.8	3.7	0.20	3.0	0.11
ENDURANCE	60	93.8	2.5	97.6	6.7	4.5	0.45	2.5	0.15
DELIVER	60	93.8	2.5	96.4	6.5	3.8	0.10	3.0	0.09
OK_BULLET	60	92.5	2.9	92.5	2.9	3.9	0.55	3.0	0.14
CENTERFIELD	60	82.5	2.9	83.6	2.4	3.5	0.35	2.9	0.23
GUYMON	60	96.3	2.5	97.5	2.9	5.6	1.02	2.5	0.15
DUSTER	60	85.0	0.0	87.4	4.7	3.4	0.00	2.9	0.15
OK_RISING	60	88.8	2.5	88.8	2.5	3.8	0.49	2.8	0.12
OK02405	60	92.5	2.9	93.7	2.5	3.7	0.12	2.9	0.08
PETE	60	93.8	2.5	94.9	0.1	4.0	0.52	3.0	0.21
BILLINGS	60	81.3	2.5	84.8	6.7	3.3	0.10	3.0	0.20
OK04505	60	92.5	2.9	92.5	2.9	3.9	0.39	2.8	0.23
OK04525	60	90.0	4.1	90.0	4.1	3.6	0.16	2.8	0.04
OK04507	60	93.8	2.5	93.8	2.5	4.0	0.35	2.7	0.12
OK05830	60	91.3	2.5	93.8	4.8	3.9	0.43	2.9	0.18
OK04111	60	93.8	2.5	95.0	4.1	3.8	0.10	3.1	0.27
OK04415	60	91.3	2.5	91.3	2.5	3.9	0.43	3.0	0.15
OK05711W	60	93.8	2.5	96.4	6.5	3.8	0.10	2.9	0.12
OK05723W	60	95.0	0.0	95.0	0.0	3.8	0.00	2.9	0.05
OK05108	60	95.0	0.0	96.3	2.5	3.8	0.00	3.0	0.05
OK05122	60	86.3	2.5	88.6	4.5	3.5	0.10	3.1	0.17
OK05526	60	92.5	2.9	92.5	2.9	3.7	0.12	3.1	0.08
OK05134	60	93.8	2.5	95.0	4.1	3.8	0.10	3.0	0.05

OK05303	60	91.3	2.5	92.4	2.8	3.7	0.10	3.0	0.04
OK05312	60	93.8	2.5	95.0	4.1	4.0	0.52	3.0	0.16
OK05511	60	91.3	4.8	92.5	6.5	3.7	0.19	3.0	0.18
OK05204	60	93.8	2.5	95.0	4.1	3.8	0.10	3.1	0.11
GARRISON	60	95.0	0.0	97.6	5.3	4.3	0.55	2.8	0.22
OK06114	60	93.8	2.5	97.9	9.5	3.8	0.10	3.1	0.13
OK06210	60	93.8	2.5	93.8	2.5	3.8	0.10	2.8	0.05
OK06319	60	92.5	2.9	93.7	2.5	3.7	0.12	3.1	0.03
OK06318	60	85.0	16.8	85.0	16.8	3.4	0.67	3.1	0.14
OK06336	60	95.0	0.0	97.6	5.3	3.8	0.00	2.9	0.18
AGATE	60	93.8	2.5	94.9	0.1	4.0	0.52	2.9	0.10
ALLIANCE	60	91.3	7.5	92.5	8.7	3.7	0.30	2.9	0.04
ANTELOPE	60	95.0	0.0	96.3	2.5	3.8	0.00	3.1	0.05
ARAPAHOE	60	95.0	0.0	96.3	2.5	4.3	0.55	2.9	0.19
BENNETT	60	95.0	0.0	95.0	0.0	3.8	0.00	3.1	0.11
BUCKSKIN	60	92.5	2.9	92.5	2.9	3.7	0.12	2.8	0.05
CENTURK78	60	95.0	0.0	96.3	2.5	4.0	0.48	2.9	0.18
CHEYENNE	60	95.0	0.0	97.6	5.3	4.0	0.48	2.9	0.25
COLT	60	92.5	2.9	92.5	2.9	3.7	0.12	2.9	0.12
COUGAR	60	93.8	4.8	94.9	4.1	4.0	0.54	2.8	0.15
CULVER	60	95.0	4.1	96.2	2.5	3.8	0.16	3.0	0.07
GAGE	60	96.3	2.5	97.5	2.9	4.8	0.13	2.6	0.02
GOODSTREAK	60	95.0	4.1	95.0	4.1	3.8	0.16	3.0	0.09
HALLAM	60	93.8	2.5	96.4	6.5	3.8	0.10	3.1	0.03
HARRY	60	95.0	0.0	96.3	2.5	3.8	0.00	3.1	0.12
HOMESTEAD	60	93.8	4.8	93.8	4.8	4.0	0.39	2.8	0.10
INFINITY_CL	60	93.8	2.5	94.9	0.1	3.8	0.10	2.9	0.12
KHARKOF	60	93.8	2.5	93.8	2.5	4.2	0.49	2.7	0.13
MILLENNIUM	60	92.5	2.9	92.5	2.9	3.7	0.12	3.0	0.04
CAMELOT	60	96.3	2.5	97.5	2.9	3.9	0.10	3.0	0.11
OVERLAND	60	95.0	0.0	96.3	2.5	3.8	0.00	3.0	0.09
NE99495	60	96.3	2.5	96.3	2.5	3.9	0.10	2.9	0.09
NIOBRARA	60	92.5	2.9	93.8	4.8	3.9	0.55	2.8	0.21
NUPLAINS	60	93.8	4.8	95.0	5.8	4.0	0.54	2.7	0.04
PRONGHORN	60	93.8	2.5	94.9	0.1	4.0	0.35	2.9	0.17
RAWHIDE	60	92.5	2.9	93.8	4.8	3.7	0.12	2.9	0.13
REDLAND	60	95.0	4.1	96.3	6.4	3.8	0.16	3.0	0.15
SCOUT66	60	92.5	2.9	92.5	2.9	3.7	0.12	3.0	0.05
SIOUXLAND	60	83.8	2.5	85.9	2.4	3.6	0.30	2.8	0.19
TURKEY_NEBSEL	60	95.0	0.0	97.5	2.9	3.8	0.00	3.1	0.04
VISTA	60	91.3	2.5	93.6	2.4	3.9	0.43	2.8	0.19

WAHOO	60	93.8	4.8	93.8	4.8	3.8	0.19	3.1	0.17
WARRIOR	60	95.0	4.1	95.0	4.1	4.0	0.50	2.8	0.20
WESLEY	60	93.8	2.5	95.0	4.1	4.0	0.52	2.9	0.09
WICHITA	60	93.8	6.3	93.8	6.3	3.8	0.25	2.9	0.06
WINDSTAR	60	93.8	6.3	94.9	4.3	3.8	0.25	3.1	0.17
LANCER	60	92.5	2.9	92.5	2.9	3.7	0.12	3.0	0.12
ANTON	60	91.3	2.5	93.8	4.8	3.7	0.10	2.9	0.21
MACE	60	93.8	4.8	95.1	7.2	3.8	0.19	2.9	0.09
TAM107-R7	60	92.5	2.9	93.7	2.5	3.7	0.12	2.9	0.03
ARLIN	60	93.8	2.5	97.5	2.9	3.8	0.10	3.0	0.14
ALICE	60	96.3	2.5	96.3	2.5	3.9	0.10	2.9	0.18
DARRELL	60	95.0	0.0	96.3	2.5	4.0	0.48	2.9	0.23
EXPEDITION	60	92.5	2.9	94.9	4.1	3.7	0.12	3.0	0.08
WENDY	60	96.3	2.5	96.3	2.5	3.9	0.10	3.0	0.03
SD00111-9	60	93.8	2.5	96.3	4.8	3.8	0.10	3.0	0.07
SD01237	60	93.8	2.5	94.9	0.1	4.0	0.52	2.9	0.20
SD01058	60	96.3	2.5	97.5	2.9	4.1	0.45	2.9	0.23
SD05118	60	95.0	0.0	95.0	0.0	4.7	1.20	2.7	0.22
SD05210	60	91.3	7.5	94.8	7.4	4.3	1.40	2.8	0.20
SD05W018	60	93.8	2.5	96.3	4.8	3.8	0.10	3.0	0.11
NEKOTA	60	95.0	0.0	96.3	2.5	4.0	0.48	2.9	0.17
TANDEM	60	95.0	0.0	97.6	5.3	3.8	0.00	3.0	0.06
CRIMSON	60	96.3	2.5	96.3	2.5	3.9	0.10	3.0	0.11
ROSE	60	91.3	4.8	93.7	6.3	4.1	0.51	2.8	0.18
DAWN	60	96.3	2.5	98.9	5.0	3.9	0.10	3.0	0.07
WINOKA	60	93.8	2.5	96.3	4.8	3.8	0.10	2.9	0.09
NELL	60	93.8	2.5	95.0	4.1	4.2	0.61	2.8	0.17
RITA	60	93.8	4.8	95.1	7.2	3.8	0.19	2.9	0.18
BRONZE	60	95.0	4.1	96.3	4.8	3.8	0.16	3.0	0.12
HUME	60	93.8	6.3	96.1	2.6	3.8	0.25	3.0	0.12
GENT	60	93.8	2.5	97.6	5.3	3.8	0.10	2.9	0.15
HARDING	60	93.8	4.8	93.8	4.8	3.8	0.19	3.0	0.09
HV9W03-1551WP	60	95.0	0.0	95.0	0.0	3.8	0.00	2.9	0.04
G1878	60	93.8	2.5	93.8	2.5	3.8	0.10	2.9	0.13
HV9W03-1379R	60	95.0	4.1	96.2	2.5	3.8	0.16	3.0	0.07
HV9W03-1596R	60	93.8	2.5	95.0	4.1	3.8	0.10	2.9	0.06
HV9W05-1280R	60	93.8	2.5	96.3	2.5	3.8	0.10	3.0	0.12
HV9W06-504	60	95.0	0.0	96.3	2.5	3.8	0.00	3.1	0.11
SPARTAN	60	93.8	2.5	94.9	0.1	3.8	0.10	3.0	0.08
HV906-865	60	95.0	0.0	95.0	0.0	3.8	0.00	3.0	0.13
TARKIO	60	93.8	2.5	95.0	4.1	3.8	0.10	2.9	0.03

SMOKYHILL	60	85.0	0.0	90.7	2.5	3.6	0.43	2.9	0.13
SHOCKER	60	93.8	2.5	94.9	0.1	4.0	0.52	2.8	0.14
VONA	60	93.8	4.8	93.8	4.8	3.8	0.19	3.0	0.14
CO940610	60	93.8	2.5	93.8	2.5	3.8	0.10	3.0	0.10
AVALANCHE	60	97.5	2.9	98.8	2.5	4.8	1.10	2.8	0.29
BOND_CL	60	93.8	2.5	93.8	2.5	3.8	0.10	2.9	0.07
PLATTE	60	93.8	2.5	95.0	4.1	3.8	0.10	3.0	0.07
LINDON	60	95.0	4.1	96.3	4.8	3.8	0.16	3.0	0.11
CO03W043	60	96.3	2.5	96.3	2.5	3.9	0.10	3.0	0.08
SNOWMASS	60	92.5	2.9	96.2	2.5	3.9	0.39	2.8	0.20
THUNDER_CL	60	93.8	2.5	96.4	6.5	3.8	0.10	2.9	0.09
CO04025	60	95.0	4.1	97.4	3.0	3.8	0.16	3.0	0.10
CO04393	60	92.5	2.9	95.1	7.3	3.9	0.55	2.8	0.15
CO04499	60	95.0	0.0	95.0	0.0	3.8	0.00	3.1	0.18
CO04W320	60	77.5	5.0	78.6	6.0	4.5	0.64	2.6	0.01
LAMAR	60	93.8	4.8	93.8	4.8	4.2	0.64	2.7	0.11
CARSON	60	86.3	2.5	87.4	2.7	3.9	0.44	3.0	0.33
HAIL	60	88.8	2.5	91.1	4.7	3.6	0.10	2.9	0.11
SANDY	60	93.8	2.5	93.8	2.5	3.8	0.10	2.9	0.09
DUKE	60	95.0	0.0	98.9	5.0	3.8	0.00	3.0	0.06
HALT	60	93.8	2.5	93.8	2.5	3.8	0.10	3.0	0.07
HATCHER	60	82.5	2.9	82.5	2.9	3.3	0.12	3.3	0.25
PRAIRIE_RED	60	93.8	2.5	96.4	6.5	3.8	0.10	3.0	0.11
ABOVE	60	96.3	2.5	96.3	2.5	3.9	0.10	3.0	0.03
CO03064	60	93.8	2.5	96.3	4.8	3.8	0.10	3.0	0.08
BILL_BROWN	60	88.8	2.5	89.9	4.0	3.6	0.10	3.2	0.27
RIPPER	60	91.3	2.5	93.6	2.4	3.7	0.10	3.0	0.12
PROWERS	60	93.8	2.5	95.0	4.1	3.8	0.10	3.0	0.15
AKRON	60	92.5	2.9	92.5	2.9	3.7	0.12	3.0	0.13
JULES	60	93.8	4.8	93.8	4.8	3.8	0.19	2.9	0.15
YUMA	60	93.8	2.5	96.2	2.5	3.8	0.10	3.1	0.15
TAMW-101	60	93.8	2.5	96.4	6.5	3.8	0.10	3.1	0.07
TAM105	60	95.0	0.0	96.3	2.5	3.8	0.00	3.0	0.07
TAM107	60	91.3	2.5	92.5	5.0	3.7	0.10	2.9	0.13
TAM109	60	96.3	2.5	97.6	5.1	3.9	0.10	3.0	0.07
TAM110	60	93.8	2.5	95.0	4.1	3.8	0.10	2.9	0.15
TAM111	60	95.0	0.0	98.9	5.0	3.8	0.00	3.0	0.13
TAM112	60	93.8	2.5	95.0	4.1	3.8	0.10	3.0	0.13
TAM200	60	95.0	4.1	96.2	2.5	4.0	0.50	2.8	0.15
TAM202	60	78.8	4.8	81.8	2.8	3.3	0.32	2.9	0.13
TAM203	60	95.0	0.0	98.9	5.0	4.0	0.48	3.0	0.26

TAM302	60	95.0	0.0	95.0	0.0	3.8	0.00	2.9	0.05
TAM303	60	87.5	2.9	87.5	2.9	3.5	0.12	3.0	0.07
TAM304	60	93.8	2.5	95.0	4.1	4.0	0.52	2.9	0.16
TAM400	60	80.0	0.0	82.1	2.4	3.2	0.00	3.2	0.06
LOCKETT	60	93.8	2.5	93.8	2.5	3.8	0.10	3.2	0.23
STURDY	60	85.0	4.1	87.2	4.8	3.8	0.38	2.9	0.25
STURDY_2K	60	93.8	6.3	95.0	7.1	3.8	0.25	3.2	0.23
MIT	60	87.5	6.5	89.7	4.4	4.6	1.05	2.8	0.32
CAPROCK	60	92.5	2.9	95.0	4.1	3.7	0.12	2.9	0.12
TX01A5936	60	95.0	4.1	95.0	4.1	3.8	0.16	3.0	0.16
TAM401	60	95.0	4.1	95.0	4.1	4.0	0.50	2.9	0.26
TX02A0252	60	95.0	0.0	97.5	2.9	3.8	0.00	2.9	0.10
TX03A0148	60	88.8	2.5	88.8	2.5	3.6	0.10	3.1	0.05
TX03A0563	60	87.5	2.9	88.6	2.4	3.5	0.12	3.0	0.14
TX04A001246	60	91.3	4.8	96.1	5.0	4.1	0.35	2.8	0.27
TX01V5134RC-3	60	97.5	2.9	97.5	2.9	3.9	0.12	2.9	0.09
TX04M410164	60	90.0	4.1	91.2	4.7	3.6	0.16	3.0	0.23
TX04M410211	60	95.0	0.0	96.3	2.5	4.0	0.48	2.8	0.14
TX04V075080	60	85.0	0.0	87.2	2.6	3.4	0.00	3.1	0.07
TX99A0153-1	60	87.5	6.5	87.5	6.5	4.2	0.68	2.6	0.13
TX01M5009-28	60	87.5	5.0	88.6	4.7	3.5	0.20	2.9	0.05
TX00V1131	60	92.5	2.9	96.1	2.6	3.7	0.12	3.0	0.07
TX99U8618	60	93.8	4.8	93.8	4.8	3.8	0.19	2.9	0.13
TX96D1073	60	91.3	4.8	92.5	6.5	4.3	0.41	2.7	0.27
2180	60	95.0	4.1	100.5	9.8	3.8	0.16	2.9	0.15
HG-9	60	88.8	4.8	92.3	6.5	3.6	0.19	3.0	0.12
TX86A5606	60	95.0	4.1	96.3	4.8	4.0	0.33	2.8	0.12
TX86A8072	60	90.0	4.1	90.0	4.1	4.5	0.20	2.6	0.04
CREST	60	96.3	7.5	96.3	7.5	4.1	0.13	2.9	0.23
ROSEBUD	60	95.0	0.0	96.3	2.5	3.8	0.00	2.9	0.04
JUDITH	60	91.3	4.8	92.5	6.5	4.1	0.51	2.8	0.22
MT85200	60	92.5	5.0	92.5	5.0	4.4	0.46	2.6	0.11
NUSKY	60	91.3	6.3	93.7	7.7	3.7	0.25	2.9	0.10
MT9513	60	91.3	4.8	92.4	3.0	4.1	0.73	2.7	0.12
MT9904	60	93.8	2.5	96.4	6.5	4.0	0.35	2.8	0.16
NORRIS	60	91.3	4.8	92.4	5.0	3.7	0.19	2.9	0.12
YELLOWSTONE	60	95.0	4.1	95.0	4.1	3.8	0.16	2.9	0.14
MT0495	60	92.5	2.9	93.7	2.5	3.7	0.12	3.0	0.09
MTS0531	60	98.8	2.5	100.1	4.2	4.9	1.26	2.7	0.19
DECADE	60	95.0	4.1	97.6	6.6	3.8	0.16	3.0	0.05
MT06103	60	88.8	2.5	92.4	6.4	4.0	0.46	2.7	0.14

JUDEE	60	88.8	2.5	89.9	4.0	3.6	0.10	3.0	0.14
LAKIN	60	91.3	2.5	92.4	2.8	3.7	0.10	3.1	0.05
STANTON	60	92.5	2.9	93.8	4.8	3.7	0.12	3.0	0.14
TREGO	60	90.0	4.1	91.2	4.7	4.3	0.33	2.6	0.15
KARL_92	60	92.5	5.0	93.8	6.3	3.7	0.20	2.9	0.05
DODGE	60	93.8	4.8	97.6	6.6	3.8	0.19	2.9	0.13
NORKAN	60	93.8	2.5	95.0	4.1	3.8	0.10	2.9	0.07
CHENEY	60	91.3	7.5	92.4	6.5	3.7	0.30	2.9	0.04
NEWTON	60	91.3	4.8	92.5	6.5	3.9	0.28	2.8	0.13
LARNED	60	91.3	7.5	92.5	8.7	3.9	0.36	2.8	0.08
PARKER76	60	92.5	2.9	93.8	4.8	3.7	0.12	3.0	0.11
KIRWIN	60	95.0	4.1	96.3	4.8	3.8	0.16	3.0	0.04
SAGE	60	95.0	4.1	96.3	4.8	3.8	0.16	2.8	0.08
TRISON	60	93.8	2.5	97.6	6.7	3.8	0.10	2.9	0.11
EAGLE	60	90.0	5.8	92.4	6.5	3.6	0.23	2.8	0.08
SHAWNEE	60	95.0	4.1	96.2	2.5	3.8	0.16	3.1	0.07
PARKER	60	93.8	6.3	95.0	7.1	4.0	0.21	2.8	0.14
KAW61	60	93.8	2.5	97.9	9.5	4.2	0.61	2.6	0.17
TASCOSA	60	95.0	4.1	97.6	6.6	5.1	0.60	2.5	0.07
BISON	60	91.3	4.8	93.6	4.9	3.7	0.19	2.9	0.13
KIOWA	60	96.3	4.8	97.5	5.0	3.9	0.19	2.9	0.15
WICHITA	60	91.3	2.5	92.5	5.0	4.1	0.47	2.8	0.16
COMANCHE	60	91.3	4.8	93.7	6.3	3.7	0.19	2.8	0.08
BAKERS_WHITE	60	91.3	4.8	96.3	6.9	3.7	0.19	2.9	0.03
BURCHETT	60	93.8	2.5	94.9	0.1	3.8	0.10	3.0	0.09
CUTTER	60	93.8	6.3	95.0	7.1	4.0	0.21	2.8	0.21
DUMAS	60	92.5	2.9	96.2	2.5	3.9	0.55	2.8	0.21
HONDO	60	93.8	6.3	95.0	7.1	4.7	0.31	2.6	0.04
JAGALENE	60	92.5	2.9	93.7	2.5	3.7	0.12	3.0	0.06
LONGHORN	60	92.5	5.0	93.8	6.3	3.7	0.20	3.0	0.08
NEOSHO	60	91.3	2.5	92.4	2.8	3.7	0.10	3.0	0.14
OGALLALA	60	93.8	4.8	94.9	4.1	3.8	0.19	3.0	0.11
POSTROCK	60	93.8	2.5	97.5	2.9	3.8	0.10	3.0	0.08
THUNDERBOLT	60	91.3	6.3	93.8	8.6	3.9	0.32	2.8	0.17
W04-417	60	96.3	2.5	98.8	2.5	3.9	0.10	3.0	0.08
NUFRONTIER	60	92.5	2.9	93.8	4.8	3.7	0.12	3.0	0.11
NUHORIZON	60	91.3	2.5	92.4	2.8	3.9	0.43	2.9	0.16
ONAGA	60	96.3	4.8	97.6	6.6	4.1	0.48	2.9	0.26
RONL	60	92.5	6.5	93.8	7.5	3.7	0.26	3.0	0.04
2145	60	90.0	0.0	91.2	2.4	3.8	0.45	2.8	0.13
HEYNE	60	91.3	4.8	95.1	9.3	3.7	0.19	2.9	0.11

KS00F5-20-3	60	95.0	4.1	98.8	4.9	4.0	0.33	2.9	0.15
OVERLEY	60	95.0	4.1	96.3	6.4	3.8	0.16	3.0	0.05
FULLER	60	91.3	2.5	93.6	2.4	3.9	0.43	2.8	0.12
COSSACK	60	91.3	6.3	94.9	5.9	3.7	0.25	2.9	0.07
ENHANCER	60	90.0	7.1	91.1	5.1	3.6	0.28	2.9	0.11
SANTA_FE	60	95.0	4.1	96.3	6.4	3.8	0.16	3.0	0.08
VENANGO	60	91.3	4.8	92.4	3.0	3.7	0.19	2.9	0.03
WB411W	60	88.8	6.3	88.8	6.3	4.0	0.39	2.7	0.20
KEOTA	60	95.0	4.1	97.4	3.0	3.8	0.16	3.1	0.07
TX05A001822	60	90.0	4.1	93.8	7.5	3.8	0.62	2.8	0.18
TX06A001263	60	92.5	6.5	93.7	6.3	3.7	0.26	3.0	0.11
TX06A001132	60	90.0	4.1	91.1	2.6	4.1	0.66	2.7	0.23
TX06A001281	60	92.5	2.9	95.0	4.1	3.7	0.12	2.9	0.07
TX06A001386	60	95.0	7.1	96.3	8.6	4.0	0.18	2.8	0.17
TX05V7259	60	90.0	7.1	91.1	5.1	4.3	0.44	2.7	0.08
TX05V7269	60	91.3	7.5	92.5	8.7	3.9	0.10	2.9	0.16
TX05A001188	60	92.5	2.9	93.8	4.8	3.9	0.55	2.9	0.18
TX07A001279	60	93.8	4.8	96.3	4.8	3.8	0.19	3.0	0.05
TX07A001318	60	90.0	9.1	91.1	7.7	3.8	0.45	2.8	0.13
TX07A001420	60	88.8	7.5	88.8	7.5	3.8	0.43	2.8	0.23
TX06V7266	60	93.8	6.3	95.0	7.1	4.0	0.57	2.8	0.09
OK1067071	60	91.3	4.8	94.9	4.3	3.9	0.60	2.8	0.22
OK1067274	60	91.3	7.5	91.3	7.5	3.9	0.76	2.9	0.16
OK1068002	60	86.3	10.3	87.2	9.0	4.2	0.57	2.8	0.34
OK1068009	60	93.8	6.3	93.8	6.3	3.8	0.25	3.0	0.05
OK1068026	60	93.8	6.3	95.0	7.1	3.8	0.25	3.0	0.08
OK1068112	60	90.0	7.1	91.2	7.5	3.6	0.28	2.9	0.07
OK1070275	60	97.5	2.9	97.5	2.9	3.9	0.12	3.0	0.06
OK1070267	60	88.8	4.8	89.9	4.1	3.8	0.52	2.7	0.17
OK09634	60	92.5	6.5	94.9	7.1	3.9	0.28	2.9	0.16
OK10119	60	92.5	2.9	94.9	4.1	4.2	0.55	2.8	0.12
GALLAGHER	60	91.3	6.3	91.3	6.3	3.9	0.49	2.8	0.10
OK07231	60	87.5	8.7	88.8	10.3	3.7	0.73	2.7	0.16
OK07S117	60	91.3	4.8	91.3	4.8	3.7	0.19	2.9	0.03
OK08328	60	87.5	6.5	88.8	8.5	3.5	0.26	2.9	0.09
BIG_SKY	60	93.8	2.5	93.8	2.5	3.8	0.10	2.9	0.08
DANBY	60	93.8	6.3	95.0	7.1	4.0	0.21	2.8	0.15
E2041	60	95.0	4.1	97.8	9.2	3.8	0.16	3.0	0.03
DENALI	60	87.5	6.5	91.1	8.5	3.9	0.60	2.7	0.18
CO050337-2	60	88.8	4.8	92.9	12.8	4.0	0.62	2.7	0.17
BYRD	60	93.8	6.3	95.0	7.1	3.8	0.25	2.9	0.07

CO07W245	60	90.0	9.1	90.0	9.1	3.8	0.28	2.8	0.14
MCGILL	60	93.8	6.3	97.6	8.8	3.8	0.25	2.9	0.07
NE02558	60	90.0	4.1	92.5	6.5	3.6	0.16	2.9	0.06
NW03666	60	92.5	2.9	93.7	2.5	3.7	0.12	2.9	0.00
NE04490	60	90.0	4.1	91.2	4.7	3.6	0.16	2.8	0.06
NE05430	60	91.3	4.8	91.3	4.8	3.9	0.46	2.8	0.15
NE05496	60	91.3	7.5	92.5	8.7	3.7	0.30	2.9	0.15
NE05548	60	91.3	4.8	92.5	6.5	4.1	0.51	2.8	0.15
NE06545	60	88.8	4.8	89.9	4.1	3.8	0.36	2.8	0.17
NE06607	60	91.3	7.5	92.6	9.7	3.9	0.36	2.8	0.20
ROBIDOUX	60	88.8	4.8	88.8	4.8	4.0	0.62	2.7	0.17
NI06736	60	93.8	6.3	94.9	4.3	4.0	0.21	2.8	0.15
NI06737	60	91.3	4.8	95.1	8.4	3.7	0.19	2.9	0.09
NI07703	60	92.5	5.0	94.9	0.3	3.7	0.20	2.9	0.07
NI08707	60	91.3	7.5	93.6	6.3	3.9	0.36	3.0	0.26
NI08708	60	92.5	5.0	96.4	8.7	3.7	0.20	2.9	0.09
EVEREST	60	91.3	7.5	93.9	10.5	3.7	0.30	2.9	0.07
TRIUMPH64	120	65.0	5.8	65.9	7.0	2.4	0.04	3.5	0.29
CHISHOLM	120	86.3	4.8	88.4	2.8	3.2	0.19	3.1	0.20
CUSTER	120	38.8	7.5	40.2	6.7	1.6	0.18	3.4	0.44
2174-05	120	28.8	2.5	29.1	2.9	1.1	0.13	3.7	0.45
INTRADA	120	45.0	5.8	45.5	5.2	1.7	0.27	3.6	0.49
OK101	120	41.3	6.3	42.3	6.1	1.7	0.07	3.6	0.49
OK102	120	42.5	5.0	43.0	4.8	1.6	0.15	3.8	0.53
ENDURANCE	120	81.3	4.8	84.5	3.9	2.8	0.29	3.4	0.27
DELIVER	120	42.5	8.7	44.0	11.6	1.8	0.37	3.4	0.19
OK_BULLET	120	42.5	9.6	42.5	9.6	1.5	0.43	3.7	0.34
CENTERFIELD	120	60.0	7.1	60.9	8.0	1.9	0.21	4.0	0.11
GUYMON	120	86.3	2.5	87.4	2.7	4.3	0.13	2.5	0.06
DUSTER	120	60.0	4.1	61.8	7.3	2.1	0.11	3.8	0.16
OK_RISING	120	51.3	4.8	51.3	4.8	1.9	0.30	3.7	0.43
OK02405	120	52.5	2.9	53.2	2.4	1.8	0.10	3.9	0.34
PETE	120	51.3	2.5	51.9	2.4	1.7	0.08	4.0	0.14
BILLINGS	120	56.3	2.5	58.7	4.7	1.9	0.08	4.0	0.11
OK04505	120	68.8	4.8	68.8	4.8	2.2	0.09	3.9	0.48
OK04525	120	47.5	10.4	47.5	10.4	2.0	0.52	3.3	0.15
OK04507	120	87.5	2.9	87.5	2.9	2.8	0.27	3.8	0.17
OK05830	120	53.8	2.5	55.3	4.5	1.7	0.20	4.1	0.24
OK04111	120	41.3	10.3	41.7	10.0	1.5	0.23	3.8	0.49
OK04415	120	45.0	9.1	45.0	9.1	1.8	0.14	3.5	0.33
OK05711W	120	68.8	4.8	70.7	6.7	2.4	0.19	3.6	0.18

OK05723W	120	70.0	4.1	70.0	4.1	2.5	0.27	3.5	0.31
OK05108	120	60.0	4.1	60.9	5.6	2.7	0.40	3.2	0.32
OK05122	120	53.8	4.8	55.3	6.1	2.0	0.36	3.8	0.47
OK05526	120	48.8	2.5	48.8	2.5	1.6	0.08	4.1	0.13
OK05134	120	46.3	13.1	46.8	13.1	1.5	0.44	4.1	0.06
OK05303	120	47.5	5.0	48.1	4.7	1.6	0.17	4.1	0.29
OK05312	120	55.0	4.1	55.7	3.1	1.8	0.14	4.2	0.14
OK05511	120	47.5	6.5	48.2	6.9	1.6	0.22	3.7	0.17
OK05204	120	48.8	6.3	49.4	6.6	1.6	0.21	4.1	0.16
GARRISON	120	70.0	0.0	71.9	3.9	2.3	0.00	4.1	0.06
OK06114	120	47.5	2.9	49.7	6.5	1.6	0.10	4.4	0.16
OK06210	120	82.5	6.5	82.5	6.5	2.8	0.22	3.7	0.27
OK06319	120	50.0	4.1	50.7	4.3	1.7	0.14	4.2	0.15
OK06318	120	58.8	2.5	58.8	2.5	2.1	0.24	4.0	0.39
OK06336	120	51.3	2.5	52.6	3.1	1.7	0.08	4.0	0.21
AGATE	120	41.3	6.3	41.7	5.7	1.5	0.37	3.8	0.44
ALLIANCE	120	51.3	2.5	51.9	2.4	1.6	0.17	4.4	0.28
ANTELOPE	120	42.5	8.7	43.1	9.0	1.4	0.29	4.0	0.14
ARAPAHOE	120	38.8	8.5	39.4	9.7	1.4	0.27	3.9	0.32
BENNETT	120	50.0	0.0	50.0	0.0	2.1	0.83	3.6	0.60
BUCKSKIN	120	40.0	4.1	40.0	4.1	1.5	0.52	4.1	0.78
CENTURK78	120	46.3	9.5	46.8	9.1	1.8	0.31	3.5	0.59
CHEYENNE	120	72.5	5.0	74.6	7.5	2.5	0.34	3.8	0.24
COLT	120	48.8	2.5	48.8	2.5	1.8	0.25	3.7	0.31
COUGAR	120	75.0	4.1	76.0	4.5	2.5	0.14	4.1	0.06
CULVER	120	57.5	2.9	58.3	4.0	2.0	0.27	3.9	0.30
GAGE	120	85.0	0.0	86.1	2.2	4.4	0.94	2.6	0.12
GOODSTREAK	120	86.3	2.5	86.3	2.5	2.9	0.08	3.8	0.08
HALLAM	120	86.3	2.5	88.8	7.5	2.8	0.13	3.8	0.30
HARRY	120	38.8	2.5	39.3	3.0	1.7	0.40	3.4	0.49
HOMESTEAD	120	73.8	2.5	73.8	2.5	2.5	0.08	3.9	0.09
INFINITY_CL	120	50.0	8.2	50.7	8.3	1.7	0.27	3.8	0.07
KHARKOF	120	68.8	4.8	68.8	4.8	2.3	0.16	4.0	0.14
MILLENNIUM	120	45.0	8.2	45.0	8.2	1.8	0.33	3.5	0.37
CAMELOT	120	42.5	9.6	42.9	8.9	1.6	0.33	3.8	0.48
OVERLAND	120	48.8	8.5	49.3	8.3	1.6	0.28	3.8	0.14
NE99495	120	83.8	4.8	83.8	4.8	2.7	0.31	3.8	0.11
NIOBRARA	120	83.8	6.3	84.7	4.5	2.8	0.21	3.8	0.14
NUPLAINS	120	71.3	2.5	72.2	2.6	2.5	0.22	4.0	0.41
PRONGHORN	120	48.8	2.5	49.4	3.2	1.6	0.08	4.1	0.36
RAWHIDE	120	58.8	2.5	59.5	3.4	2.0	0.08	4.0	0.34

REDLAND	120	53.8	4.8	54.5	5.2	2.0	0.22	3.6	0.28
SCOUT66	120	71.3	4.8	71.3	4.8	2.4	0.16	3.9	0.19
SIOUXLAND	120	56.3	8.5	57.6	7.4	2.2	0.48	3.6	0.28
TURKEY_NEBSEL	120	67.5	2.9	69.3	3.6	2.2	0.22	3.9	0.16
VISTA	120	58.8	4.8	60.4	6.6	2.4	0.19	3.4	0.02
WAHOO	120	56.3	2.5	56.3	2.5	1.9	0.08	3.9	0.29
WARRIOR	120	67.5	6.5	67.5	6.5	2.3	0.22	3.9	0.09
WESLEY	120	85.0	4.1	86.2	6.2	2.8	0.14	4.0	0.15
WICHITA	120	67.5	2.9	67.5	2.9	2.3	0.10	3.9	0.11
WINDSTAR	120	57.5	6.5	58.3	7.0	1.9	0.28	3.8	0.17
LANCER	120	63.8	2.5	63.8	2.5	2.0	0.15	4.3	0.23
ANTON	120	53.8	2.5	55.1	0.3	1.9	0.23	3.9	0.30
MACE	120	46.3	10.3	46.7	9.7	1.7	0.49	3.7	0.50
TAM107-R7	120	46.3	2.5	46.8	2.4	1.6	0.15	3.8	0.28
ARLIN	120	51.3	6.3	53.6	9.3	1.7	0.21	4.0	0.21
ALICE	120	55.0	4.1	55.0	4.1	1.9	0.23	4.0	0.24
DARRELL	120	72.5	2.9	73.5	4.3	2.4	0.10	3.9	0.11
EXPEDITION	120	66.3	2.5	68.0	2.1	2.2	0.08	3.9	0.15
WENDY	120	85.0	7.1	85.0	7.1	2.6	0.37	4.0	0.34
SD00111-9	120	52.5	8.7	53.9	9.7	2.0	0.46	3.9	0.68
SD01237	120	72.5	2.9	73.4	2.4	2.4	0.10	3.9	0.20
SD01058	120	48.8	2.5	49.4	3.2	1.9	0.28	3.6	0.60
SD05118	120	77.5	6.5	77.5	6.5	2.6	0.22	4.2	0.08
SD05210	120	55.0	4.1	57.2	5.4	2.2	0.16	3.5	0.06
SD05W018	120	72.5	5.0	74.3	4.4	2.4	0.20	4.1	0.43
NEKOTA	120	62.5	2.9	63.3	2.4	2.1	0.10	4.1	0.18
TANDEM	120	72.5	2.9	74.4	3.2	2.4	0.10	3.9	0.20
CRIMSON	120	58.8	2.5	58.8	2.5	2.0	0.08	4.0	0.16
ROSE	120	36.3	6.3	37.3	7.3	1.5	0.26	3.5	0.41
DAWN	120	72.5	5.0	74.6	7.5	2.4	0.17	3.9	0.18
WINOKA	120	36.3	9.5	37.1	9.1	1.4	0.22	3.9	0.13
NELL	120	73.8	7.5	74.7	7.1	2.5	0.25	4.0	0.13
RITA	120	72.5	2.9	73.5	4.3	2.4	0.10	4.0	0.09
BRONZE	120	51.3	2.5	52.0	3.9	1.7	0.08	4.1	0.21
HUME	120	48.8	6.3	50.3	8.6	1.8	0.16	3.7	0.45
GENT	120	51.3	2.5	53.3	2.5	2.1	0.10	3.1	0.05
HARDING	120	56.3	4.8	56.3	4.8	1.9	0.16	4.1	0.29
HV9W03-1551WP	120	43.8	4.8	43.8	4.8	1.5	0.14	3.8	0.41
G1878	120	58.8	2.5	58.8	2.5	2.0	0.08	4.0	0.20
HV9W03-1379R	120	47.5	5.0	48.2	5.6	1.6	0.17	4.1	0.21
HV9W03-1596R	120	72.5	2.9	73.5	4.3	2.4	0.10	3.9	0.22

HV9W05-1280R	120	47.5	5.0	48.8	4.8	1.6	0.17	4.1	0.19
HV9W06-504	120	71.3	2.5	72.2	4.5	2.7	0.44	3.5	0.19
SPARTAN	120	63.8	2.5	64.6	3.5	2.0	0.15	3.9	0.15
HV906-865	120	66.3	2.5	66.3	2.5	2.0	0.15	4.0	0.14
TARKIO	120	50.0	7.1	50.6	6.6	1.7	0.24	3.9	0.18
SMOKYHILL	120	56.3	2.5	60.1	4.4	1.9	0.08	4.1	0.13
SHOCKER	120	68.8	4.8	69.7	5.4	2.3	0.16	4.2	0.16
VONA	120	53.8	4.8	53.8	4.8	1.8	0.16	4.1	0.21
CO940610	120	63.8	4.8	63.8	4.8	2.1	0.16	3.8	0.08
AVALANCHE	120	61.3	8.5	62.2	9.9	3.2	1.01	3.0	0.18
BOND_CL	120	58.8	2.5	58.8	2.5	2.0	0.08	3.8	0.13
PLATTE	120	51.3	6.3	51.8	5.6	1.7	0.21	4.0	0.19
LINDON	120	47.5	5.0	48.2	6.4	1.6	0.26	3.9	0.49
CO03W043	120	72.5	5.0	72.5	5.0	2.6	0.49	3.6	0.44
SNOWMASS	120	75.0	4.1	78.1	7.2	2.5	0.14	3.9	0.20
THUNDER_CL	120	72.5	2.9	74.6	6.3	2.4	0.10	3.9	0.10
CO04025	120	67.5	2.9	69.2	0.9	2.3	0.10	3.9	0.07
CO04393	120	73.8	2.5	75.8	5.5	2.5	0.08	3.9	0.15
CO04499	120	71.3	4.8	71.3	4.8	2.4	0.16	4.1	0.06
CO04W320	120	36.3	2.5	36.7	2.4	1.4	0.25	3.4	0.50
LAMAR	120	77.5	5.0	77.5	5.0	2.5	0.04	4.0	0.06
CARSON	120	36.3	2.5	36.8	3.6	1.5	0.19	3.3	0.44
HAIL	120	37.5	2.9	38.5	3.2	1.3	0.10	3.7	0.15
SANDY	120	51.3	4.8	51.3	4.8	1.7	0.16	4.0	0.23
DUKE	120	48.8	2.5	50.8	4.5	1.6	0.08	4.1	0.16
HALT	120	57.5	2.9	57.5	2.9	1.9	0.10	4.0	0.21
HATCHER	120	36.3	6.3	36.3	6.3	1.4	0.16	3.6	0.51
PRAIRIE_RED	120	63.8	10.3	65.6	11.2	2.1	0.34	3.8	0.21
ABOVE	120	71.3	4.8	71.3	4.8	2.4	0.16	3.9	0.16
CO03064	120	57.5	2.9	59.1	4.7	2.1	0.25	3.5	0.29
BILL_BROWN	120	36.3	2.5	36.8	3.6	1.4	0.25	3.7	0.68
RIPPER	120	35.0	0.0	35.9	1.1	1.4	0.28	3.5	0.58
PROWERS	120	78.8	2.5	79.7	0.5	2.6	0.08	3.9	0.15
AKRON	120	47.5	2.9	47.5	2.9	1.6	0.10	4.1	0.23
JULES	120	61.3	4.8	61.3	4.8	2.0	0.15	3.9	0.15
YUMA	120	62.5	5.0	64.1	4.4	2.1	0.17	4.2	0.10
TAMW-101	120	72.5	2.9	74.6	6.3	2.4	0.10	4.1	0.11
TAM105	120	66.3	2.5	67.2	4.3	2.2	0.08	4.0	0.07
TAM107	120	50.0	4.1	50.6	3.2	1.9	0.57	4.1	0.83
TAM109	120	75.0	4.1	76.0	4.5	2.4	0.11	4.0	0.27
TAM110	120	75.0	0.0	76.0	2.0	2.5	0.00	3.8	0.18

TAM111	120	57.5	2.9	59.9	5.0	1.9	0.10	4.0	0.21
TAM112	120	76.3	2.5	77.2	2.6	2.5	0.08	4.0	0.14
TAM200	120	57.5	2.9	58.2	2.4	2.0	0.27	3.9	0.22
TAM202	120	28.8	2.5	30.0	3.6	1.6	0.48	3.0	0.71
TAM203	120	48.8	2.5	50.7	3.4	1.6	0.08	3.8	0.16
TAM302	120	82.5	6.5	82.5	6.5	2.6	0.25	3.8	0.15
TAM303	120	37.5	2.9	37.5	2.9	2.1	0.74	2.9	0.65
TAM304	120	66.3	6.3	67.2	8.2	2.2	0.21	4.0	0.17
TAM400	120	35.0	4.1	35.9	4.4	1.4	0.39	3.6	0.55
LOCKETT	120	57.5	2.9	57.5	2.9	2.0	0.15	3.8	0.27
STURDY	120	30.0	0.0	30.8	0.9	1.5	0.41	3.2	0.27
STURDY_2K	120	53.8	2.5	54.4	1.2	1.8	0.08	3.7	0.20
MIT	120	47.5	2.9	48.8	3.3	1.9	0.44	3.7	0.44
CAPROCK	120	71.3	2.5	73.2	3.9	2.4	0.08	3.8	0.23
TX01A5936	120	70.0	4.1	70.0	4.1	2.3	0.14	4.1	0.18
TAM401	120	75.0	4.1	75.0	4.1	2.5	0.14	4.1	0.14
TX02A0252	120	36.3	9.5	37.1	9.1	1.5	0.34	3.4	0.73
TX03A0148	120	35.0	0.0	35.0	0.0	1.5	0.29	3.3	0.21
TX03A0563	120	37.5	2.9	38.0	2.5	1.5	0.36	3.7	0.51
TX04A001246	120	75.0	4.1	79.0	4.0	2.7	0.21	3.5	0.26
TX01V5134RC-3	120	86.3	4.8	86.3	4.8	2.9	0.16	3.7	0.09
TX04M410164	120	57.5	2.9	58.2	2.4	1.9	0.10	3.9	0.16
TX04M410211	120	38.8	2.5	39.2	1.6	1.4	0.13	3.3	0.25
TX04V075080	120	36.3	4.8	37.2	4.8	1.4	0.50	3.7	0.78
TX99A0153-1	120	47.5	2.9	47.5	2.9	1.6	0.10	4.1	0.38
TX01M5009-28	120	52.5	2.9	53.2	2.4	2.1	0.48	3.4	0.28
TX00V1131	120	48.8	2.5	50.7	2.5	1.8	0.25	3.8	0.48
TX99U8618	120	83.8	6.3	83.8	6.3	2.8	0.21	3.8	0.15
TX96D1073	120	62.5	2.9	63.4	4.1	2.1	0.10	4.0	0.11
2180	120	47.5	2.9	50.3	6.0	1.7	0.12	3.9	0.38
HG-9	120	37.5	6.5	38.9	6.6	1.4	0.16	3.9	0.60
TX86A5606	120	58.8	4.8	59.5	4.2	2.5	0.24	3.3	0.23
TX86A8072	120	66.3	4.8	66.3	4.8	2.1	0.16	4.0	0.29
CREST	120	52.5	2.9	52.5	2.9	1.8	0.10	3.9	0.05
ROSEBUD	120	58.8	4.8	59.6	6.3	2.0	0.16	3.8	0.04
JUDITH	120	63.8	2.5	64.6	3.5	2.1	0.08	4.0	0.14
MT85200	120	65.0	8.2	65.0	8.2	2.2	0.27	3.6	0.17
NUSKY	120	38.8	4.8	39.8	5.5	1.7	0.27	3.3	0.42
MT9513	120	77.5	2.9	78.6	4.4	2.6	0.10	3.7	0.11
MT9904	120	72.5	5.0	74.4	5.2	2.4	0.17	3.7	0.31
NORRIS	120	72.5	2.9	73.4	2.4	2.4	0.10	3.8	0.19

YELLOWSTONE	120	58.8	2.5	58.8	2.5	2.1	0.10	3.8	0.31
MT0495	120	40.0	7.1	40.4	6.3	1.5	0.41	3.7	0.47
MTS0531	120	87.5	6.5	88.6	6.3	4.8	1.06	2.5	0.08
DECADE	120	71.3	8.5	73.0	8.0	2.9	0.76	3.6	0.59
MT06103	120	68.8	2.5	71.5	1.8	2.4	0.27	3.8	0.40
JUDEE	120	47.5	2.9	48.1	2.4	1.5	0.16	4.2	0.24
LAKIN	120	67.5	6.5	68.3	5.3	2.2	0.14	4.1	0.06
STANTON	120	60.0	4.1	60.7	3.0	2.0	0.14	4.1	0.16
TREGO	120	73.8	2.5	74.7	3.7	3.0	0.10	3.3	0.11
KARL_92	120	73.8	6.3	74.6	4.7	2.5	0.21	4.0	0.15
DODGE	120	76.3	2.5	79.5	6.6	2.5	0.08	4.0	0.14
NORKAN	120	56.3	2.5	57.0	2.4	2.1	0.64	3.9	0.75
CHENEY	120	36.3	4.8	36.6	4.1	1.5	0.36	3.5	0.77
NEWTON	120	63.8	4.8	64.5	4.2	2.1	0.16	4.0	0.13
LARNED	120	75.0	4.1	76.0	4.5	2.5	0.14	4.1	0.13
PARKER76	120	70.0	4.1	71.0	5.8	2.3	0.14	4.1	0.17
KIRWIN	120	77.5	2.9	78.6	4.4	2.6	0.10	3.9	0.14
SAGE	120	65.0	4.1	65.9	5.7	2.2	0.14	4.2	0.10
TRISON	120	57.5	5.0	60.0	8.2	1.9	0.17	4.0	0.23
EAGLE	120	52.5	5.0	53.8	4.3	2.0	0.39	3.7	0.57
SHAWNEE	120	57.5	2.9	58.3	4.0	2.1	0.41	3.8	0.72
PARKER	120	72.5	6.5	73.4	5.2	2.4	0.22	3.8	0.17
KAW61	120	72.5	2.9	75.6	5.1	2.9	0.12	3.4	0.13
TASCOSA	120	86.3	2.5	88.6	4.6	4.1	0.33	2.6	0.24
BISON	120	75.0	4.1	76.9	3.0	2.5	0.14	4.0	0.25
KIOWA	120	73.8	2.5	74.7	3.7	2.5	0.08	4.2	0.07
WICHITA	120	66.3	2.5	67.2	4.3	2.2	0.08	4.1	0.20
COMANCHE	120	72.5	6.5	74.3	4.8	2.4	0.22	3.9	0.17
BAKERS_WHITE	120	48.8	4.8	51.5	6.5	1.6	0.16	4.1	0.24
BURCHETT	120	36.3	4.8	36.7	4.7	1.5	0.36	3.5	0.60
CUTTER	120	72.5	2.9	73.5	4.3	2.9	0.12	3.6	0.17
DUMAS	120	57.5	5.0	59.9	6.4	1.9	0.24	4.2	0.42
HONDO	120	41.3	2.5	41.8	2.4	2.0	0.55	3.2	0.58
JAGALENE	120	66.3	4.8	67.1	4.8	2.0	0.20	4.2	0.11
LONGHORN	120	57.5	2.9	58.3	4.0	1.9	0.10	4.0	0.40
NEOSHO	120	73.8	2.5	74.7	3.7	2.5	0.08	3.9	0.08
OGALLALA	120	53.8	4.8	54.4	4.3	1.7	0.19	4.5	0.71
POSTROCK	120	40.0	4.1	41.6	3.9	1.7	0.32	3.3	0.59
THUNDERBOLT	120	75.0	0.0	77.0	2.3	2.5	0.00	4.1	0.08
W04-417	120	36.3	6.3	37.1	5.7	1.7	0.64	3.3	0.59
NUFRONTIER	120	55.0	8.2	55.7	8.3	1.8	0.25	4.1	0.45

NUHORIZON	120	66.3	4.8	67.1	4.8	2.2	0.16	3.9	0.10
ONAGA	120	60.0	9.1	60.7	8.2	2.2	0.39	3.7	0.43
RONL	120	62.5	2.9	63.4	4.1	2.1	0.10	4.3	0.15
2145	120	48.8	2.5	49.4	3.2	1.9	0.25	3.7	0.49
HEYNE	120	60.0	4.1	62.6	7.2	2.0	0.22	4.1	0.59
KS00F5-20-3	120	43.8	6.3	45.3	4.7	1.8	0.32	3.4	0.72
OVERLEY	120	42.5	8.7	43.0	8.5	1.6	0.22	3.7	0.50
FULLER	120	72.5	5.0	74.3	4.4	2.5	0.34	3.9	0.22
COSSACK	120	75.0	0.0	78.1	4.0	2.5	0.00	3.8	0.14
ENHANCER	120	75.0	4.1	75.9	2.8	2.5	0.14	4.0	0.20
SANTA_FE	120	62.5	2.9	63.3	2.4	2.1	0.10	4.1	0.13
VENANGO	120	71.3	2.5	72.2	2.6	2.4	0.08	4.1	0.19
WB411W	120	72.5	2.9	72.5	2.9	2.3	0.15	4.0	0.20
KEOTA	120	67.5	6.5	69.3	7.8	2.2	0.30	4.0	0.13
TX05A001822	120	43.8	4.8	45.7	6.6	1.8	0.60	3.6	0.75
TX06A001263	120	50.0	4.1	50.6	3.2	1.7	0.14	4.1	0.05
TX06A001132	120	57.5	5.0	58.2	4.7	2.0	0.20	3.9	0.27
TX06A001281	120	67.5	6.5	69.3	6.5	2.2	0.34	4.2	0.11
TX06A001386	120	61.3	6.3	62.0	5.4	2.0	0.21	4.0	0.14
TX05V7259	120	70.0	4.1	71.0	5.8	2.3	0.22	4.2	0.23
TX05V7269	120	43.8	4.8	44.3	4.3	1.4	0.22	4.2	0.37
TX05A001188	120	43.8	2.5	44.3	3.1	1.5	0.19	4.1	0.45
TX07A001279	120	63.8	7.5	65.4	7.1	2.1	0.25	4.0	0.18
TX07A001318	120	72.5	2.9	73.4	2.4	2.4	0.10	3.9	0.19
TX07A001420	120	72.5	2.9	72.5	2.9	2.4	0.10	4.0	0.07
TX06V7266	120	71.3	2.5	72.2	2.6	2.4	0.08	4.1	0.11
OK1067071	120	50.0	4.1	52.1	6.1	1.6	0.08	4.0	0.18
OK1067274	120	70.0	4.1	70.0	4.1	2.3	0.14	3.9	0.16
OK1068002	120	76.3	8.5	77.1	7.1	2.6	0.23	3.8	0.43
OK1068009	120	71.3	4.8	71.3	4.8	2.4	0.16	4.1	0.09
OK1068026	120	48.8	4.8	49.3	4.3	2.3	0.31	3.1	0.05
OK1068112	120	45.0	4.1	45.5	3.3	1.7	0.40	3.6	0.64
OK1070275	120	42.5	5.0	42.5	5.0	1.6	0.32	3.6	0.45
OK1070267	120	72.5	2.9	73.5	4.3	2.5	0.32	3.8	0.17
OK09634	120	48.8	2.5	50.0	2.1	1.8	0.45	3.9	0.67
OK10119	120	42.5	6.5	43.5	5.5	1.6	0.48	3.6	0.65
GALLAGHER	120	73.8	4.8	73.8	4.8	2.4	0.28	3.9	0.47
OK07231	120	71.3	4.8	72.1	3.4	2.4	0.16	4.0	0.09
OK07S117	120	66.3	4.8	66.3	4.8	2.2	0.16	4.0	0.16
OK08328	120	62.5	6.5	63.4	8.0	2.1	0.51	3.9	0.45
BIG_SKY	120	71.3	2.5	71.3	2.5	2.4	0.08	3.8	0.14

DANBY	120	68.8	6.3	69.5	4.9	2.3	0.21	3.9	0.13			
E2041	120	46.3	6.3	47.5	6.5	1.9	0.55	3.5	0.53			
DENALI	120	73.8	6.3	76.5	3.6	2.4	0.17	3.9	0.26			
CO050337-2	120	75.0	0.0	78.3	6.6	2.5	0.00	3.9	0.14			
BYRD	120	70.0	0.0	70.9	1.8	2.3	0.17	4.1	0.60			
CO07W245	120	71.3	4.8	71.3	4.8	2.4	0.16	3.8	0.12			
MCGILL	120	52.5	5.0	54.5	4.3	1.8	0.17	3.7	0.16			
NE02558	120	57.5	5.0	59.0	4.9	2.1	0.37	3.5	0.35			
NW03666	120	66.3	2.5	67.2	4.3	2.2	0.08	4.0	0.22			
NE04490	120	73.8	2.5	74.7	0.7	2.5	0.08	3.9	0.19			
NE05430	120	48.8	6.3	48.8	6.3	1.9	0.62	3.8	0.70			
NE05496	120	67.5	2.9	68.4	4.2	2.3	0.10	4.0	0.19			
NE05548	120	57.5	2.9	58.3	4.0	1.9	0.20	4.4	0.56			
NE06545	120	52.5	2.9	53.2	2.4	2.0	0.37	3.7	0.52			
NE06607	120	67.5	2.9	68.4	4.2	2.3	0.10	4.0	0.17			
ROBIDOUX	120	51.3	6.3	51.3	6.3	2.0	0.24	3.7	0.58			
NI06736	120	45.0	4.1	45.7	5.2	1.6	0.20	3.8	0.36			
NI06737	120	62.5	5.0	65.0	4.3	2.0	0.25	4.1	0.58			
NI07703	120	73.8	2.5	75.8	5.5	2.5	0.08	3.9	0.22			
NI08707	120	63.8	4.8	65.7	8.4	2.1	0.16	4.1	0.19			
NI08708	120	71.3	4.8	74.2	6.7	2.3	0.17	3.9	0.28			
EVEREST	120	70.0	5.8	72.1	8.9	2.3	0.19	4.0	0.30			

Appendix C - The mean values for shoot length (cm), root length (cm), seedling fresh

weight (g), seedling dry weight (g), salinity tolerance and seedling vigor index of 292 winter

wheat genotypes treated with three level of salinity (0, 60.120 mM/L^{-1}).

Genotype name	salinity level	Shoot length	Std Dev	Root length	Std Dev	Seedling fresh weight	Std Dev	Seedling dry weight	Std Dev	Salinity Tolerance	Std Dev	Seedling vigor index	Std Dev
TRIUMPH64	0	8	0.4	6	0.3	0.15	0.01	0.06	0.01	100	0	14	0.5
CHISHOLM	0	8	0.5	6	0.5	0.15	0.02	0.06	0.01	100	0	14	0.9
CUSTER	0	8	0.2	6	0.3	0.15	0.01	0.06	0.01	100	0	14	0.6
2174-05	0	8	0.6	7	0.6	0.16	0.01	0.07	0.01	100	0	15	0.2
INTRADA	0	8	0.8	6	0.6	0.15	0.01	0.06	0.00	100	0	14	0.5
OK101	0	8	0.3	6	0.3	0.16	0.01	0.05	0.00	100	0	14	0.4
OK102	0	8	0.3	6	0.4	0.15	0.01	0.05	0.01	100	0	14	0.4
ENDURANCE	0	8	0.4	6	0.4	0.16	0.01	0.06	0.01	100	0	13	0.5
DELIVER	0	8	0.7	6	0.3	0.15	0.01	0.05	0.00	100	0	14	0.8
OK_BULLET	0	8	0.4	6	0.4	0.16	0.01	0.06	0.01	100	0	14	0.3
CENTERFIELD	0	8	0.5	6	0.3	0.15	0.01	0.06	0.00	100	0	14	0.6

GUYMON	0	8	0.4	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.1
DUSTER	0	7	0.6	6	0.4	0.15	0.01	0.05	0.01	100	0	12	0.7
OK_RISING	0	8	0.5	6	0.3	0.15	0.01	0.06	0.01	100	0	14	0.2
OK02405	0	8	0.4	6	0.3	0.16	0.01	0.06	0.01	100	0	14	0.4
PETE	0	8	0.5	6	0.3	0.16	0.01	0.06	0.01	100	0	14	0.6
BILLINGS	0	7	0.3	6	0.3	0.16	0.01	0.05	0.01	100	0	13	1.1
OK04505	0	7	0.6	6	0.5	0.16	0.01	0.06	0.01	100	0	14	0.7
OK04525	0	7	0.2	6	0.3	0.16	0.01	0.06	0.01	100	0	13	0.2
OK04507	0	8	0.6	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.5
OK05830	0	7	0.3	6	0.3	0.15	0.01	0.06	0.01	100	0	13	0.6
OK04111	0	7	0.4	6	0.4	0.16	0.01	0.06	0.01	100	0	13	0.2
OK04415	0	8	0.4	6	0.4	0.15	0.01	0.06	0.01	100	0	14	0.3
OK05711W	0	8	0.6	6	0.6	0.16	0.01	0.06	0.01	100	0	14	1.1
OK05723W	0	8	0.8	6	0.4	0.16	0.01	0.06	0.01	100	0	14	0.3
OK05108	0	8	0.6	7	0.5	0.16	0.01	0.07	0.01	100	0	15	0.3
OK05122	0	8	0.6	6	0.5	0.16	0.01	0.06	0.01	100	0	14	0.5
OK05526	0	8	0.7	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.3
OK05134	0	7	0.5	6	0.3	0.16	0.01	0.06	0.01	100	0	13	0.4
OK05303	0	7	0.4	6	0.3	0.15	0.01	0.05	0.01	100	0	13	0.3
OK05312	0	7	0.4	6	0.3	0.16	0.01	0.06	0.01	100	0	13	0.2
OK05511	0	7	0.4	6	0.4	0.15	0.01	0.06	0.01	100	0	13	0.5
OK05204	0	7	0.5	6	0.4	0.16	0.01	0.06	0.01	100	0	13	0.5
GARRISON	0	8	0.5	7	0.6	0.16	0.01	0.06	0.01	100	0	14	1.0
OK06114	0	8	0.5	6	0.3	0.16	0.01	0.06	0.01	100	0	13	1.4
OK06210	0	8	0.7	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.7
OK06319	0	8	0.8	6	0.5	0.16	0.01	0.06	0.01	100	0	14	1.2
OK06318	0	8	0.5	7	0.4	0.16	0.01	0.06	0.01	100	0	15	0.3
OK06336	0	8	0.8	6	0.5	0.16	0.01	0.06	0.01	100	0	14	0.9
AGATE	0	8	0.5	7	0.4	0.15	0.01	0.06	0.01	100	0	14	0.4
ALLIANCE	0	8	0.5	6	0.4	0.16	0.01	0.06	0.01	100	0	14	0.5
ANTELOPE	0	7	0.4	6	0.3	0.16	0.01	0.06	0.01	100	0	13	0.3
ARAPAHOE	0	7	0.4	6	0.2	0.16	0.01	0.06	0.01	100	0	13	0.4
BENNETT	0	8	0.4	7	0.5	0.16	0.01	0.06	0.01	100	0	14	0.7
BUCKSKIN	0	8	0.5	6	0.4	0.16	0.01	0.06	0.01	100	0	14	0.5
CENTURK78	0	8	0.5	6	0.3	0.16	0.01	0.06	0.01	100	0	14	0.3
CHEYENNE	0	7	0.5	6	0.5	0.15	0.01	0.06	0.01	100	0	13	0.8
COLT	0	8	0.7	7	0.4	0.15	0.01	0.06	0.01	100	0	14	0.3
COUGAR	0	8	0.7	7	0.4	0.16	0.01	0.06	0.01	100	0	14	0.5
CULVER	0	8	0.5	7	0.4	0.16	0.01	0.06	0.01	100	0	15	0.3
GAGE	0	8	0.5	7	0.5	0.16	0.01	0.05	0.01	100	0	15	0.4
GOODSTREAK	0	8	0.6	7	0.4	0.16	0.01	0.06	0.01	100	0	14	0.4

HALLAM	0	7	0.5	7	0.4	0.16	0.01	0.06	0.01	100	0	14	1.0
HARRY	0	7	0.6	6	0.4	0.15	0.01	0.06	0.00	100	0	13	0.3
HOMESTEAD	0	8	0.6	6	0.5	0.16	0.01	0.06	0.01	100	0	14	0.5
INFINITY_CL	0	8	0.5	6	0.3	0.15	0.01	0.06	0.01	100	0	14	0.2
KHARKOF	0	8	0.7	6	0.5	0.16	0.01	0.06	0.01	100	0	14	0.3
MILLENNIUM	0	7	0.9	7	0.7	0.16	0.01	0.06	0.01	100	0	14	1.2
CAMELOT	0	7	0.5	6	0.3	0.16	0.01	0.06	0.00	100	0	13	0.6
OVERLAND	0	7	0.6	7	0.7	0.15	0.01	0.06	0.01	100	0	14	0.3
NE99495	0	8	0.3	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.4
NIOBRARA	0	8	0.5	6	0.3	0.16	0.01	0.06	0.01	100	0	14	0.4
NUPLAINS	0	8	0.3	6	0.2	0.16	0.00	0.06	0.01	100	0	14	0.5
PRONGHORN	0	7	0.5	6	0.3	0.16	0.01	0.06	0.01	100	0	13	0.5
RAWHIDE	0	7	0.4	6	0.6	0.15	0.01	0.06	0.01	100	0	14	0.3
REDLAND	0	7	0.4	6	0.3	0.16	0.01	0.06	0.01	100	0	13	0.6
SCOUT66	0	8	0.7	7	0.6	0.16	0.01	0.06	0.01	100	0	14	0.8
SIOUXLAND	0	7	0.4	6	0.4	0.16	0.01	0.06	0.01	100	0	13	0.6
TURKEY_NEBSEL	0	7	0.4	6	0.2	0.16	0.00	0.06	0.01	100	0	13	0.7
VISTA	0	8	0.5	6	0.2	0.16	0.01	0.06	0.01	100	0	13	0.5
WAHOO	0	8	0.8	7	0.6	0.16	0.01	0.06	0.01	100	0	15	0.5
WARRIOR	0	7	0.6	6	0.5	0.16	0.01	0.06	0.00	100	0	14	0.5
WESLEY	0	8	0.4	6	0.4	0.16	0.01	0.06	0.01	100	0	14	0.0
WICHITA	0	8	0.5	7	0.2	0.16	0.01	0.06	0.01	100	0	14	0.1
WINDSTAR	0	7	0.5	6	0.4	0.16	0.01	0.06	0.01	100	0	13	0.7
LANCER	0	8	0.5	7	0.3	0.16	0.01	0.06	0.01	100	0	15	0.2
ANTON	0	7	0.3	7	0.4	0.16	0.01	0.06	0.01	100	0	14	0.8
MACE	0	7	0.3	6	0.4	0.16	0.01	0.06	0.01	100	0	13	0.3
TAM107-R7	0	7	0.4	6	0.5	0.16	0.01	0.06	0.01	100	0	13	0.5
ARLIN	0	8	0.5	6	0.5	0.16	0.01	0.06	0.01	100	0	13	0.9
ALICE	0	8	0.4	7	0.5	0.15	0.01	0.06	0.01	100	0	15	0.5
DARRELL	0	8	0.5	6	0.3	0.16	0.01	0.06	0.01	100	0	14	0.4
EXPEDITION	0	8	0.5	6	0.4	0.16	0.01	0.06	0.01	100	0	13	0.2
WENDY	0	8	0.5	7	0.3	0.16	0.01	0.06	0.01	100	0	15	0.4
SD00111-9	0	8	0.5	7	0.4	0.16	0.01	0.06	0.01	100	0	14	0.7
SD01237	0	7	0.4	7	0.4	0.15	0.01	0.06	0.01	100	0	14	0.3
SD01058	0	7	0.5	6	0.4	0.16	0.01	0.06	0.01	100	0	13	0.6
SD05118	0	8	0.5	7	0.4	0.16	0.01	0.06	0.01	100	0	15	0.5
SD05210	0	8	0.7	6	0.4	0.16	0.01	0.06	0.01	100	0	13	0.5
SD05W018	0	7	0.4	6	0.5	0.16	0.01	0.06	0.01	100	0	13	0.2
NEKOTA	0	8	0.6	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.8
TANDEM	0	8	0.3	7	0.5	0.16	0.01	0.06	0.01	100	0	14	1.0
CRIMSON	0	7	0.3	6	0.5	0.16	0.01	0.06	0.01	100	0	14	0.2

ROSE	0	7	0.4	6	0.5	0.16	0.01	0.06	0.01	100	0	13	0.5
DAWN	0	8	0.4	7	0.5	0.16	0.01	0.06	0.01	100	0	14	0.8
WINOKA	0	7	0.5	6	0.2	0.15	0.01	0.06	0.01	100	0	12	0.2
NELL	0	8	0.6	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.4
RITA	0	7	0.4	6	0.3	0.15	0.01	0.06	0.01	100	0	13	0.2
BRONZE	0	7	0.3	6	0.4	0.16	0.01	0.06	0.01	100	0	13	0.4
HUME	0	8	0.6	7	0.5	0.16	0.01	0.06	0.01	100	0	14	0.6
GENT	0	7	0.5	6	0.3	0.15	0.01	0.06	0.01	100	0	13	0.6
HARDING	0	7	0.4	6	0.3	0.15	0.01	0.06	0.01	100	0	13	0.2
HV9W03-1551WP	0	8	0.5	7	0.5	0.16	0.01	0.06	0.01	100	0	14	0.6
G1878	0	8	0.6	7	0.4	0.17	0.01	0.06	0.01	100	0	15	0.3
HV9W03-1379R	0	8	0.5	7	0.5	0.16	0.01	0.06	0.01	100	0	14	0.1
HV9W03-1596R	0	7	0.4	6	0.3	0.16	0.01	0.06	0.01	100	0	13	0.5
HV9W05-1280R	0	7	0.4	6	0.2	0.15	0.01	0.05	0.01	100	0	12	0.5
HV9W06-504	0	7	0.2	6	0.4	0.16	0.01	0.06	0.01	100	0	13	0.5
SPARTAN	0	7	0.6	7	0.4	0.16	0.01	0.06	0.01	100	0	14	0.3
HV906-865	0	8	0.9	7	0.8	0.16	0.01	0.07	0.01	100	0	15	0.5
TARKIO	0	7	0.3	6	0.4	0.16	0.01	0.06	0.01	100	0	13	0.5
SMOKYHILL	0	7	0.5	6	0.6	0.16	0.01	0.06	0.01	100	0	13	0.6
SHOCKER	0	7	0.5	7	0.7	0.16	0.01	0.06	0.01	100	0	13	0.6
VONA	0	7	0.4	6	0.4	0.16	0.01	0.06	0.01	100	0	13	0.3
CO940610	0	7	0.5	6	0.5	0.16	0.01	0.06	0.01	100	0	14	0.3
AVALANCHE	0	8	0.5	7	0.4	0.16	0.01	0.06	0.01	100	0	15	0.4
BOND_CL	0	7	0.5	6	0.5	0.16	0.01	0.06	0.01	100	0	13	0.4
PLATTE	0	7	0.4	6	0.3	0.16	0.01	0.05	0.01	100	0	13	0.4
LINDON	0	7	0.5	7	0.5	0.16	0.01	0.06	0.01	100	0	14	0.7
CO03W043	0	7	0.6	6	0.5	0.16	0.01	0.06	0.01	100	0	14	0.5
SNOWMASS	0	7	0.6	6	0.5	0.16	0.01	0.06	0.01	100	0	13	1.1
THUNDER_CL	0	8	0.5	7	0.6	0.16	0.01	0.06	0.01	100	0	14	0.7
CO04025	0	7	0.3	7	0.5	0.16	0.01	0.06	0.01	100	0	13	0.2
CO04393	0	8	0.5	7	0.5	0.16	0.01	0.06	0.01	100	0	14	1.1
CO04499	0	7	0.5	6	0.5	0.16	0.01	0.06	0.01	100	0	14	0.3
CO04W320	0	9	0.9	7	0.5	0.16	0.01	0.07	0.01	100	0	16	0.5
LAMAR	0	8	0.6	7	0.5	0.15	0.01	0.06	0.01	100	0	14	0.5
CARSON	0	9	0.9	8	0.7	0.17	0.01	0.07	0.01	100	0	16	0.5
HAIL	0	8	0.7	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.4
SANDY	0	7	0.3	6	0.5	0.16	0.01	0.06	0.01	100	0	14	0.4
DUKE	0	7	0.5	7	0.5	0.16	0.01	0.06	0.01	100	0	13	0.9
HALT	0	8	0.7	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.6
HATCHER	0	7	0.3	6	0.2	0.15	0.01	0.06	0.01	100	0	13	0.1
PRAIRIE_RED	0	8	0.5	7	0.5	0.16	0.01	0.06	0.01	100	0	14	1.0

ABOVE	0	7	0.4	6	0.5	0.16	0.01	0.06	0.00	100	0	13	0.3
CO03064	0	7	0.3	6	0.5	0.15	0.01	0.06	0.01	100	0	13	0.6
BILL_BROWN	0	8	0.6	7	0.4	0.16	0.01	0.06	0.01	100	0	14	0.4
RIPPER	0	7	0.5	7	0.6	0.16	0.01	0.06	0.01	100	0	14	1.1
PROWERS	0	8	0.8	7	0.6	0.16	0.01	0.06	0.01	100	0	14	0.8
AKRON	0	8	0.5	7	0.6	0.16	0.01	0.06	0.01	100	0	14	0.3
JULES	0	8	0.5	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.6
YUMA	0	8	0.6	7	0.4	0.16	0.01	0.06	0.01	100	0	15	0.7
TAMW-101	0	8	0.6	7	0.4	0.16	0.01	0.06	0.01	100	0	15	1.2
TAM105	0	8	0.6	7	0.4	0.16	0.01	0.06	0.01	100	0	15	0.6
TAM107	0	7	0.3	6	0.5	0.16	0.01	0.05	0.01	100	0	13	0.3
TAM109	0	7	0.4	6	0.2	0.15	0.01	0.05	0.01	100	0	13	0.1
TAM110	0	8	0.5	7	0.6	0.16	0.01	0.05	0.00	100	0	14	0.9
TAM111	0	8	0.6	7	0.6	0.16	0.01	0.05	0.00	100	0	14	1.0
TAM112	0	8	0.4	7	0.4	0.16	0.01	0.06	0.01	100	0	15	0.6
TAM200	0	7	0.5	6	0.5	0.16	0.00	0.05	0.01	100	0	13	0.4
TAM202	0	7	0.5	7	0.4	0.16	0.01	0.06	0.01	100	0	14	1.0
TAM203	0	7	0.4	7	0.6	0.16	0.00	0.05	0.00	100	0	13	0.9
TAM302	0	8	0.7	7	0.3	0.16	0.01	0.06	0.01	100	0	15	0.5
TAM303	0	8	0.4	7	0.8	0.15	0.01	0.05	0.01	100	0	14	0.8
TAM304	0	7	0.3	6	0.6	0.16	0.01	0.05	0.00	100	0	14	0.7
TAM400	0	8	0.6	7	0.4	0.16	0.01	0.05	0.00	100	0	14	0.6
LOCKETT	0	8	0.5	7	0.7	0.16	0.01	0.06	0.01	100	0	14	0.6
STURDY	0	7	0.5	7	0.4	0.16	0.01	0.05	0.00	100	0	13	0.6
STURDY_2K	0	7	0.3	6	0.3	0.15	0.01	0.06	0.01	100	0	13	0.4
MIT	0	7	0.3	6	0.4	0.16	0.01	0.05	0.00	100	0	13	0.3
CAPROCK	0	8	0.5	7	0.7	0.16	0.01	0.05	0.00	100	0	14	0.8
TX01A5936	0	7	0.5	6	0.4	0.16	0.01	0.06	0.01	100	0	13	0.5
TAM401	0	8	0.7	7	0.6	0.16	0.01	0.05	0.00	100	0	15	0.7
TX02A0252	0	6	0.5	6	0.2	0.16	0.01	0.05	0.00	100	0	12	0.7
TX03A0148	0	7	0.5	6	0.3	0.15	0.01	0.05	0.01	100	0	13	0.3
TX03A0563	0	7	0.5	6	0.2	0.15	0.01	0.06	0.01	100	0	13	0.6
TX04A001246	0	8	0.6	7	0.6	0.17	0.01	0.06	0.01	100	0	13	0.6
TX01V5134RC-3	0	8	0.5	7	0.3	0.16	0.01	0.05	0.00	100	0	15	0.2
TX04M410164	0	6	0.6	6	0.3	0.15	0.01	0.06	0.01	100	0	12	0.2
TX04M410211	0	9	0.8	8	0.5	0.17	0.01	0.07	0.01	100	0	16	0.4
TX04V075080	0	8	0.3	7	0.3	0.16	0.01	0.05	0.01	100	0	15	0.6
TX99A0153-1	0	7	0.5	6	0.2	0.15	0.01	0.06	0.00	100	0	13	0.4
TX01M5009-28	0	8	0.5	7	0.5	0.16	0.01	0.05	0.00	100	0	15	0.5
TX00V1131	0	7	0.5	7	0.5	0.15	0.01	0.06	0.01	100	0	13	0.9
TX99U8618	0	7	0.4	7	0.6	0.16	0.01	0.06	0.01	100	0	14	0.6

TX96D1073	0	7	0.6	7	0.6	0.16	0.01	0.05	0.00	100	0	14	0.8
2180	0	7	0.5	6	0.3	0.16	0.01	0.05	0.01	100	0	13	1.2
HG-9	0	7	0.5	6	0.3	0.15	0.01	0.05	0.01	100	0	12	0.7
TX86A5606	0	9	0.7	8	0.5	0.17	0.01	0.07	0.01	100	0	16	0.4
TX86A8072	0	8	0.7	7	0.6	0.16	0.01	0.06	0.01	100	0	15	0.4
CREST	0	7	0.3	6	0.4	0.16	0.01	0.05	0.00	100	0	13	0.5
ROSEBUD	0	8	0.7	7	0.6	0.16	0.01	0.05	0.01	100	0	15	0.2
JUDITH	0	7	0.5	6	0.4	0.15	0.01	0.05	0.01	100	0	13	0.7
MT85200	0	8	0.4	7	0.4	0.16	0.01	0.06	0.01	100	0	15	0.2
NUSKY	0	8	0.6	7	0.5	0.16	0.01	0.06	0.01	100	0	15	1.2
MT9513	0	8	0.5	7	0.5	0.16	0.01	0.06	0.01	100	0	14	0.4
MT9904	0	8	0.3	7	0.5	0.16	0.01	0.06	0.01	100	0	14	0.9
NORRIS	0	8	0.4	7	0.6	0.16	0.01	0.06	0.01	100	0	15	0.5
YELLOWSTONE	0	8	0.4	7	0.6	0.16	0.01	0.06	0.01	100	0	15	0.4
MT0495	0	7	0.7	7	0.7	0.16	0.01	0.05	0.01	100	0	14	1.0
MTS0531	0	8	0.4	7	0.4	0.16	0.01	0.05	0.01	100	0	15	0.3
DECADE	0	8	0.5	6	0.3	0.15	0.01	0.06	0.01	100	0	14	0.7
MT06103	0	8	0.7	7	0.5	0.16	0.01	0.06	0.01	100	0	14	1.0
JUDEE	0	8	0.5	6	0.3	0.15	0.01	0.06	0.01	100	0	14	0.4
LAKIN	0	7	0.7	6	0.5	0.15	0.01	0.06	0.01	100	0	14	0.8
STANTON	0	7	0.6	7	0.4	0.15	0.01	0.06	0.01	100	0	14	0.6
TREGO	0	8	0.5	7	0.6	0.16	0.01	0.05	0.01	100	0	15	0.4
KARL_92	0	7	0.5	6	0.4	0.15	0.01	0.05	0.01	100	0	13	0.5
DODGE	0	8	0.6	7	0.5	0.15	0.01	0.06	0.01	100	0	14	1.1
NORKAN	0	7	0.6	6	0.5	0.15	0.01	0.06	0.01	100	0	14	0.4
CHENEY	0	7	0.6	6	0.4	0.15	0.01	0.05	0.01	100	0	13	0.6
NEWTON	0	8	0.8	7	0.6	0.15	0.01	0.06	0.01	100	0	15	0.6
LARNED	0	8	0.5	6	0.5	0.16	0.00	0.06	0.01	100	0	14	0.7
PARKER76	0	7	0.7	6	0.3	0.15	0.01	0.05	0.01	100	0	13	0.9
KIRWIN	0	8	1.0	7	0.6	0.15	0.01	0.05	0.01	100	0	14	1.2
SAGE	0	8	0.6	6	0.5	0.15	0.01	0.06	0.01	100	0	14	1.1
TRISON	0	7	0.8	7	0.4	0.15	0.01	0.05	0.01	100	0	14	0.7
EAGLE	0	7	0.4	6	0.2	0.15	0.01	0.05	0.01	100	0	13	0.4
SHAWNEE	0	8	0.4	7	0.4	0.14	0.02	0.05	0.01	100	0	14	0.5
PARKER	0	8	0.5	7	0.5	0.15	0.01	0.06	0.01	100	0	14	0.4
KAW61	0	8	0.4	7	0.5	0.15	0.01	0.06	0.00	100	0	14	1.1
TASCOSA	0	8	0.4	7	0.3	0.16	0.01	0.06	0.01	100	0	15	0.5
BISON	0	8	0.4	7	0.5	0.15	0.01	0.06	0.01	100	0	14	0.5
KIOWA	0	8	0.5	6	0.4	0.15	0.01	0.06	0.01	100	0	14	0.6
WICHITA	0	7	0.5	6	0.2	0.15	0.01	0.06	0.00	100	0	13	0.6
COMANCHE	0	8	0.6	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.7

BAKERS_WHITE	0	8	0.6	7	0.4	0.15	0.00	0.06	0.01	100	0	13	1.4
BURCHETT	0	7	0.7	6	0.2	0.15	0.01	0.06	0.01	100	0	13	0.4
CUTTER	0	8	0.5	7	0.5	0.16	0.01	0.06	0.01	100	0	14	0.5
DUMAS	0	7	0.7	6	0.3	0.15	0.01	0.05	0.00	100	0	13	0.3
HONDO	0	7	0.6	6	0.2	0.15	0.01	0.06	0.01	100	0	13	0.6
JAGALENE	0	7	0.5	6	0.3	0.15	0.01	0.05	0.01	100	0	13	0.6
LONGHORN	0	7	0.4	6	0.2	0.15	0.01	0.05	0.00	100	0	13	0.3
NEOSHO	0	8	0.5	7	0.5	0.16	0.01	0.06	0.01	100	0	14	0.6
OGALLALA	0	7	0.6	6	0.3	0.15	0.01	0.05	0.00	100	0	13	0.7
POSTROCK	0	7	0.4	6	0.2	0.15	0.01	0.06	0.01	100	0	13	0.9
THUNDERBOLT	0	8	0.3	7	0.3	0.16	0.01	0.06	0.01	100	0	15	0.3
W04-417	0	7	0.5	6	0.4	0.15	0.01	0.05	0.01	100	0	13	0.6
NUFRONTIER	0	8	0.5	7	0.4	0.15	0.01	0.06	0.01	100	0	14	0.3
NUHORIZON	0	7	0.5	6	0.4	0.15	0.00	0.05	0.01	100	0	13	0.5
ONAGA	0	9	0.9	8	0.7	0.16	0.01	0.06	0.01	100	0	17	0.9
RONL	0	7	0.5	6	0.6	0.15	0.01	0.06	0.00	100	0	14	0.4
2145	0	8	0.5	6	0.4	0.15	0.01	0.06	0.01	100	0	14	0.5
HEYNE	0	7	0.5	6	0.5	0.15	0.01	0.06	0.00	100	0	13	0.4
KS00F5-20-3	0	7	0.4	6	0.5	0.15	0.01	0.06	0.01	100	0	13	0.7
OVERLEY	0	7	0.6	7	0.5	0.15	0.01	0.06	0.01	100	0	14	0.7
FULLER	0	8	0.1	7	0.4	0.16	0.01	0.06	0.01	100	0	15	0.4
COSSACK	0	8	0.3	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.8
ENHANCER	0	8	0.0	7	0.3	0.16	0.01	0.06	0.01	100	0	15	0.3
SANTA_FE	0	8	0.0	7	0.3	0.15	0.01	0.05	0.01	100	0	15	0.3
VENANGO	0	8	0.4	7	0.4	0.15	0.01	0.05	0.01	100	0	14	0.5
WB411W	0	8	0.4	7	0.4	0.16	0.01	0.06	0.01	100	0	15	0.2
KEOTA	0	8	0.5	7	0.5	0.16	0.01	0.06	0.01	100	0	14	0.5
TX05A001822	0	7	0.5	7	0.5	0.15	0.01	0.06	0.00	100	0	13	0.7
TX06A001263	0	7	0.5	6	0.4	0.15	0.01	0.06	0.01	100	0	13	0.7
TX06A001132	0	7	0.6	7	0.5	0.15	0.01	0.06	0.01	100	0	14	0.9
TX06A001281	0	8	0.4	6	0.4	0.15	0.01	0.05	0.01	100	0	14	0.9
TX06A001386	0	7	0.4	6	0.4	0.15	0.01	0.06	0.00	100	0	13	0.5
TX05V7259	0	8	0.4	7	0.4	0.15	0.01	0.06	0.01	100	0	14	0.5
TX05V7269	0	8	0.4	7	0.5	0.15	0.01	0.06	0.01	100	0	14	0.6
TX05A001188	0	8	0.3	6	0.5	0.16	0.01	0.06	0.01	100	0	14	0.4
TX07A001279	0	7	0.4	7	0.5	0.16	0.01	0.06	0.01	100	0	14	0.5
TX07A001318	0	8	0.5	7	0.6	0.16	0.01	0.06	0.01	100	0	14	0.4
TX07A001420	0	8	0.5	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.2
TX06V7266	0	8	0.4	7	0.6	0.16	0.01	0.06	0.01	100	0	14	0.8
OK1067071	0	8	0.4	7	0.5	0.16	0.01	0.06	0.01	100	0	14	0.9
OK1067274	0	8	0.4	7	0.4	0.16	0.01	0.06	0.01	100	0	15	0.2

OK1068002	0	8	0.6	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.4
OK1068009	0	8	0.8	7	0.5	0.16	0.01	0.05	0.00	100	0	15	0.3
OK1068026	0	8	0.7	7	0.4	0.16	0.01	0.06	0.01	100	0	15	0.8
OK1068112	0	8	0.5	7	0.5	0.15	0.01	0.06	0.01	100	0	14	0.6
OK1070275	0	8	0.5	7	0.4	0.16	0.01	0.06	0.01	100	0	14	0.3
OK1070267	0	8	0.5	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.4
OK09634	0	8	0.4	7	0.5	0.15	0.01	0.06	0.01	100	0	14	0.3
OK10119	0	8	0.4	7	0.5	0.15	0.01	0.06	0.00	100	0	14	0.3
GALLAGHER	0	8	0.6	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.3
OK07231	0	8	0.5	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.6
OK07S117	0	8	0.5	7	0.6	0.15	0.01	0.06	0.01	100	0	15	0.3
OK08328	0	8	0.6	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.7
BIG_SKY	0	8	0.5	6	0.4	0.16	0.01	0.06	0.01	100	0	14	0.2
DANBY	0	8	0.3	7	0.3	0.16	0.01	0.06	0.01	100	0	15	0.6
E2041	0	8	0.5	7	0.5	0.15	0.01	0.06	0.01	100	0	15	0.8
DENALI	0	8	0.4	7	0.4	0.16	0.01	0.06	0.01	100	0	14	1.2
CO050337-2	0	8	0.7	7	0.3	0.15	0.01	0.06	0.00	100	0	14	1.3
BYRD	0	8	0.3	7	0.4	0.16	0.01	0.06	0.01	100	0	15	0.3
CO07W245	0	8	0.5	7	0.5	0.15	0.01	0.06	0.00	100	0	15	0.2
MCGILL	0	8	0.1	7	0.3	0.15	0.01	0.05	0.01	100	0	15	0.9
NE02558	0	8	0.6	7	0.4	0.16	0.01	0.06	0.01	100	0	15	0.6
NW03666	0	8	0.3	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.3
NE04490	0	8	0.4	7	0.5	0.16	0.01	0.06	0.01	100	0	14	0.6
NE05430	0	8	0.5	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.3
NE05496	0	8	0.3	7	0.3	0.16	0.01	0.06	0.01	100	0	15	0.4
NE05548	0	8	0.6	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.7
NE06545	0	8	0.4	7	0.3	0.16	0.01	0.06	0.01	100	0	15	0.4
NE06607	0	8	0.5	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.5
ROBIDOUX	0	8	0.5	7	0.4	0.16	0.01	0.06	0.01	100	0	15	0.4
NI06736	0	8	0.5	7	0.5	0.16	0.01	0.06	0.01	100	0	15	0.4
NI06737	0	8	0.4	7	0.3	0.16	0.01	0.06	0.01	100	0	14	0.8
NI07703	0	8	0.6	7	0.5	0.16	0.01	0.06	0.01	100	0	14	0.7
NI08707	0	8	0.6	7	0.4	0.16	0.01	0.06	0.01	100	0	14	1.1
NI08708	0	8	0.7	7	0.5	0.16	0.01	0.06	0.01	100	0	14	0.7
EVEREST	0	8	0.6	7	0.4	0.16	0.01	0.06	0.01	100	0	15	0.5
TRIUMPH64	60	6	0.6	4	0.3	0.12	0.02	0.04	0.00	66	11	9	1.0
CHISHOLM	60	6	0.3	4	0.6	0.14	0.01	0.05	0.01	77	9	10	0.7
CUSTER	60	6	0.5	4	0.3	0.13	0.01	0.04	0.00	75	15	9	0.4
2174-05	60	5	0.6	4	0.6	0.14	0.01	0.04	0.01	58	9	9	0.8
INTRADA	60	5	0.4	4	0.4	0.13	0.01	0.03	0.00	50	8	8	0.4
OK101	60	5	0.3	4	0.4	0.14	0.01	0.03	0.01	65	15	8	0.5

OK102	60	6	0.5	4	0.7	0.13	0.01	0.03	0.01	60	12	9	0.7
ENDURANCE	60	6	0.2	5	0.3	0.15	0.01	0.04	0.00	76	10	11	0.4
DELIVER	60	5	0.4	4	0.8	0.14	0.01	0.03	0.01	58	17	9	1.0
OK_BULLET	60	5	0.5	4	0.6	0.14	0.01	0.03	0.01	57	14	8	0.2
CENTERFIELD	60	5	0.4	4	0.6	0.12	0.01	0.03	0.01	59	11	8	0.6
GUYMON	60	7	1.0	6	0.8	0.14	0.01	0.05	0.01	80	15	12	1.1
DUSTER	60	5	0.4	4	0.5	0.14	0.01	0.03	0.01	52	13	8	0.5
OK_RISING	60	5	0.4	4	0.5	0.13	0.01	0.05	0.01	81	14	8	0.5
OK02405	60	5	0.3	4	0.6	0.14	0.01	0.03	0.01	60	18	9	0.9
PETE	60	5	0.3	4	0.6	0.14	0.00	0.04	0.01	75	13	9	0.4
BILLINGS	60	5	0.4	4	0.5	0.13	0.01	0.04	0.01	65	14	8	0.7
OK04505	60	5	0.5	4	0.3	0.14	0.01	0.04	0.01	78	13	9	0.5
OK04525	60	6	0.3	4	0.4	0.13	0.01	0.03	0.00	51	9	9	0.4
OK04507	60	6	0.4	4	0.3	0.14	0.01	0.04	0.01	71	14	9	0.3
OK05830	60	6	0.4	4	0.8	0.13	0.01	0.03	0.00	51	9	9	0.6
OK04111	60	5	0.5	4	0.8	0.14	0.01	0.04	0.01	64	14	9	0.5
OK04415	60	5	0.3	4	0.7	0.13	0.01	0.03	0.01	59	15	8	0.4
OK05711W	60	5	0.4	4	0.4	0.15	0.01	0.04	0.01	71	14	9	0.6
OK05723W	60	5	0.3	5	0.5	0.15	0.01	0.04	0.01	76	11	9	0.4
OK05108	60	6	0.7	5	0.9	0.15	0.01	0.05	0.01	71	16	10	0.3
OK05122	60	5	0.4	4	0.4	0.12	0.02	0.04	0.01	77	13	8	0.5
OK05526	60	5	0.5	4	0.7	0.13	0.01	0.04	0.01	62	12	9	0.2
OK05134	60	5	0.5	4	0.5	0.13	0.01	0.04	0.01	65	14	9	0.7
OK05303	60	5	0.3	4	0.6	0.14	0.01	0.03	0.01	65	10	8	0.5
OK05312	60	5	0.3	4	0.6	0.14	0.01	0.03	0.00	57	11	9	0.7
OK05511	60	5	0.4	4	0.7	0.13	0.01	0.03	0.00	59	11	9	0.4
OK05204	60	5	0.3	4	0.6	0.13	0.01	0.04	0.01	65	11	9	0.2
GARRISON	60	5	0.3	4	0.4	0.14	0.01	0.05	0.01	77	8	9	0.2
OK06114	60	6	0.3	4	0.6	0.14	0.01	0.03	0.00	54	7	9	0.3
OK06210	60	5	0.4	5	0.4	0.15	0.01	0.04	0.01	74	9	9	0.5
OK06319	60	5	0.5	4	0.5	0.13	0.01	0.04	0.01	72	11	9	0.7
OK06318	60	6	0.5	4	0.2	0.13	0.01	0.04	0.01	74	9	8	1.6
OK06336	60	5	0.3	4	0.5	0.12	0.01	0.03	0.00	58	8	9	0.1
AGATE	60	5	0.3	4	0.3	0.13	0.02	0.03	0.00	53	9	8	0.3
ALLIANCE	60	6	0.3	4	0.2	0.12	0.01	0.03	0.00	56	9	9	0.8
ANTELOPE	60	5	0.3	4	0.5	0.13	0.01	0.03	0.00	53	10	9	0.3
ARAPAHOE	60	6	0.3	4	0.5	0.13	0.01	0.03	0.00	57	8	9	0.5
BENNETT	60	6	0.2	5	0.5	0.14	0.01	0.04	0.01	77	13	10	0.4
BUCKSKIN	60	5	0.4	4	0.6	0.14	0.01	0.04	0.01	70	17	9	0.6
CENTURK78	60	5	0.3	4	0.3	0.14	0.01	0.05	0.00	78	12	9	0.3
CHEYENNE	60	5	0.4	4	0.5	0.14	0.01	0.04	0.01	73	10	9	0.6

COLT	60	5	0.4	4	0.7	0.13	0.02	0.03	0.00	58	11	9	0.2
COUGAR	60	5	0.4	4	0.7	0.13	0.02	0.03	0.00	58	8	9	0.9
CULVER	60	5	0.4	4	0.7	0.13	0.01	0.03	0.01	61	12	9	0.7
GAGE	60	7	0.7	5	0.7	0.14	0.01	0.04	0.01	81	16	11	0.6
GOODSTREAK	60	5	0.4	4	0.4	0.15	0.01	0.04	0.01	75	10	8	0.6
HALLAM	60	4	0.4	3	0.2	0.13	0.01	0.04	0.01	66	12	7	0.2
HARRY	60	5	0.4	4	0.6	0.14	0.01	0.03	0.00	54	5	9	0.8
HOMESTEAD	60	6	0.5	4	0.3	0.14	0.01	0.04	0.01	73	9	9	0.7
INFINITY_CL	60	5	0.3	4	0.6	0.13	0.01	0.04	0.01	64	10	9	0.5
KHARKOF	60	5	0.4	4	0.4	0.14	0.01	0.05	0.00	76	8	9	0.3
MILLENNIUM	60	5	0.3	4	0.7	0.14	0.01	0.04	0.01	61	10	8	0.5
CAMELOT	60	5	0.5	4	0.5	0.13	0.01	0.04	0.01	60	9	9	0.6
OVERLAND	60	5	0.4	4	0.4	0.14	0.01	0.03	0.01	58	11	9	0.4
NE99495	60	4	0.2	4	0.2	0.14	0.01	0.05	0.01	74	9	8	0.2
NIOBRARA	60	5	0.3	4	0.2	0.14	0.01	0.04	0.01	71	10	8	0.5
NUPLAINS	60	5	0.4	4	0.3	0.13	0.02	0.04	0.01	60	13	8	0.7
PRONGHORN	60	5	0.4	4	0.6	0.14	0.01	0.03	0.00	60	13	8	0.5
RAWHIDE	60	5	0.4	4	0.5	0.13	0.01	0.04	0.01	63	14	9	0.3
REDLAND	60	5	0.3	4	0.7	0.13	0.01	0.03	0.00	60	14	9	0.2
SCOUT66	60	5	0.4	4	0.4	0.14	0.01	0.04	0.01	73	11	9	0.6
SIOUXLAND	60	6	0.4	4	0.6	0.14	0.01	0.04	0.01	61	13	8	0.6
TURKEY_NEBSEL	60	5	0.5	4	0.5	0.13	0.02	0.04	0.01	65	12	9	0.4
VISTA	60	5	0.5	4	0.5	0.13	0.02	0.03	0.00	55	8	9	0.3
WAHOO	60	5	0.3	4	0.6	0.12	0.02	0.03	0.01	58	11	9	0.7
WARRIOR	60	5	0.4	4	0.5	0.14	0.01	0.04	0.01	72	9	9	0.4
WESLEY	60	5	0.3	4	0.2	0.14	0.01	0.04	0.01	73	12	8	0.4
WICHITA	60	5	0.5	4	0.4	0.14	0.00	0.04	0.01	74	9	9	1.0
WINDSTAR	60	5	0.5	4	0.5	0.13	0.01	0.03	0.01	60	8	9	0.8
LANCER	60	5	0.5	4	0.3	0.14	0.01	0.05	0.01	75	7	8	0.6
ANTON	60	6	0.4	4	0.3	0.13	0.02	0.04	0.01	62	11	8	0.4
MACE	60	5	0.4	4	0.3	0.11	0.02	0.04	0.00	64	9	8	0.5
TAM107-R7	60	5	0.4	4	0.5	0.13	0.01	0.03	0.00	60	14	9	0.6
ARLIN	60	6	0.5	4	0.5	0.14	0.01	0.04	0.01	68	16	9	0.4
ALICE	60	5	0.4	4	0.3	0.13	0.02	0.03	0.00	59	11	9	0.3
DARRELL	60	5	0.3	4	0.3	0.13	0.01	0.03	0.00	57	10	9	0.4
EXPEDITION	60	5	0.3	4	0.3	0.13	0.01	0.03	0.01	60	10	8	0.3
WENDY	60	5	0.3	4	0.2	0.14	0.01	0.04	0.01	68	10	8	0.3
SD00111-9	60	5	0.4	4	0.3	0.13	0.02	0.03	0.00	57	8	8	0.5
SD01237	60	5	0.3	4	0.5	0.12	0.02	0.03	0.00	57	9	9	0.4
SD01058	60	5	0.4	4	0.5	0.13	0.02	0.03	0.00	58	9	9	0.2
SD05118	60	5	0.5	4	0.4	0.14	0.01	0.04	0.01	72	12	9	0.6

SD05210	60	5	0.3	4	0.6	0.13	0.02	0.03	0.00	55	10	8	1.0
SD05W018	60	5	0.3	4	0.6	0.13	0.01	0.03	0.00	56	9	9	0.4
NEKOTA	60	5	0.5	4	0.3	0.14	0.01	0.05	0.01	78	11	9	0.4
TANDEM	60	5	0.4	4	0.5	0.13	0.01	0.04	0.01	71	9	9	0.2
CRIMSON	60	5	0.4	4	0.5	0.13	0.01	0.03	0.00	57	11	9	0.3
ROSE	60	5	0.3	4	0.5	0.13	0.02	0.03	0.00	57	10	8	0.8
DAWN	60	5	0.4	4	0.3	0.14	0.01	0.05	0.01	76	12	9	0.3
WINOKA	60	5	0.4	4	0.3	0.14	0.01	0.03	0.00	57	17	8	0.4
NELL	60	5	0.5	4	0.5	0.14	0.01	0.04	0.00	73	12	9	0.3
RITA	60	5	0.5	4	0.5	0.13	0.02	0.03	0.00	61	12	9	0.6
BRONZE	60	5	0.3	4	0.5	0.11	0.02	0.03	0.00	56	8	9	0.2
HUME	60	5	0.4	4	0.7	0.13	0.02	0.03	0.00	52	12	9	0.0
GENT	60	5	0.4	4	0.4	0.13	0.02	0.03	0.01	62	16	8	0.6
HARDING	60	5	0.4	4	0.4	0.13	0.02	0.03	0.00	58	10	8	0.8
HV9W03-1551WP	60	5	0.5	4	0.2	0.14	0.01	0.04	0.01	76	13	9	0.6
G1878	60	5	0.4	4	0.5	0.13	0.01	0.05	0.01	75	12	9	0.5
HV9W03-1379R	60	5	0.5	4	0.4	0.13	0.02	0.03	0.00	52	7	9	0.9
HV9W03-1596R	60	5	0.6	4	0.5	0.13	0.01	0.03	0.00	55	11	8	0.6
HV9W05-1280R	60	5	0.4	4	0.5	0.13	0.02	0.04	0.01	71	15	9	0.4
HV9W06-504	60	5	0.4	4	0.7	0.13	0.01	0.03	0.00	61	11	9	0.4
SPARTAN	60	5	0.5	4	0.4	0.13	0.01	0.04	0.01	64	16	9	0.8
HV906-865	60	5	0.5	4	0.3	0.13	0.01	0.05	0.01	71	8	9	0.4
TARKIO	60	5	0.5	4	0.5	0.13	0.01	0.03	0.00	57	10	9	0.6
SMOKYHILL	60	6	0.5	4	0.5	0.12	0.02	0.04	0.01	68	13	8	0.6
SHOCKER	60	5	0.4	4	0.4	0.13	0.01	0.03	0.01	57	11	8	0.5
VONA	60	5	0.4	4	0.4	0.13	0.02	0.03	0.00	54	9	8	0.6
CO940610	60	5	0.4	4	0.5	0.12	0.02	0.03	0.00	55	11	8	0.6
AVALANCHE	60	6	0.9	5	0.7	0.13	0.01	0.04	0.01	69	15	10	0.8
BOND_CL	60	5	0.5	4	0.6	0.13	0.02	0.03	0.00	59	10	9	0.5
PLATTE	60	5	0.5	4	0.6	0.13	0.01	0.03	0.00	61	11	9	0.4
LINDON	60	5	0.4	4	0.4	0.13	0.01	0.04	0.01	62	11	8	0.7
CO03W043	60	5	0.5	4	0.5	0.13	0.01	0.03	0.01	60	12	9	0.4
SNOWMASS	60	5	0.5	4	0.5	0.13	0.02	0.03	0.01	59	10	8	0.4
THUNDER_CL	60	5	0.4	4	0.2	0.13	0.01	0.04	0.01	72	10	9	0.5
CO04025	60	5	0.4	4	0.5	0.13	0.01	0.03	0.00	57	11	9	0.7
CO04393	60	5	0.5	4	0.4	0.13	0.01	0.04	0.00	74	11	9	0.4
CO04499	60	5	0.4	4	0.4	0.14	0.01	0.03	0.00	54	9	9	0.6
CO04W320	60	6	0.9	5	1.0	0.14	0.01	0.04	0.01	56	17	9	0.7
LAMAR	60	5	0.4	4	0.5	0.14	0.01	0.04	0.01	69	10	9	0.8
CARSON	60	6	0.9	5	0.8	0.15	0.01	0.04	0.01	59	8	10	0.1
HAIL	60	5	0.2	4	0.7	0.14	0.01	0.03	0.00	52	5	8	0.7

SANDY	60	5	0.4	4	0.5	0.13	0.01	0.03	0.00	56	8	9	0.7
DUKE	60	5	0.4	4	0.5	0.13	0.01	0.03	0.00	57	8	9	0.4
HALT	60	5	0.5	4	0.4	0.14	0.01	0.05	0.01	73	10	9	0.2
HATCHER	60	5	0.4	4	0.6	0.13	0.01	0.03	0.00	57	8	8	0.5
PRAIRIE_RED	60	5	0.5	5	0.4	0.13	0.01	0.04	0.01	63	14	9	0.4
ABOVE	60	5	0.3	4	0.6	0.13	0.00	0.03	0.00	57	9	9	0.6
CO03064	60	5	0.3	4	0.6	0.13	0.01	0.04	0.01	68	13	9	0.6
BILL_BROWN	60	5	0.4	4	0.5	0.13	0.01	0.03	0.01	59	12	8	0.3
RIPPER	60	5	0.4	4	0.6	0.12	0.02	0.03	0.00	53	6	9	0.3
PROWERS	60	5	0.4	4	0.3	0.13	0.01	0.04	0.01	64	11	8	0.4
AKRON	60	5	0.5	4	0.5	0.13	0.01	0.04	0.01	67	14	9	0.6
JULES	60	5	0.4	4	0.3	0.14	0.01	0.04	0.01	66	11	9	0.9
YUMA	60	5	0.5	4	0.5	0.13	0.01	0.04	0.01	66	11	8	0.7
TAMW-101	60	5	0.4	4	0.3	0.13	0.01	0.04	0.01	67	10	8	0.4
TAM105	60	5	0.4	4	0.4	0.14	0.01	0.03	0.01	58	10	9	0.4
TAM107	60	5	0.4	4	0.5	0.13	0.01	0.04	0.01	65	10	8	0.2
TAM109	60	5	0.4	4	0.5	0.13	0.01	0.04	0.00	73	10	9	0.3
TAM110	60	5	0.4	4	0.2	0.14	0.01	0.04	0.00	70	10	9	0.5
TAM111	60	5	0.5	4	0.4	0.14	0.01	0.04	0.01	76	17	9	0.5
TAM112	60	5	0.5	4	0.2	0.12	0.01	0.04	0.00	77	10	8	0.4
TAM200	60	5	0.3	4	0.3	0.13	0.02	0.04	0.01	77	13	8	0.3
TAM202	60	5	0.5	4	0.3	0.13	0.01	0.03	0.01	62	12	7	0.8
TAM203	60	5	0.5	4	0.2	0.13	0.01	0.04	0.00	75	8	8	0.5
TAM302	60	5	0.4	4	0.4	0.13	0.01	0.04	0.01	71	9	8	0.3
TAM303	60	5	0.4	4	0.3	0.13	0.01	0.03	0.00	63	14	8	0.6
TAM304	60	5	0.4	4	0.2	0.13	0.01	0.04	0.01	67	11	8	0.4
TAM400	60	5	0.3	4	0.3	0.14	0.01	0.03	0.01	65	10	7	0.2
LOCKETT	60	5	0.5	4	0.4	0.14	0.01	0.03	0.01	63	11	9	0.6
STURDY	60	5	0.3	4	0.5	0.13	0.01	0.04	0.01	70	14	8	0.6
STURDY_2K	60	5	0.5	4	0.6	0.13	0.01	0.04	0.00	79	12	9	0.3
MIT	60	5	0.4	4	0.3	0.13	0.02	0.04	0.01	74	14	8	0.6
CAPROCK	60	5	0.4	4	0.4	0.13	0.01	0.04	0.00	71	10	9	0.5
TX01A5936	60	5	0.6	4	0.2	0.13	0.01	0.03	0.00	61	13	8	0.4
TAM401	60	5	0.4	4	0.5	0.13	0.01	0.04	0.00	72	10	9	0.3
TX02A0252	60	5	0.5	4	0.4	0.13	0.01	0.04	0.01	80	12	9	0.5
TX03A0148	60	5	0.4	4	0.6	0.13	0.01	0.04	0.01	71	12	8	0.2
TX03A0563	60	5	0.4	4	0.5	0.13	0.01	0.04	0.01	64	12	8	0.8
TX04A001246	60	5	0.3	4	0.5	0.12	0.02	0.05	0.01	84	13	8	0.7
TX01V5134RC-3	60	4	0.4	4	0.3	0.13	0.01	0.04	0.00	76	11	8	0.1
TX04M410164	60	5	0.4	4	0.4	0.13	0.01	0.04	0.01	66	13	8	0.6
TX04M410211	60	6	0.6	5	0.8	0.15	0.01	0.04	0.01	59	17	11	0.6

TX04V075080	60	5	0.4	4	0.4	0.13	0.01	0.04	0.00	72	8	7	0.4
TX99A0153-1	60	5	0.4	4	0.6	0.14	0.01	0.04	0.01	63	9	8	0.6
TX01M5009-28	60	5	0.4	4	0.5	0.13	0.01	0.04	0.00	75	8	8	0.8
TX00V1131	60	5	0.4	4	0.6	0.13	0.01	0.04	0.00	71	9	9	0.3
TX99U8618	60	4	0.4	4	0.4	0.13	0.01	0.04	0.01	64	12	8	0.8
TX96D1073	60	5	0.4	4	0.4	0.13	0.01	0.04	0.01	69	11	8	0.4
2180	60	5	0.3	4	0.6	0.14	0.01	0.03	0.00	58	9	9	0.6
HG-9	60	5	0.4	4	0.5	0.14	0.01	0.04	0.01	69	15	8	0.4
TX86A5606	60	6	0.7	5	0.7	0.15	0.01	0.05	0.01	69	9	11	0.5
TX86A8072	60	5	0.4	4	0.4	0.14	0.01	0.04	0.00	77	9	8	0.4
CREST	60	5	0.5	4	0.4	0.13	0.01	0.04	0.01	68	12	9	0.9
ROSEBUD	60	5	0.5	4	0.4	0.13	0.01	0.04	0.00	70	9	9	0.3
JUDITH	60	5	0.5	4	0.6	0.13	0.01	0.04	0.01	65	10	8	0.6
MT85200	60	5	0.5	4	0.3	0.14	0.01	0.04	0.01	71	15	9	0.8
NUSKY	60	5	0.4	4	0.5	0.14	0.01	0.03	0.00	59	13	8	0.8
MT9513	60	5	0.3	4	0.5	0.14	0.01	0.04	0.01	69	13	8	0.5
MT9904	60	5	0.4	4	0.4	0.13	0.01	0.04	0.01	72	11	9	0.2
NORRIS	60	5	0.3	4	0.5	0.14	0.01	0.03	0.01	59	9	8	0.2
YELLOWSTONE	60	5	0.4	4	0.5	0.14	0.01	0.03	0.01	57	12	9	0.9
MT0495	60	5	0.4	4	0.5	0.12	0.02	0.04	0.01	78	15	8	0.3
MTS0531	60	6	0.9	5	0.8	0.13	0.01	0.04	0.01	80	14	11	1.5
DECADE	60	6	0.4	4	0.3	0.13	0.01	0.04	0.01	68	16	9	0.5
MT06103	60	5	0.4	4	0.5	0.14	0.01	0.04	0.01	64	11	8	0.5
JUDEE	60	5	0.3	4	0.3	0.13	0.00	0.04	0.01	63	11	8	0.1
LAKIN	60	5	0.4	4	0.4	0.13	0.01	0.03	0.00	59	10	9	0.5
STANTON	60	6	0.5	4	0.4	0.13	0.01	0.04	0.01	67	12	9	0.2
TREGO	60	5	0.3	4	0.4	0.14	0.01	0.04	0.00	70	13	9	0.7
KARL_92	60	5	0.4	4	0.5	0.13	0.01	0.03	0.00	62	9	9	0.5
DODGE	60	5	0.3	4	0.5	0.13	0.01	0.04	0.01	71	21	9	0.5
NORKAN	60	5	0.4	4	0.5	0.13	0.01	0.04	0.01	63	10	9	0.6
CHENEY	60	5	0.4	4	0.4	0.13	0.01	0.03	0.00	61	11	8	0.4
NEWTON	60	5	0.4	4	0.4	0.12	0.02	0.04	0.01	64	11	8	0.6
LARNED	60	5	0.4	4	0.5	0.13	0.01	0.04	0.01	67	13	8	0.7
PARKER76	60	5	0.3	4	0.6	0.13	0.01	0.03	0.00	59	6	8	0.2
KIRWIN	60	5	0.4	4	0.4	0.12	0.01	0.03	0.00	60	6	9	0.7
SAGE	60	5	0.5	4	0.6	0.12	0.02	0.03	0.00	61	10	9	0.5
TRISON	60	5	0.4	4	0.6	0.12	0.02	0.03	0.00	60	13	9	0.5
EAGLE	60	5	0.4	4	0.6	0.12	0.02	0.03	0.00	57	7	8	0.5
SHAWNEE	60	5	0.4	4	0.6	0.13	0.02	0.03	0.00	60	11	8	0.5
PARKER	60	5	0.4	4	0.3	0.14	0.01	0.04	0.01	65	14	9	1.0
KAW61	60	5	0.4	4	0.3	0.13	0.01	0.03	0.01	59	8	8	0.5

TASCOSA	60	7	0.8	5	0.9	0.14	0.01	0.04	0.01	79	16	11	0.3
BISON	60	5	0.3	4	0.5	0.12	0.02	0.03	0.01	62	14	9	0.7
KIOWA	60	5	0.5	4	0.2	0.13	0.02	0.03	0.01	64	12	8	0.5
WICHITA	60	5	0.4	4	0.2	0.13	0.01	0.04	0.01	64	12	8	0.1
COMANCHE	60	5	0.4	4	0.4	0.13	0.01	0.04	0.01	58	9	8	0.4
BAKERS_WHITE	60	5	0.4	4	0.5	0.13	0.01	0.03	0.00	60	9	8	0.5
BURCHETT	60	5	0.4	4	0.6	0.13	0.01	0.03	0.00	54	7	8	0.4
CUTTER	60	5	0.4	4	0.5	0.13	0.01	0.03	0.01	58	13	9	0.9
DUMAS	60	5	0.3	4	0.6	0.13	0.02	0.03	0.01	64	10	8	0.5
HONDO	60	5	0.4	4	0.5	0.13	0.02	0.03	0.00	56	6	8	1.0
JAGALENE	60	5	0.4	4	0.4	0.13	0.01	0.03	0.00	62	12	9	0.5
LONGHORN	60	5	0.4	4	0.5	0.13	0.01	0.03	0.00	62	10	8	0.5
NEOSHO	60	5	0.4	4	0.5	0.13	0.01	0.03	0.00	54	8	9	0.5
OGALLALA	60	5	0.4	4	0.6	0.13	0.01	0.03	0.00	57	5	9	0.7
POSTROCK	60	5	0.3	4	0.8	0.13	0.01	0.03	0.00	53	7	8	0.8
THUNDERBOLT	60	5	0.4	4	0.7	0.13	0.01	0.03	0.01	55	11	8	0.4
W04-417	60	5	0.4	4	0.6	0.13	0.01	0.03	0.01	54	8	9	0.4
NUFRONTIER	60	5	0.3	4	0.6	0.12	0.02	0.03	0.00	57	6	8	0.3
NUHORIZON	60	5	0.5	4	0.5	0.13	0.01	0.03	0.00	57	9	8	0.3
ONAGA	60	6	0.5	5	0.7	0.15	0.01	0.04	0.01	64	9	11	0.9
RONL	60	5	0.4	4	0.5	0.13	0.01	0.03	0.01	53	11	8	0.7
2145	60	5	0.4	4	0.4	0.13	0.01	0.03	0.00	49	9	8	0.3
HEYNE	60	5	0.5	4	0.2	0.13	0.01	0.03	0.01	50	10	8	0.4
KS00F5-20-3	60	5	0.4	4	0.3	0.13	0.01	0.03	0.00	52	8	9	0.8
OVERLEY	60	5	0.4	4	0.3	0.13	0.01	0.03	0.00	51	8	9	0.4
FULLER	60	5	0.4	4	0.5	0.13	0.01	0.03	0.01	50	9	8	0.5
COSSACK	60	5	0.4	4	0.4	0.13	0.01	0.03	0.01	55	11	8	0.8
ENHANCER	60	5	0.4	4	0.3	0.13	0.01	0.03	0.00	52	6	8	0.9
SANTA_FE	60	5	0.4	4	0.6	0.13	0.01	0.03	0.00	54	8	9	0.2
VENANGO	60	5	0.4	4	0.5	0.12	0.02	0.03	0.00	54	8	8	0.5
WB411W	60	5	0.4	4	0.6	0.13	0.01	0.03	0.00	56	10	8	0.8
KEOTA	60	5	0.5	4	0.5	0.13	0.00	0.03	0.00	53	5	9	0.4
TX05A001822	60	6	0.4	4	0.6	0.13	0.00	0.03	0.00	52	5	8	0.4
TX06A001263	60	5	0.5	4	0.5	0.13	0.00	0.03	0.00	56	8	8	0.7
TX06A001132	60	5	0.4	4	0.5	0.13	0.00	0.03	0.00	56	8	8	0.7
TX06A001281	60	5	0.4	4	0.5	0.13	0.00	0.03	0.00	56	6	9	0.5
TX06A001386	60	5	0.4	4	0.4	0.13	0.00	0.03	0.00	55	6	9	0.8
TX05V7259	60	5	0.4	4	0.6	0.13	0.02	0.03	0.00	50	9	8	0.6
TX05V7269	60	5	0.4	4	0.5	0.13	0.00	0.03	0.00	55	5	8	0.8
TX05A001188	60	5	0.3	4	0.5	0.13	0.00	0.03	0.00	54	5	8	0.3
TX07A001279	60	5	0.4	4	0.6	0.13	0.00	0.03	0.00	57	8	9	0.7

TX07A001318	60	5	0.4	4	0.6	0.13	0.00	0.03	0.00	58	11	8	0.7
TX07A001420	60	6	0.5	4	0.5	0.13	0.01	0.03	0.01	58	7	8	0.9
TX06V7266	60	5	0.5	4	0.5	0.13	0.00	0.03	0.01	61	8	9	0.7
OK1067071	60	5	0.4	4	0.4	0.13	0.00	0.04	0.01	64	12	8	0.9
OK1067274	60	5	0.4	4	0.4	0.13	0.00	0.03	0.00	57	7	9	0.8
OK1068002	60	5	0.4	4	0.4	0.13	0.00	0.04	0.01	62	10	8	1.1
OK1068009	60	6	0.5	4	0.7	0.13	0.00	0.03	0.00	62	10	9	0.9
OK1068026	60	5	0.4	4	0.5	0.12	0.02	0.03	0.00	57	9	9	0.6
OK1068112	60	5	0.4	4	0.5	0.13	0.02	0.03	0.01	59	10	8	0.6
OK1070275	60	5	0.3	4	0.7	0.13	0.00	0.03	0.00	60	9	9	0.5
OK1070267	60	6	0.5	4	0.5	0.13	0.00	0.03	0.01	59	6	8	0.6
OK09634	60	5	0.3	4	0.5	0.13	0.00	0.03	0.00	61	9	9	0.8
OK10119	60	5	0.4	4	0.5	0.13	0.00	0.03	0.00	59	7	8	0.4
GALLAGHER	60	5	0.5	4	0.5	0.13	0.01	0.03	0.01	58	7	9	0.9
OK07231	60	5	0.4	4	0.5	0.13	0.00	0.03	0.01	64	15	8	0.9
OK07S117	60	5	0.4	4	0.5	0.13	0.01	0.03	0.01	60	10	8	0.8
OK08328	60	5	0.4	4	0.6	0.13	0.00	0.03	0.00	59	7	8	0.9
BIG_SKY	60	5	0.3	4	0.4	0.13	0.01	0.03	0.01	62	10	8	0.2
DANBY	60	6	0.5	4	0.6	0.13	0.01	0.03	0.01	59	10	9	0.5
E2041	60	5	0.4	4	0.3	0.13	0.01	0.03	0.00	55	7	9	0.5
DENALI	60	5	0.4	4	0.3	0.13	0.01	0.03	0.00	55	9	8	0.8
CO050337-2	60	5	0.4	4	0.3	0.13	0.00	0.03	0.00	58	11	8	0.5
BYRD	60	5	0.4	4	0.3	0.13	0.01	0.03	0.01	56	8	9	0.8
CO07W245	60	5	0.4	4	0.4	0.13	0.00	0.03	0.00	60	10	8	0.7
MCGILL	60	5	0.5	4	0.5	0.13	0.01	0.03	0.00	61	10	9	0.5
NE02558	60	5	0.4	4	0.4	0.13	0.01	0.03	0.01	62	11	8	0.6
NW03666	60	5	0.4	4	0.3	0.13	0.01	0.04	0.01	70	17	8	0.2
NE04490	60	5	0.4	4	0.4	0.13	0.01	0.03	0.01	62	9	8	0.5
NE05430	60	5	0.5	4	0.3	0.13	0.01	0.04	0.01	62	9	8	0.2
NE05496	60	5	0.4	4	0.5	0.13	0.00	0.04	0.01	63	7	9	0.7
NE05548	60	5	0.4	4	0.5	0.13	0.00	0.04	0.01	63	8	8	0.3
NE06545	60	5	0.5	4	0.5	0.13	0.01	0.04	0.01	62	12	8	1.0
NE06607	60	5	0.5	4	0.5	0.13	0.01	0.04	0.01	65	10	8	0.8
ROBIDOUX	60	5	0.4	4	0.5	0.13	0.01	0.04	0.01	62	8	8	0.2
NI06736	60	5	0.4	4	0.5	0.13	0.01	0.03	0.01	59	8	8	0.4
NI06737	60	5	0.5	4	0.5	0.13	0.01	0.03	0.01	59	10	8	0.5
NI07703	60	5	0.3	4	0.5	0.13	0.01	0.03	0.01	57	12	8	0.7
NI08707	60	5	0.4	4	0.4	0.13	0.00	0.03	0.01	61	11	8	0.4
NI08708	60	5	0.4	4	0.5	0.13	0.01	0.04	0.01	61	9	8	0.3
EVEREST	60	5	0.5	4	0.5	0.13	0.01	0.04	0.01	61	7	8	0.8
TRIUMPH64	120	2	0.6	2	0.4	0.08	0.01	0.02	0.01	28	11	3	0.5

CHISHOLM	120	3	0.5	2	0.4	0.10	0.01	0.02	0.01	35	16	4	0.5
CUSTER	120	3	0.6	2	0.5	0.09	0.01	0.02	0.01	38	16	2	0.4
2174-05	120	3	0.8	2	0.7	0.10	0.02	0.02	0.01	23	11	1	0.2
INTRADA	120	2	0.5	1	0.4	0.08	0.01	0.01	0.01	26	10	2	0.3
OK101	120	3	0.6	2	0.3	0.10	0.01	0.02	0.01	41	18	2	0.4
OK102	120	3	0.5	2	0.4	0.08	0.01	0.02	0.01	31	15	2	0.4
ENDURANCE	120	4	0.3	3	0.2	0.10	0.01	0.03	0.01	44	7	6	0.4
DELIVER	120	3	0.6	1	0.4	0.09	0.01	0.02	0.01	30	16	2	0.5
OK_BULLET	120	3	0.6	2	0.4	0.09	0.01	0.02	0.01	33	12	2	0.6
CENTERFIELD	120	3	0.6	2	0.4	0.09	0.01	0.02	0.01	28	13	3	0.2
GUYMON	120	6	1.0	4	0.6	0.11	0.01	0.03	0.01	53	18	8	0.4
DUSTER	120	3	0.6	2	0.5	0.08	0.01	0.02	0.01	31	16	3	0.5
OK_RISING	120	3	0.4	2	0.4	0.10	0.01	0.02	0.01	30	17	2	0.5
OK02405	120	2	0.5	2	0.4	0.10	0.01	0.02	0.01	28	15	2	0.3
PETE	120	3	0.6	2	0.4	0.10	0.01	0.02	0.01	38	17	2	0.3
BILLINGS	120	2	0.5	2	0.5	0.08	0.01	0.02	0.01	33	15	2	0.4
OK04505	120	2	0.4	1	0.5	0.10	0.01	0.01	0.01	26	17	2	0.5
OK04525	120	3	0.6	2	0.5	0.09	0.01	0.02	0.01	29	15	2	0.6
OK04507	120	3	0.3	3	0.3	0.10	0.01	0.02	0.01	38	13	5	0.4
OK05830	120	3	0.5	2	0.5	0.09	0.01	0.02	0.01	32	19	2	0.3
OK04111	120	3	0.5	2	0.4	0.09	0.01	0.02	0.01	31	15	2	0.5
OK04415	120	3	0.5	2	0.4	0.09	0.01	0.01	0.01	27	14	2	0.6
OK05711W	120	3	0.6	2	0.2	0.10	0.01	0.02	0.01	35	16	3	0.2
OK05723W	120	2	0.4	1	0.3	0.10	0.01	0.01	0.01	26	16	2	0.3
OK05108	120	3	0.6	2	0.6	0.11	0.01	0.02	0.01	32	9	3	0.1
OK05122	120	3	0.6	2	0.4	0.09	0.01	0.02	0.01	41	19	2	0.4
OK05526	120	3	0.6	2	0.5	0.09	0.01	0.02	0.01	28	14	2	0.4
OK05134	120	3	0.6	2	0.5	0.10	0.01	0.02	0.01	27	15	2	0.8
OK05303	120	2	0.6	2	0.5	0.09	0.01	0.02	0.01	36	15	2	0.5
OK05312	120	3	0.5	2	0.3	0.10	0.01	0.02	0.01	30	15	2	0.3
OK05511	120	3	0.6	2	0.4	0.09	0.01	0.01	0.01	25	14	2	0.5
OK05204	120	3	0.4	2	0.4	0.10	0.01	0.02	0.01	39	18	2	0.5
GARRISON	120	3	0.4	2	0.4	0.10	0.01	0.02	0.01	35	13	3	0.3
OK06114	120	3	0.5	2	0.6	0.09	0.01	0.02	0.01	27	13	2	0.5
OK06210	120	3	0.4	2	0.3	0.10	0.01	0.02	0.01	41	17	4	0.4
OK06319	120	2	0.4	2	0.5	0.09	0.01	0.02	0.01	33	17	2	0.4
OK06318	120	2	0.4	2	0.3	0.10	0.01	0.02	0.01	35	17	2	0.2
OK06336	120	2	0.2	2	0.5	0.10	0.01	0.02	0.01	37	16	2	0.3
AGATE	120	2	0.3	1	0.4	0.10	0.01	0.01	0.01	25	14	1	0.4
ALLIANCE	120	2	0.4	1	0.5	0.09	0.01	0.01	0.01	26	16	2	0.1
ANTELOPE	120	2	0.3	1	0.5	0.08	0.01	0.01	0.01	23	16	2	0.5

ARAPAHOE	120	2	0.4	1	0.6	0.10	0.01	0.02	0.01	29	13	1	0.6
BENNETT	120	3	0.6	2	0.4	0.10	0.01	0.02	0.01	34	15	2	0.3
BUCKSKIN	120	2	0.5	2	0.5	0.09	0.01	0.02	0.01	34	17	2	0.2
CENTURK78	120	3	0.6	2	0.5	0.10	0.01	0.02	0.01	37	16	2	0.6
CHEYENNE	120	3	0.5	2	0.3	0.10	0.01	0.02	0.01	37	17	3	0.2
COLT	120	2	0.4	1	0.6	0.10	0.01	0.02	0.01	29	15	2	0.4
COUGAR	120	2	0.5	2	0.6	0.09	0.01	0.02	0.01	29	15	3	0.6
CULVER	120	2	0.6	2	0.5	0.08	0.01	0.02	0.01	32	18	2	0.4
GAGE	120	4	0.5	3	0.8	0.10	0.01	0.03	0.01	52	19	7	0.5
GOODSTREAK	120	3	0.2	2	0.3	0.10	0.01	0.02	0.01	36	15	5	0.1
HALLAM	120	3	0.3	2	0.2	0.09	0.01	0.01	0.01	26	14	4	0.2
HARRY	120	2	0.4	1	0.5	0.09	0.01	0.02	0.01	28	14	1	0.3
HOMESTEAD	120	3	0.5	2	0.3	0.10	0.01	0.02	0.01	34	16	3	0.1
INFINITY_CL	120	2	0.4	2	0.4	0.09	0.01	0.02	0.01	29	18	2	0.5
KHARKOF	120	3	0.6	2	0.3	0.10	0.01	0.02	0.01	34	16	3	0.3
MILLENNIUM	120	2	0.5	2	0.4	0.09	0.01	0.02	0.01	32	15	2	0.4
CAMELOT	120	2	0.4	1	0.4	0.09	0.01	0.02	0.01	27	13	2	0.5
OVERLAND	120	3	0.6	2	0.4	0.09	0.01	0.02	0.01	34	17	2	0.5
NE99495	120	3	0.3	2	0.2	0.10	0.01	0.02	0.01	33	14	5	0.3
NIOBRARA	120	4	0.4	3	0.2	0.10	0.01	0.02	0.01	38	18	5	0.5
NUPLAINS	120	2	0.5	2	0.5	0.09	0.01	0.02	0.01	26	16	3	0.4
PRONGHORN	120	2	0.3	2	0.5	0.09	0.01	0.02	0.01	28	16	2	0.2
RAWHIDE	120	2	0.4	1	0.6	0.09	0.02	0.02	0.01	35	19	2	0.3
REDLAND	120	2	0.5	2	0.5	0.09	0.01	0.02	0.01	30	15	2	0.4
SCOUT66	120	3	0.5	2	0.3	0.10	0.01	0.02	0.01	36	18	3	0.2
SIOUXLAND	120	2	0.5	1	0.5	0.09	0.01	0.02	0.01	32	13	2	0.3
TURKEY_NEBSEL	120	2	0.4	2	0.6	0.09	0.01	0.02	0.01	32	18	3	0.4
VISTA	120	2	0.5	1	0.5	0.09	0.01	0.02	0.01	34	19	2	0.5
WAHOO	120	2	0.5	1	0.6	0.09	0.01	0.01	0.01	25	16	2	0.4
WARRIOR	120	3	0.6	2	0.6	0.09	0.01	0.02	0.01	35	13	3	0.3
WESLEY	120	3	0.2	2	0.5	0.10	0.01	0.02	0.01	38	18	5	0.5
WICHITA	120	3	0.6	2	0.6	0.09	0.01	0.02	0.01	38	16	3	0.3
WINDSTAR	120	2	0.5	2	0.6	0.09	0.01	0.02	0.01	30	19	2	0.6
LANCER	120	2	0.6	2	0.7	0.10	0.01	0.02	0.01	33	15	3	0.3
ANTON	120	2	0.5	1	0.6	0.09	0.01	0.02	0.01	34	15	2	0.4
MACE	120	2	0.4	1	0.5	0.08	0.01	0.01	0.01	25	18	2	0.5
TAM107-R7	120	2	0.5	2	0.5	0.09	0.01	0.01	0.01	23	16	2	0.3
ARLIN	120	3	0.7	2	0.4	0.10	0.01	0.02	0.01	40	19	2	0.3
ALICE	120	2	0.4	2	0.5	0.09	0.01	0.02	0.01	28	12	2	0.5
DARRELL	120	2	0.4	2	0.7	0.09	0.01	0.02	0.01	32	12	3	0.5
EXPEDITION	120	2	0.4	2	0.5	0.09	0.01	0.02	0.01	30	18	3	0.3

WENDY	120	3	0.3	2	0.3	0.11	0.01	0.02	0.01	41	13	5	0.5
SD00111-9	120	2	0.4	2	0.5	0.09	0.01	0.02	0.01	30	12	2	0.5
SD01237	120	2	0.4	2	0.6	0.09	0.01	0.02	0.01	32	15	3	0.4
SD01058	120	2	0.4	1	0.4	0.09	0.01	0.02	0.01	32	13	2	0.2
SD05118	120	3	0.7	2	0.6	0.10	0.01	0.02	0.01	37	18	3	0.3
SD05210	120	2	0.5	1	0.4	0.09	0.01	0.01	0.01	27	17	2	0.3
SD05W018	120	2	0.4	2	0.5	0.09	0.01	0.02	0.01	27	14	3	0.6
NEKOTA	120	3	0.6	2	0.3	0.10	0.01	0.02	0.01	38	16	3	0.2
TANDEM	120	3	0.6	2	0.4	0.10	0.01	0.02	0.01	35	17	3	0.2
CRIMSON	120	2	0.4	1	0.6	0.09	0.01	0.02	0.01	31	15	2	0.4
ROSE	120	2	0.3	1	0.5	0.09	0.01	0.02	0.01	27	16	1	0.2
DAWN	120	3	0.4	2	0.5	0.10	0.01	0.02	0.01	35	14	3	0.4
WINOKA	120	2	0.5	2	0.5	0.09	0.01	0.02	0.01	31	20	1	0.6
NELL	120	3	0.5	2	0.5	0.10	0.01	0.02	0.01	36	16	3	0.5
RITA	120	2	0.4	2	0.5	0.09	0.01	0.02	0.01	30	16	3	0.3
BRONZE	120	2	0.5	1	0.4	0.08	0.01	0.02	0.01	28	15	2	0.3
HUME	120	3	0.5	2	0.4	0.09	0.01	0.02	0.01	31	14	2	0.4
GENT	120	2	0.4	2	0.6	0.09	0.01	0.02	0.01	28	15	2	0.5
HARDING	120	2	0.6	1	0.5	0.09	0.01	0.02	0.01	32	16	2	0.4
HV9W03-1551WP	120	2	0.6	2	0.3	0.10	0.01	0.02	0.01	33	17	2	0.2
G1878	120	2	0.5	2	0.6	0.10	0.01	0.02	0.01	34	16	2	0.3
HV9W03-1379R	120	2	0.3	1	0.5	0.09	0.01	0.01	0.01	26	16	2	0.3
HV9W03-1596R	120	2	0.4	2	0.6	0.08	0.01	0.02	0.01	28	16	3	0.4
HV9W05-1280R	120	2	0.6	2	0.7	0.09	0.01	0.02	0.01	33	19	2	0.6
HV9W06-504	120	2	0.5	2	0.5	0.09	0.01	0.02	0.01	30	16	3	0.3
SPARTAN	120	2	0.5	1	0.6	0.09	0.01	0.02	0.01	28	16	2	0.4
HV906-865	120	2	0.6	2	0.6	0.10	0.01	0.02	0.01	36	16	3	0.4
TARKIO	120	2	0.5	1	0.6	0.09	0.01	0.02	0.01	32	18	2	0.3
SMOKYHILL	120	2	0.4	1	0.5	0.09	0.01	0.02	0.01	33	17	2	0.5
SHOCKER	120	2	0.4	1	0.5	0.10	0.01	0.02	0.01	27	16	2	0.4
VONA	120	2	0.4	2	0.5	0.08	0.01	0.02	0.01	31	16	2	0.4
CO940610	120	2	0.4	1	0.5	0.09	0.01	0.02	0.01	32	16	2	0.3
AVALANCHE	120	3	0.9	2	0.8	0.10	0.01	0.02	0.01	40	17	3	0.4
BOND_CL	120	2	0.5	2	0.5	0.09	0.01	0.02	0.01	29	16	2	0.5
PLATTE	120	2	0.3	1	0.6	0.09	0.01	0.02	0.01	32	14	2	0.4
LINDON	120	2	0.4	1	0.5	0.08	0.01	0.02	0.01	32	18	2	0.2
CO03W043	120	2	0.5	1	0.6	0.10	0.01	0.02	0.01	29	12	3	0.4
SNOWMASS	120	2	0.5	2	0.5	0.09	0.01	0.02	0.01	28	11	3	0.8
THUNDER_CL	120	3	0.5	2	0.4	0.10	0.01	0.02	0.01	33	15	3	0.4
CO04025	120	2	0.4	2	0.6	0.09	0.01	0.02	0.01	30	16	3	0.5
CO04393	120	3	0.4	2	0.5	0.10	0.01	0.02	0.01	37	16	4	0.5

CO04499	120	2	0.5	2	0.6	0.09	0.01	0.01	0.01	25	17	3	0.9
CO04W320	120	4	0.7	2	0.8	0.11	0.01	0.02	0.01	28	11	2	0.5
LAMAR	120	3	0.5	2	0.5	0.10	0.01	0.02	0.01	35	18	3	0.4
CARSON	120	4	0.7	2	0.9	0.10	0.02	0.02	0.01	33	10	2	0.3
HAIL	120	2	0.7	2	0.5	0.10	0.01	0.02	0.01	28	13	1	0.2
SANDY	120	2	0.5	2	0.5	0.10	0.01	0.02	0.01	30	16	2	0.4
DUKE	120	2	0.6	1	0.6	0.09	0.01	0.02	0.01	31	14	2	0.3
HALT	120	3	0.5	2	0.5	0.10	0.01	0.02	0.01	33	16	3	0.1
HATCHER	120	2	0.5	2	0.4	0.09	0.01	0.01	0.01	27	15	1	0.4
PRAIRIE_RED	120	3	0.6	2	0.5	0.10	0.01	0.02	0.01	33	17	3	0.7
ABOVE	120	2	0.4	2	0.5	0.10	0.01	0.02	0.01	30	16	3	0.5
CO03064	120	2	0.4	2	0.5	0.09	0.01	0.02	0.01	33	18	2	0.4
BILL_BROWN	120	2	0.5	1	0.6	0.09	0.01	0.02	0.01	27	16	1	0.2
RIPPER	120	2	0.3	1	0.4	0.09	0.01	0.02	0.01	30	12	1	0.2
PROWERS	120	3	0.5	2	0.6	0.10	0.01	0.02	0.01	34	17	4	0.4
AKRON	120	2	0.5	2	0.4	0.10	0.01	0.02	0.01	35	17	2	0.2
JULES	120	3	0.6	2	0.5	0.10	0.01	0.02	0.01	33	17	3	0.3
YUMA	120	2	0.3	1	0.4	0.09	0.01	0.02	0.01	29	18	2	0.4
TAMW-101	120	2	0.4	1	0.5	0.10	0.01	0.02	0.01	34	17	3	0.3
TAM105	120	2	0.4	1	0.5	0.09	0.01	0.02	0.01	32	18	2	0.4
TAM107	120	2	0.4	1	0.4	0.08	0.01	0.02	0.01	30	14	2	0.6
TAM109	120	2	0.4	1	0.4	0.08	0.01	0.02	0.01	39	21	3	0.6
TAM110	120	3	0.6	2	0.4	0.10	0.01	0.02	0.01	40	18	3	0.2
TAM111	120	3	0.6	2	0.4	0.10	0.01	0.02	0.01	31	15	3	0.4
TAM112	120	3	0.5	2	0.5	0.09	0.01	0.02	0.01	36	18	3	0.2
TAM200	120	3	0.3	2	0.3	0.09	0.01	0.02	0.01	31	15	3	0.2
TAM202	120	2	0.4	2	0.4	0.09	0.01	0.02	0.01	29	11	1	0.2
TAM203	120	2	0.4	2	0.6	0.09	0.01	0.02	0.01	29	15	2	0.4
TAM302	120	3	0.2	3	0.3	0.10	0.01	0.02	0.01	35	14	5	0.5
TAM303	120	2	0.4	1	0.5	0.09	0.01	0.02	0.01	33	19	1	0.3
TAM304	120	2	0.3	1	0.3	0.09	0.01	0.01	0.01	27	16	2	0.2
TAM400	120	2	0.4	2	0.5	0.09	0.01	0.02	0.01	31	14	1	0.3
LOCKETT	120	3	0.5	2	0.1	0.10	0.01	0.02	0.01	39	15	3	0.2
STURDY	120	2	0.3	1	0.4	0.09	0.01	0.02	0.01	34	16	1	0.1
STURDY_2K	120	2	0.4	1	0.5	0.08	0.01	0.02	0.01	31	17	2	0.3
MIT	120	2	0.4	1	0.5	0.08	0.01	0.01	0.01	28	15	2	0.3
CAPROCK	120	3	0.6	2	0.4	0.10	0.01	0.02	0.01	35	15	3	0.4
TX01A5936	120	2	0.2	1	0.3	0.08	0.00	0.02	0.01	33	17	2	0.3
TAM401	120	2	0.3	2	0.4	0.10	0.01	0.02	0.01	32	17	3	0.5
TX02A0252	120	2	0.4	1	0.5	0.09	0.01	0.01	0.01	29	17	1	0.4
TX03A0148	120	2	0.4	1	0.5	0.08	0.01	0.01	0.01	28	16	1	0.3

TX03A0563	120	2	0.4	1	0.5	0.09	0.01	0.02	0.01	31	17	1	0.3
TX04A001246	120	2	0.2	1	0.5	0.09	0.01	0.02	0.01	31	22	2	0.4
TX01V5134RC-3	120	3	0.2	2	0.5	0.10	0.01	0.02	0.01	39	14	5	0.2
TX04M410164	120	2	0.2	1	0.3	0.09	0.01	0.01	0.01	24	14	2	0.3
TX04M410211	120	3	0.7	2	0.7	0.10	0.01	0.02	0.01	29	15	2	0.3
TX04V075080	120	2	0.4	1	0.5	0.09	0.01	0.02	0.01	32	13	1	0.4
TX99A0153-1	120	2	0.4	1	0.5	0.08	0.01	0.01	0.01	27	17	2	0.2
TX01M5009-28	120	2	0.5	2	0.4	0.10	0.01	0.02	0.01	35	12	2	0.3
TX00V1131	120	2	0.6	1	0.5	0.08	0.01	0.02	0.01	38	20	2	0.3
TX99U8618	120	3	0.1	2	0.3	0.10	0.01	0.02	0.01	34	16	4	0.4
TX96D1073	120	2	0.4	1	0.5	0.08	0.01	0.01	0.01	26	14	2	0.1
2180	120	2	0.3	1	0.5	0.09	0.01	0.02	0.01	30	16	2	0.2
HG-9	120	2	0.4	2	0.5	0.09	0.01	0.01	0.01	27	15	1	0.4
TX86A5606	120	3	0.7	2	0.7	0.11	0.01	0.03	0.01	40	11	3	0.5
TX86A8072	120	3	0.5	2	0.3	0.10	0.01	0.02	0.01	38	15	3	0.5
CREST	120	3	0.5	2	0.2	0.09	0.01	0.02	0.01	30	16	2	0.2
ROSEBUD	120	3	0.5	2	0.3	0.10	0.01	0.02	0.01	37	19	3	0.3
JUDITH	120	2	0.4	1	0.5	0.08	0.01	0.01	0.01	28	16	2	0.3
MT85200	120	3	0.5	2	0.6	0.10	0.01	0.02	0.01	36	18	3	0.3
NUSKY	120	2	0.5	1	0.5	0.08	0.01	0.02	0.01	30	19	1	0.4
MT9513	120	2	0.6	2	0.5	0.10	0.01	0.02	0.01	37	16	3	0.3
MT9904	120	3	0.7	2	0.5	0.10	0.01	0.02	0.01	35	14	3	0.7
NORRIS	120	3	0.6	2	0.5	0.10	0.01	0.02	0.01	32	14	3	0.4
YELLOWSTONE	120	2	0.5	1	0.5	0.10	0.01	0.02	0.01	32	14	2	0.3
MT0495	120	2	0.3	1	0.4	0.08	0.01	0.02	0.01	30	18	1	0.3
MTS0531	120	4	0.7	4	0.7	0.10	0.01	0.03	0.01	50	19	7	0.6
DECADE	120	2	0.4	1	0.5	0.10	0.01	0.02	0.01	32	18	3	0.5
MT06103	120	2	0.2	1	0.4	0.10	0.01	0.02	0.01	33	18	2	0.3
JUDEE	120	2	0.4	2	0.5	0.09	0.01	0.02	0.01	30	17	2	0.3
LAKIN	120	2	0.3	1	0.4	0.10	0.01	0.02	0.01	34	19	2	0.5
STANTON	120	2	0.3	1	0.5	0.09	0.01	0.02	0.01	31	18	2	0.3
TREGO	120	2	0.1	1	0.3	0.10	0.01	0.02	0.01	32	19	2	0.0
KARL_92	120	2	0.4	1	0.4	0.09	0.01	0.02	0.01	32	17	3	0.3
DODGE	120	2	0.4	2	0.4	0.09	0.01	0.02	0.01	32	18	3	0.4
NORKAN	120	2	0.2	1	0.3	0.08	0.01	0.01	0.01	28	18	2	0.1
CHENEY	120	2	0.4	1	0.4	0.08	0.01	0.02	0.01	30	16	1	0.3
NEWTON	120	2	0.2	1	0.4	0.08	0.01	0.01	0.01	28	15	2	0.4
LARNED	120	2	0.5	2	0.4	0.10	0.01	0.02	0.01	32	15	3	0.2
PARKER76	120	2	0.2	1	0.4	0.09	0.01	0.02	0.01	32	14	2	0.3
KIRWIN	120	2	0.5	2	0.5	0.10	0.01	0.02	0.01	30	16	3	0.4
SAGE	120	2	0.4	1	0.5	0.08	0.01	0.01	0.01	28	18	2	0.3

TRISON	120	2	0.3	1	0.5	0.08	0.01	0.01	0.01	30	18	2	0.2
EAGLE	120	2	0.3	1	0.3	0.08	0.01	0.02	0.01	29	18	2	0.1
SHAWNEE	120	2	0.1	1	0.4	0.08	0.01	0.01	0.01	27	18	2	0.1
PARKER	120	2	0.4	2	0.6	0.10	0.01	0.02	0.01	36	16	3	0.5
KAW61	120	2	0.4	2	0.5	0.10	0.01	0.02	0.01	29	12	3	0.4
TASCOSA	120	4	0.5	3	0.5	0.11	0.01	0.03	0.01	51	14	7	0.1
BISON	120	2	0.6	1	0.5	0.08	0.01	0.02	0.01	30	19	3	0.3
KIOWA	120	2	0.2	1	0.2	0.09	0.01	0.01	0.01	28	17	2	0.2
WICHITA	120	2	0.2	1	0.4	0.09	0.01	0.02	0.01	29	19	2	0.2
COMANCHE	120	2	0.5	2	0.5	0.10	0.01	0.02	0.01	34	16	3	0.6
BAKERS_WHITE	120	2	0.3	1	0.4	0.09	0.01	0.02	0.01	29	16	2	0.1
BURCHETT	120	2	0.5	1	0.4	0.08	0.01	0.01	0.01	25	15	1	0.3
CUTTER	120	3	0.5	2	0.5	0.10	0.01	0.02	0.01	33	17	3	0.3
DUMAS	120	2	0.3	1	0.4	0.08	0.01	0.01	0.01	28	15	2	0.2
HONDO	120	2	0.1	1	0.2	0.08	0.01	0.01	0.01	27	16	1	0.1
JAGALENE	120	2	0.4	2	0.4	0.09	0.01	0.02	0.01	30	18	3	0.3
LONGHORN	120	2	0.1	1	0.2	0.08	0.01	0.01	0.01	28	13	2	0.1
NEOSHO	120	2	0.5	2	0.4	0.10	0.01	0.02	0.01	26	14	3	0.4
OGALLALA	120	2	0.2	1	0.4	0.08	0.01	0.01	0.01	28	16	2	0.4
POSTROCK	120	3	0.5	2	0.5	0.09	0.02	0.02	0.01	39	23	2	0.4
THUNDERBOLT	120	2	0.4	2	0.4	0.10	0.01	0.02	0.01	35	16	3	0.3
W04-417	120	2	0.2	1	0.3	0.09	0.01	0.02	0.01	29	16	1	0.2
NUFRONTIER	120	3	0.5	2	0.6	0.08	0.01	0.02	0.01	31	17	3	0.3
NUHORIZON	120	2	0.2	1	0.3	0.10	0.01	0.02	0.01	29	17	2	0.2
ONAGA	120	4	0.7	2	0.5	0.12	0.02	0.02	0.01	37	11	4	0.5
RONL	120	2	0.2	1	0.3	0.09	0.01	0.02	0.01	29	17	2	0.1
2145	120	2	0.2	1	0.2	0.09	0.01	0.01	0.01	26	16	1	0.0
HEYNE	120	2	0.2	1	0.2	0.09	0.01	0.01	0.01	27	15	2	0.1
KS00F5-20-3	120	2	0.3	1	0.3	0.08	0.01	0.01	0.01	25	14	1	0.2
OVERLEY	120	3	0.7	1	0.6	0.09	0.01	0.02	0.01	33	19	2	0.4
FULLER	120	3	0.6	2	0.4	0.10	0.01	0.02	0.01	30	13	3	0.5
COSSACK	120	3	0.6	2	0.5	0.10	0.01	0.02	0.01	33	15	3	0.4
ENHANCER	120	3	0.3	2	0.2	0.10	0.01	0.02	0.01	31	16	4	0.4
SANTA_FE	120	2	0.2	1	0.3	0.10	0.01	0.01	0.01	28	14	2	0.2
VENANGO	120	2	0.3	1	0.3	0.08	0.01	0.01	0.01	28	18	2	0.1
WB411W	120	2	0.4	2	0.4	0.10	0.01	0.02	0.01	30	11	3	0.4
KEOTA	120	2	0.4	1	0.5	0.09	0.01	0.01	0.01	25	14	2	0.1
TX05A001822	120	2	0.2	1	0.3	0.08	0.01	0.01	0.01	25	17	1	0.1
TX06A001263	120	2	0.3	1	0.3	0.08	0.01	0.01	0.01	27	18	2	0.1
TX06A001132	120	2	0.3	1	0.3	0.08	0.01	0.01	0.01	27	18	2	0.3
TX06A001281	120	2	0.7	1	0.5	0.10	0.01	0.02	0.01	38	22	3	0.4

TX06A001386	120	2	0.3	1	0.4	0.09	0.01	0.02	0.01	28	14	2	0.2
TX05V7259	120	2	0.2	1	0.5	0.09	0.01	0.02	0.01	30	15	2	0.3
TX05V7269	120	2	0.2	1	0.2	0.08	0.01	0.01	0.01	25	12	1	0.2
TX05A001188	120	2	0.2	1	0.2	0.08	0.01	0.02	0.01	28	16	1	0.1
TX07A001279	120	2	0.3	1	0.3	0.08	0.01	0.01	0.01	28	15	2	0.4
TX07A001318	120	2	0.2	1	0.2	0.10	0.01	0.02	0.01	27	14	2	0.2
TX07A001420	120	2	0.5	2	0.4	0.10	0.01	0.02	0.01	30	13	3	0.3
TX06V7266	120	2	0.3	1	0.4	0.09	0.01	0.01	0.01	27	14	2	0.1
OK1067071	120	2	0.2	1	0.3	0.08	0.01	0.02	0.01	28	15	2	0.2
OK1067274	120	3	0.4	2	0.3	0.10	0.01	0.02	0.01	32	15	3	0.5
OK1068002	120	3	0.5	2	0.2	0.10	0.01	0.02	0.01	35	16	4	0.4
OK1068009	120	2	0.2	1	0.2	0.10	0.01	0.02	0.01	33	12	2	0.2
OK1068026	120	2	0.1	1	0.3	0.08	0.01	0.01	0.01	27	17	2	0.2
OK1068112	120	2	0.2	1	0.2	0.08	0.01	0.01	0.01	25	16	1	0.1
OK1070275	120	2	0.2	1	0.2	0.08	0.01	0.01	0.01	26	18	1	0.1
OK1070267	120	2	0.3	2	0.5	0.10	0.01	0.02	0.01	32	17	3	0.3
OK09634	120	2	0.2	1	0.3	0.08	0.01	0.02	0.01	30	18	1	0.1
OK10119	120	2	0.1	1	0.3	0.08	0.01	0.02	0.01	31	18	1	0.2
GALLAGHER	120	2	0.2	1	0.3	0.10	0.01	0.02	0.01	36	16	2	0.0
OK07231	120	2	0.5	1	0.4	0.10	0.01	0.02	0.01	31	18	3	0.4
OK07S117	120	3	0.6	1	0.5	0.09	0.01	0.02	0.01	39	23	3	0.4
OK08328	120	2	0.2	1	0.3	0.09	0.01	0.02	0.01	29	17	2	0.1
BIG_SKY	120	2	0.2	1	0.3	0.09	0.01	0.02	0.01	29	14	2	0.2
DANBY	120	2	0.4	1	0.3	0.10	0.01	0.02	0.01	30	15	2	0.3
E2041	120	2	0.2	1	0.2	0.09	0.01	0.01	0.01	25	15	1	0.1
DENALI	120	2	0.5	2	0.5	0.10	0.01	0.02	0.01	33	13	3	0.7
CO050337-2	120	2	0.3	1	0.4	0.10	0.01	0.02	0.01	30	15	3	0.2
BYRD	120	2	0.5	2	0.4	0.10	0.01	0.02	0.01	33	13	3	0.3
CO07W245	120	3	0.2	2	0.2	0.10	0.01	0.02	0.01	33	18	4	0.3
MCGILL	120	2	0.2	1	0.3	0.09	0.01	0.02	0.01	31	19	2	0.2
NE02558	120	2	0.3	1	0.4	0.09	0.01	0.02	0.01	31	19	2	0.2
NW03666	120	2	0.5	1	0.5	0.10	0.01	0.02	0.01	30	17	2	0.5
NE04490	120	2	0.6	2	0.5	0.10	0.00	0.01	0.01	27	15	3	0.3
NE05430	120	2	0.1	1	0.3	0.08	0.01	0.01	0.01	27	17	1	0.2
NE05496	120	3	0.5	2	0.5	0.09	0.01	0.02	0.01	30	18	4	0.3
NE05548	120	2	0.2	1	0.3	0.10	0.01	0.02	0.01	29	19	2	0.1
NE06545	120	2	0.2	1	0.3	0.09	0.01	0.01	0.01	25	18	2	0.1
NE06607	120	2	0.3	1	0.4	0.09	0.01	0.02	0.01	28	12	2	0.2
ROBIDOUX	120	2	0.2	1	0.2	0.09	0.01	0.01	0.01	25	14	1	0.3
NI06736	120	2	0.2	1	0.2	0.09	0.01	0.02	0.01	30	17	1	0.2
NI06737	120	2	0.2	1	0.3	0.10	0.01	0.02	0.01	30	15	2	0.2

NI07703	120	2	0.0	1	0.3	0.10	0.01	0.02	0.01	31	11	2	0.2
NI08707	120	3	0.3	2	0.5	0.09	0.01	0.02	0.01	31	16	4	0.6
NI08708	120	2	0.2	1	0.3	0.10	0.01	0.02	0.01	35	16	2	0.2
EVEREST	120	2.6	0.6	2	0.5	0.10	0.01	0.02	0.01	38	14	3	0.4

Appendix D - Pictures.

Picture 1. Growth chambers used in the experiments.

Picture 2. Winter wheat seedlings were raised in 4 cm tray. (B) After vernalization, they were transplanted into plastic pots (Chapter 3 and 4).

Picture 3. Sample instruments used in collecting physiological data.

(A) SPAD Meter (to measure leaf chlorophyll); and (B) Chlorophyll Fluorometer (to measure Maximum Quantum yield of Photosystem II)

(C) LI-6400XT Portable Photosynthesis System (to measure gas exchange and photosynthesis).