EVALUATING BARLEY LINES FOR YIELD PERFORMANCE AND ADAPTATION TO TEXAS GROWING CONDITIONS FOR FEED AND MALTING PURPOSES

A Thesis

by

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ABSTRACT

Around the 1960s, barley was grown on nearly 170,372 hectares (ha) throughout Texas. Today, it is planted on less than 12,000 ha and is mainly used as a feed and forage source for livestock. In recent years, interest in craft breweries, local malt ingredients and feed barley for a growing dairy industry in the Texas High Plains has increased the popularity of barley. Testing is required to find barley lines adapted to Texas climates that can withstand drought, disease and pest pressure.

The purpose of this study was to evaluate and identify adapted barley lines for feed and malting purposes under multiple environments across different growing regions of Texas. The specific objectives of this study were to 1) Evaluate and identify superior TCAP (Triticae Coordinated Agricultural Project) barley lines for yield and malt quality in Texas environments, 2) Determine desirable phenotypic characteristics for barley grown in Texas and 3) Evaluate the economic feasibility of barley production in Texas. Winter, facultative, spring two- and spring six-row barley was evaluated over Harvest Years 2014, 2015 and 2016.

In-field and lab evaluations were taken over the growing and harvest seasons. Statistical analysis using PROC CORR in SAS and bi-plot analysis of data was conducted to determine relationships among measured field, yield and grain quality parameters across environments. Each barley type performed differently at each location throughout Texas, however, similarities in performance were found at locations across harvest years. Insect pressure was not major limiting factors to TCAP barley

performance at all locations used. However, bird damage and rust (Harvest Year 2014 only) was evident and did affect yield of spring six-row barley in McGregor, TX.

By testing various TCAP barley breeding lines and comparing them to commercially available varieties, the project will contribute new information on barley germplasm from breeding programs within the US and identify lines adapted to varying Texas environments. Compared to other small grains, barley is more drought and salt tolerant and may be a desirable option for high-salinity soils and drought-prone regions of the state. Barley is a useful crop, with current and developing markets in Texas for feed and malting. By identifying adapted lines that can be released as commercial varieties in Texas, this research may increase yield potential and profitability of barley versus other crops. Increasing barley acres could potentially improve food security by increasing food production under stressful environments. Cropping systems would also diversify and could provide locally sourced, more sustainable food ingredients for consumers.

DEDICATION

To my family.

For their love, support and enthusiasm.

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Contributors

This work was supervised by a thesis committee consisting of chairman, Dr. Clark Neely (Dept. Soil and Crop Sciences) and committee members Dr. Redmon and Dr. Ibrahim of the Department of Soil and Crop Sciences, Dr. Knutson, Department of Entomology and Dr. Mark Welch of the Department of Agricultural Economics.

All work for the thesis was completed by the student, under the advisement and guidance of the committee members listed in the paragraph above.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

History of Barley

Barley (*Hordeum vulgare* L.), is a short-season, early maturing grain crop from the parent species *Hordeum spontaneum*. The family *Hordeum* is an ancient species, splitting from wheat (*Triticum aesstivum* L.) nearly 13 million years ago. There are 32 recognized species of *Hordeum*, originating in Southwest Asia 12 million years ago and in North America 4 million years ago. Barley belongs to the group *Triticeae*, a subgroup of the grass family *Poaceae*. Wheat, rye (*Secale cereal*e L.) and triticale (*Triticosecale*) are part of this family (Von Bothmer and Komatsuda, 2011). Barley was one of the world's first crop to be domesticated, dating back approximately 10,000 years to the Fertile Crescent (Badr et al., 2000). Historians have found writings about barley as early as 1700 BC. Egyptians used barley as both a feed and food crop and are credited for developing brewing (Atkins, 1980). Soon after its establishment in the Fertile Crescent, growing barley became popular in North Africa, the Far East, Asia and Europe (Von Bothmer and Komatsuda, 2011).

Barley is the fourth most important cereal crop in the world behind wheat, maize (*Zea mays* L.) and rice (*Oryza sativa* L.) (Brown et al., 2001). It comes in various forms, which differ in growth habit and seedhead type. Six-row barley has three kernels developed from each node, giving it a "six-rowed" look. Two-row barley has a smaller, slender seedhead versus six-row and fewer, but larger seeds per head. Winter barley types are short-day sensitive and need to undergo vernalization. Vernalization requires exposure to cold temperatures (0-7 ^{o}C) for approximately 30 days for a plant to flower in the spring and produce grain without negative impacts on yield (Schmuetz, 1978). Spring barley cannot grow in climates with cold temperatures. Lastly, facultative barley can act as either a spring or winter type. Facultative barley does not require a vernalization period, but can overwinter (Atkins, 1980).

Barley has remained an important cereal crop worldwide for several reasons including its ability to adapt to a wide variety of climates and multipurpose use as a livestock feed and human food and malt product (Brown et al., 2001). Compared to other cereal grains, barley can grow in latitudes as far as 65^{o}N in countries like Norway and elevations as high as 4500 meters (m) in countries like Peru (Ulrich, 2011). When compared to wheat, barley performs better under drought conditions and high salinity soils. Barley is however, subject to most of the same pests, disease and weather hazards as wheat and is not well-adapted to high humidity and water-logged environments (Harman et al., 1988; Ulrich, 2011).

Barley from a Global Perspective

A significant amount of barley is grown on almost every continent in the world and it plays an important role in many people's lives. Since the 1990s, global worldwide production of barley has decreased from 178 million metric tons (MMT) to 144 MMT in 2014. Over 78% of the world's barley is grown in Europe and Asia combined. In 2014, Russia (20,444,258 metric tons), France (11,770,682 metric tons) and Germany

(11,562,800 metric tons) were the top 3 barley-producing countries in the world. North America contributes approximately 11% (FAOSTAT, 2016).

The Food and Agriculture Organization (FAO) indicates from 2000 to 2005, world trade of barley grain was worth $3 billion US dollars per year (USD yr^{-1}) and world trade of barley for malt purposes was $2 billion USD yr^{-1}. Germany, United Kingdom, France and Belgium use barley mainly for malt production. Ulrich (2011) stated 94% of barley from the countries previously mentioned is used for beer, 4% for distillation for whiskey and 2% for food use. An increase in consumption of beer has increased the use and production of barley as a malt product over the past few years.

Barley is the fifth most popular crop produced worldwide and the fourth most produced cereal grain on a dry weight basis. At one point in the 1980s, barley production was twice as much as soybean (*Glycine max*) production, but has since declined by 12% (Ulrich, 2011). Technological limits, government regulations, higher-profiting crops and climate are some factors having affected barley production over the years.

Barley in the United States

Barley is believed to have entered the United States (US) in two ways: to New England and the Atlantic coast with colonists from Europe and to the southwest with the Spaniards (Atkins, 1980). After the 1800s, settlers began to move west and barley traveled with them. It was soon discovered barley grew better in fertile Midwest soils versus sandy coastal-type areas.

While the epicenter of barley production in the US is based in five states, it can be found growing in the Eastern and Southwestern parts of the country as well (Figure 1.1). Each region in the US varies in production and type(s) of barley grown. Idaho, Minnesota, Montana, North Dakota and Washington are the top barley-producing states in the US, planting approximately 82% of the total barley acreage in the 2015 planting season (WASDE, 2016).

In the US, 23% of barley is used for animal feed and 77% is used for food, seed and industrial purposes. In contrast, 83% of wheat produced is used for human consumption and 17% is used for animal feed (WASDE, 2016). Table 1.1 describes the land use and production trend for both barley and wheat between the years 2014 and 2016. In 2000, the country's demand for malt was 14.97 MMT (Brown, Hill and Velasco, 2001). Figure 1.2 shows the price trends compiled by USDA of barley grain, malt barley, wheat and corn grain on a \$ metric ton^{-1} (Mt) from 2000-2016. Overall, price trends of each commodity have fluctuated similarly over the years. Within the last four years, corn grain prices have not declined as much compared to the other commodities.

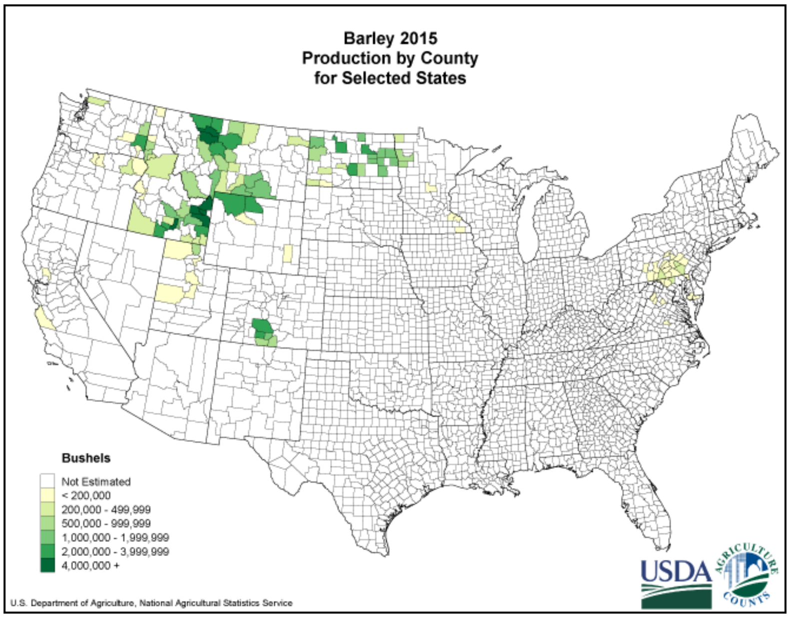

Figure 1.1: 2015 barley production in the United States. Shaded counties on map denote barley production; the darker the color, the more barley is produced. Map taken from USDA National Agriculture Statistics Service (2016).

Table 1.1: Land use and production of barley and wheat as feed grain, 2014-2017. Data compiled from the USDA World Agricultural Supply and Demand Estimates (WASDE, 2016).

	Barley			**Wheat**		
Weight of 1 bushel (kg)	21.7			27.2		
	2014/15	**2015/16**	**2016/17**	**2014/15**	**2015/16**	**2016/17**
Area harvested (million ha)	1.0	1.3	1.1	18.8	19.1	17.3
Average bushel ha^{-1}	179.5	170.2	175.4	108.0	107.7	120.0
Total million bushels harvested	182	214	193	2,026.3	2,051.8	2,077

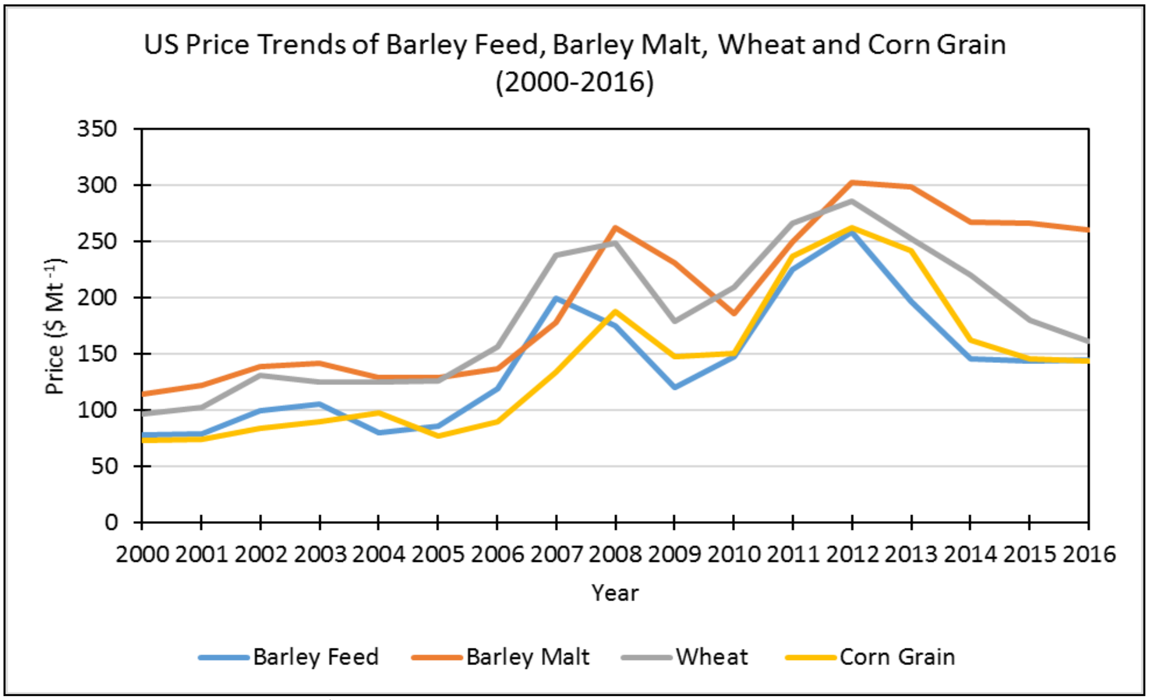

Figure 1.2: Price trends ($ Mt^{-1}) of barley feed, barley malt, wheat and corn grain in the United States (2000-2016). Data compiled from USDA National Agricultural Statistics Service (2016).

Barley in Texas

Since the late 1500s, barley has been an important crop in Texas. Barley arrived in the state through El Paso from Mexico between 1598-1685 and through south and east Texas with the establishment of missions in the 1700s (Atkins, 1980). As the numbers of settlers and missionaries increased, the cultivation of barley slowly spread across the state.

Varieties grown in Texas depended on their path of entry. Coast-type barley, originating from northern Africa, traveled to Texas with missionaries. This spring type variety grew well in central and western areas of the state, but not in south Texas. Barley originating from Europe were mainly two-row spring types and came to Texas with settlers from northern and eastern states. Producers found winter barley was more successful versus spring due to its ability to withstand cooler temperatures, drought and disease (Atkins, 1980). The Texas Agriculture Census of 1887 showed that barley production covered 4,682 ha. Cotton (1,319,263 ha), corn (1,185,431 ha) and wheat (210,525 ha) were the top three field crops produced (Foster, 2001). Introduced barley lines from Tennessee increased planted acres to 36,017 ha in the 1920s and by 1961, harvested barley acres peaked at 170,372 ha (Atkins, 1980). After the 1960s, barley production began to decrease. The 1987 Texas Agriculture Census report showed that 5,434 ha of barley were harvested, in comparison to 1,476,739 ha of wheat harvested the same year. Today, barley is planted on less than 12,000 ha across the state and is mainly used as a dual-purpose grazing and grain source for cattle (~4,700 ha) (FSA, 2015).

Texas Agricultural Experiment stations played an important role in producing barley types that performed well across the state's different environments. Researchers found winter barley with prostrate growth habits (grow low to the ground) and high cold tolerance was well-adapted to the High Plains. Intermediate types of winter barley with upright growth habits, moderate cold tolerance and no vernalization requirement were best for pastureland in the Rolling Plains and East Texas. Some of the first barley varieties adapted to Texas were, 'Finley', 'Wintex' and 'Texan'. Over the years, more varieties were released including, 'Cordova' in 1938—a more disease-resistant and high quality grain and forage variety. 'Goliad' and 'Tunis', two varieties with good disease resistance and forage characteristics were also released (Atkins, 1980). More recently, Texas A&M Agriculture Experiment Station released two winter barley varieties for commercial use. The first, 'TAMbar 500', was released in 1991 and is ideal for production in the High Plains. It is a medium to late-maturing variety that has some resistance to Barley Yellow Dwarf Virus and complete resistance to powdery mildew and the leaf rust pathogen *Puccina hordei* (Marshall et al., 1993). The second, 'TAMbar 501', was released in 2001 and is commonly used as a feed-type barley in central, east and south Texas. This variety is early-maturing, has good winter hardiness and resistance to Barley Yellow Dwarf Virus (Marshall et al., 2003).

Common Barley Diseases in Texas

Barley is susceptible to many of the same diseases and viruses as wheat, including rust and barley yellow dwarf virus. The following subsections will discuss each further.

Rust

Historically, rust has been a problem in cereal crops since the time of the Romans and today can affect cereal crops grown across the US (Paulitz and Steffenson, 2011). Three types of rust found on barley in Texas are: stripe, stem and leaf rust. The first documented case of stripe rust in the state occurred on barley research plots at the Texas A&M AgriLife Small Grain Breeding nursery in Uvalde, TX in April 1991 (Marshall and Sutton, 1995). Although barley is planted on a small amount of land in Texas, rust is still present and can potentially impact crop performance and yield if not controlled.

All rust types are caused by a fungus, belonging to the genus *Puccina* (Paulitz and Steffenson, 2011). Stripe rust in barley is due to infection by *Puccina striiformis* sp. *hordei* while wheat stripe rust is due to infection by *Puccina strifformis* sp. *tritici* (Yan and Chen, 2006; Line, 2002). *Puccina graminia* sp. *tritici* causes stem rust in wheat and barley and *Puccina recondita* sp. *tritici* causes leaf rust in wheat and barley. Formation of rust pustules on the leaf blades, sheath or stem of the plant can occur in either warm or cool environments, depending on the type of rust causing the infection (Paulitz and Steffenson, 2011; DeWolf et al., 2010). Stripe rust prefers cooler temperatures, while stem and leaf rust prefer warmer temperatures. The color of the pustules varies from a light orange or yellow hue for stripe rust, to a brick red or brown color for stem and leaf rust. The pattern also varies, depending on the specific type of rust—stripe rust forms stripes on the leaf blades, leaf rust forms small oval pustules scattered randomly across infected leaf tissue and stem rust forms oval pustules that erupt in clusters on both sides of infected stem tissue (DeWolf et al., 2010).

All-stage (AS) and high-temperature adult-plant resistance (HTAP) have been identified in both wheat and barley breeding programs. All-stage resistance begins at seedling stage and protects the wheat from a rust infection during all growth stages. The second resistance type, HTAP, protects adult plants against *Puccina* at high or low temperatures only (Chen, 2007). One disadvantage to AS resistance is that it is race specific, meaning it only protects the plant against certain strains of *Puccina*. In addition, AS is not considered "durable" because new races of *Puccina* can form and overcome the AS resistance. In contrast, HTAP resistance is both durable and not race specific (Yan and Chen, 2006).

Having both AS and HTAP resistance would be an ideal combination for protection against rust, but it is genetically difficult to do. The exact location of genes on the chromosome is still unknown (Yan and Chen, 2006). For example, through genetic testing, Chen and Line (2003) identified approximately 26 different genes in 18 barley genotypes for stripe rust resistance. They found that Grannenlose Zweizeillige, a two-row barley variety originating from Ethiopia, showed resistance to all races of barley stripe rust found in the US (Yan and Chen, 2006). Although this would be a good variety to incorporate into US barley breeding programs, identifying the resistance gene on the chromosome has been unsuccessful.

In addition to growing resistant and/or tolerant varieties, rust control with fungicides is also possible. In Texas, foliar application of fungicides increased barley grain yield by 41% and increased 1000-kernel weight by 33% when compared to fields without foliar applications (Chen, 2007). There are numerous registered fungicides available for rust control in barley. Some examples include: Quadris® (ai: azoxystrobin), Stratego® (ai: propiconazole, trifloxystrobin), Tilt® (ai: propiconazole), Headline® (ai: strobilurin) and Quilt® (ai: azoxystrobin, propiconazole).

Barley Yellow Dwarf Virus

Barley yellow dwarf virus (BYDV) can be found on most cereal grains in addition to barley. This virus is caused by the genus *Luteoviridae* (Ingwell and Bosque-Pérez, 2015). This virus is primarily transmitted by the bird cherry-oat aphid (*Rhopalosiphum padi* L.). The virus enters the phloem of barley causing a range of problems such as dwarfing of the plant, failure to head and reduced grain yield (Ulrich, 2011; Ingwell and Bosque-Pérez, 2015; Bynum et al., 2012).

Unmanaged native grasses surrounding fertile cropland can host BYDV-infected aphids (Ingwell and Bosque-Pérez, 2015). Once a barley plant is infected, yellowing and stiffness of the leaves occur and the plant gradually ceases production. Yield losses can be a significant issue for producers. In the US, average yield losses in barley from this virus can range between 11 and 37%. Once case in the US in 1989, barley crop loss from BYDV was valued at $48.5 million USD (Miller and Rasochová, 1997). Cooler temperatures (15-18 ^{o}C) and a high light intensity are favorable conditions for continuing the BYDV cycle once it is established in the plant (D'Arcy and Domier, 2005).

Proper management and control measures are vital to prevent crop loss. Jones et al. (1970) found that most barley varieties originating from Ethiopia have higher tolerance to BYDV compared to other varieties. Proper planting dates are also important to reduce aphid infestations. Early fall plantings are less desirable because aphids are highly active during this time (Marshall and Rashed, 2014). If planting barley in the springtime, an earlier planting date is desirable because seedlings will have a chance to establish before aphid numbers increase. Lastly, insecticides, specifically seed treatments, can slow field infestations. Insecticides containing active ingredients imidacloprid or thiamethoxam protect seedlings during the first 4-6 weeks post-planting (Marshall and Rashed, 2014). A producer can monitor aphid populations throughout the growing season and a foliar applied insecticide can be used, however, it is often not practical due to high costs (Marshall and Rashed, 2014). Insecticides have the potential to significantly reduce aphid numbers, thus lowering the risk of crop loss due to BYDV (D'Arcy et al., 2000).

Common Barley Pests in Texas

Barley is subject to much of the same pests as wheat and other small grains. The following subsections will discuss aphids and Hessian fly as two possible pests of barley across the state.

Aphids

Aphids (*Aphidoidea*), are soft-bodied insects that feed on small grains, ornamentals, trees and shrubs. Using their mouth, they pierce through a stem or leaf and feed primarily in the phloem of the plant. Aphid feeding results in leaf discoloration, stunting of plant growth, yield loss and in severe cases, death of plants. Aphids produce a sticky sap known as "honeydew". Honeydew is a favorable food source and environment for the fungus *Capnodium* to establish. This fungus produces a substance on leaves called "sooty mold" (Townsend, 2000). Sooty mold can block sunlight from reaching plant cells, thus reducing photosynthesis and overall productivity of the plant (Townsend, 2000; Drees, 1996). The three most common aphid types that affect barley in Texas are, Russian wheat aphid (*Diruaphis noxia*), greenbug (*Schizaphis graminum*), and bird cherry-oat aphid (Bynum et al., 2012). All three aphid types secrete toxins that affect plants; the role of the bird cherry oat aphid as a vector of BYDV is discussed above.

Early detection is important when controlling aphids, as they have an incredibly fast reproduction rate (Townsend, 2000). Seed treatments, as discussed earlier, can control aphids for 4-6 weeks post planting. However, they are expensive and must be applied at planting time, before it is known that an aphid infestation will develop. Foliar applied insecticides, if needed, can be used in place of seed treatments and can be applied later in the season. The barley varieties 'Post 90' and 'STARS 1501B' are resistant to greenbug (Armstrong et al., 2016). Research conducted by the USDA Agriculture Research Service in Stillwater, Oklahoma has found that barley lines originating from Pakistan, Turkmenistan and Oklahoma have resistance against 14 known greenbug biotypes. Two genes, *Rsg1* and *Rsg2* are the only greenbug-resistance genes in barley. All known barley varieties resistant to greenbug carry the gene *Rsg1* (Armstrong et al., 2016). Research is still on-going to find more barley lines and varieties that carry the *Rsg2* gene for greenbug resistance.

Hessian Fly

Hessian fly (HF) (*Mayetiola destructor*), was first discovered in Russia, but traveled to the northeastern US in 1779 with Hessian troops fighting in the Revolutionary War. Over the next hundred years, HF spread across the US, reaching Texas around the 1880s. By 2005, HF was reported in 67 Texas counties (Morgan et al., 2005).

Although HF prefers to infest wheat, barley can also be a host. During summer, HF remains inactive in a larval state on residual wheat/barley stubble in fields (Morgan et al., 2005). Adults emerge in late summer and early fall when temperatures cool and precipitation increases. One or more broods of larvae develop during the fall and reproduction then slows during the winter. As temperatures increase in late winter, adults become active once again and one or more broods of larvae will develop in the spring. Adults live for 2 days, during which they mate and lay eggs. Eggs hatch within 10 days and larvae begin to feed on the host plant (Morgan et al., 2005).

Hessian fly can drastically affect the productivity and yield capabilities of the plant. In seedlings and tillering stages, HF can stunt growth and even kill the plant, while in mature plants, stem breakage can occur due to HF feeding. This leads to harvest losses from lodging and low grain yield because of poor nutrient delivery to the seedhead during kernel formation (Harris et al., 1996).

Once a field is infested with HF, there is no remedial control. Producers can prevent infestations with management practices such as, planting resistant varieties, delaying fall plant date and using seed treatments to suppress fall infestations. A study by Harris et al (1996) showed that in 1989, producers who planted HF-resistant barley cultivars in the US resulted in approximately 95% reduction in HF population—a savings of over $200 million USD. Another HF study conducted by Hill et al (1952) discovered that most of the HF-resistant barley varieties tested had origins tracing back to Egypt and northern Africa. Plant breeders may be able to take advantage of this information to continue to find highly HF-resistant barley cultivars.

Malting and Craft Breweries in Texas

Beer is one beverage that has stood the test of time and has played an important role in Egyptian, Medieval and American Western eras. As defined by Helweg (2013), beer is “a beverage brewed, primarily from malted barley, hops, yeast and water”. Barley has remained a staple for beer production because it contains almost every ingredient required to make a high-quality beverage.

The Brewing Process

Four ingredients are typically needed when brewing: barley, hops, water and yeast. The first step, malting, allows enzymes to breakdown complex sugars in the kernel into simple sugars such as maltose and proteins into amino acids. The process of malting begins by soaking the barley kernels to induce germination (Helweg, 2013). Once the grain begins to sprout, the grain is heated to stop germination.

When malting is complete, the kernels are crushed, exposing the starch and soaked again. This process reactivates the enzymes which convert the newly exposed starch into sugar, producing the sugary liquid "wort". Hops are incorporated into the wort to add bitterness to the beer. After this process, yeast is added and fermentation begins. The yeast consumes the sugars and through various cellular processes, ethanol and carbon dioxide is produced, giving the beer its alcohol content and carbonation (Helweg, 2013).

There are two main types of fermentation processes which influence the final beer produced. "Top fermenting yeast producers" are used to make ale. Ale is fermented at a higher temperature and has a higher alcohol content compared to lager. A lager is produced by "bottom fermenting yeast producers" at a cooler temperature for a longer period. The lager style beer is the most common beer consumed in the world (Helweg, 2013). The amount of barley needed to produce one barrel of beer varies depending on the type of beer being produced.

Desired Characteristics for Malt Barley

Malt analysis is an important aspect for maltsters and brewers, as it helps determine the type of barley they need to use. Analysis of barley is broken down into three main categories: physical analysis, wort analysis and chemical analysis (Bies and Roberts, 2012). Parameters tested in each category will be discussed further in this section.

Physical analysis is the physical make-up of the barley grain and includes assortment, bushel weight and moisture. Assortment, also known as “plumpness”, can help a brewer determine the amount of endosperm in the seed; a plumper seed has more endosperm. The plumper the seed, the lighter the color and higher yielding malt is to be expected. Ideally, barley being used for malt should contain 80% or greater of plump seeds. The second parameter in physical analysis is bushel weight. Although bushel weight is not as important for brewers when brewing beer, it is an important parameter to determine storage of barley. The last parameter, moisture, is important for brewing beer. A low moisture barley can result in breakage during the brewing process, while a high moisture barley can shorten the shelf life of the beer and affect the brewing process. The ideal moisture range for malt barley is 3-6%, but this can vary depending on the type of brew being produced (Bies and Roberts, 2012).

The second category, wort analysis, consists of color, malt extract, wort viscosity, soluble/total protein ration (S/T ratio) and free amino nitrogen (FAN). Malt extract measures the amount of fermentable sugars in a kernel. A higher malt extract increases the alcohol that can be produced. This parameter is measured by malting the grain and measuring the amount of soluble sugars in the wort, the liquid extracted during the mashing process (Trainor, 2016). The third parameter, wort viscosity, is the measure of the liquid's ability to resist flow through a capillary column (Bies and Roberts, 2012). Too high or too low viscosity malt can cause production issues in the brewhouse. An ideal range of viscosity for malt is between 1.45 and 1.60 centipose (Bies and Roberts, 2012). Wort contains sugars used by yeast during the fermentation process. Kernels with low viscosity will germinate more uniformly and will contain less cell wall material, while a high viscosity kernel contains more cell wall material, slowing down the germination process and affecting overall fermentation (Trainor, 2016). The S/T ratio is the ratio of the soluble protein and total protein in the malt. An S/T ratio of 30 is ideal; too high of protein can decrease the amount of extract and increase color. The last parameter in wort analysis is FAN, which measures how many free aminos are available to yeast during the fermentation process. Free amino nitrogen should ideally be ≥180 parts per million (ppm) (Bies and Roberts, 2012).

Chemical analysis, the last category of malt analysis, consists of alpha amylase and diastatic power. Alpha amylase indicates the ability of the malt to convert to mash properly (Bies and Roberts, 2012). Alpha amylase is an enzyme that breaks down starch into sugar for yeast to use during the fermentation process. An all barley mash needs an α-amylase level of at least 30, while a malt with other cereal grains needs a higher level (Bies and Roberts, 2012). Lastly, diastatic power measures the amount of α-amylase, β-amylase and limit-dextrinase in the kernel. These enzymes are critical to convert starch to sugar. Enzymatic activity is observed in the malt to measure this parameter—the lower the activity, the less potential for a high-quality malt extract, ultimately resulting in a lower quality beer (Trainor, 2006). For an all barley mash, a level of ≥50 is needed (Bies and Roberts, 2012).

In addition to these parameters, brewers also look for certain seed characteristics. This includes a 97% germination rate after 2-3 days, seed protein content between 9 and 11.5% and a water content of less than 13%. Aflatoxin and pesticide residues must also meet the national standards (Agribusiness Handbook, 2009).

The Texas Craft Beer Movement

A craft brewery is defined as a small privately-owned brewery that produces less than 6 million barrels of beer annually. In the United States, craft brewers tend to use spring type barleys for malting more than winter and/or facultative. Two-row spring barley is preferred for malting, as it is higher in extract and low in protein—ideal for producing lager. Two-row is grown in central MT, ID, WA and CO. Six-row spring barley can also be used for malting, but contains more enzymes which is not ideal for lager production. Six-row can be found growing in MN, ND and eastern MT (Bouckaer et al., 2016). There are currently 189 craft breweries in Texas, ranking 7th in the US. A "beer barrel" is defined as containing 117.3 liters (L) (31 gallons). Texas craft breweries produced 1,135,043 barrels of beer in 2015, which is the equivalent of 35,186.333 gallons (133,140,543.9 L) of beer. In 2014, craft brewery production in the state had a $3,770,000 impact on the economy (Craft Beer Sales by State, 2016).

Craft breweries need local malthouses to utilize locally grown barley. In general, malt dealers prefer to contract with brewers producing greater than 20,000 barrels of beer each year (Bouckaer et al., 2016). Since Texas currently has one micro-malthouse, production is limited to the malthouse's capacity. From personal communication, malt production is expected to increase to 200 tons of barley consumed in 2017 and more malthouses are planning to be built across the state.

Statistical Approach of TCAP Yield and Quality Evaluations, Bi-plot Analysis

Bi-plot analysis is a statistical tool used to graphically show relationships between different factors at the same time. Figures 1.3-1.5 were taken from Yan and Tinker (2006) and serves as a representation of what bi-plot analysis looks like. Figure 1.3 shows the relationship between oat varieties and yield parameters including: yield, groat, oil and protein. As an example, the angle between yield and groat is less than 90^o and therefore they are positively correlated—an oat variety can have both a high yield and high groat. In contrast, the angle between oil and yield is greater than 90^o meaning that they are more negatively correlated—an oat variety cannot have a high yield and a high oil content. The closer the proximity of two lines, the greater the strength of the correlation. Parameters that make either a 90^o or 180^o angle means that there is no correlation. Since the oat variety 'Ac Goslin' is closer to the parameters yield and groat, it would have both higher yield and groat, but a lower oil content because it is further from that parameter. The variety, 'Ac Rigodon' would have the opposite characteristics because it is closer to the oil parameter and further from both yield and groat.

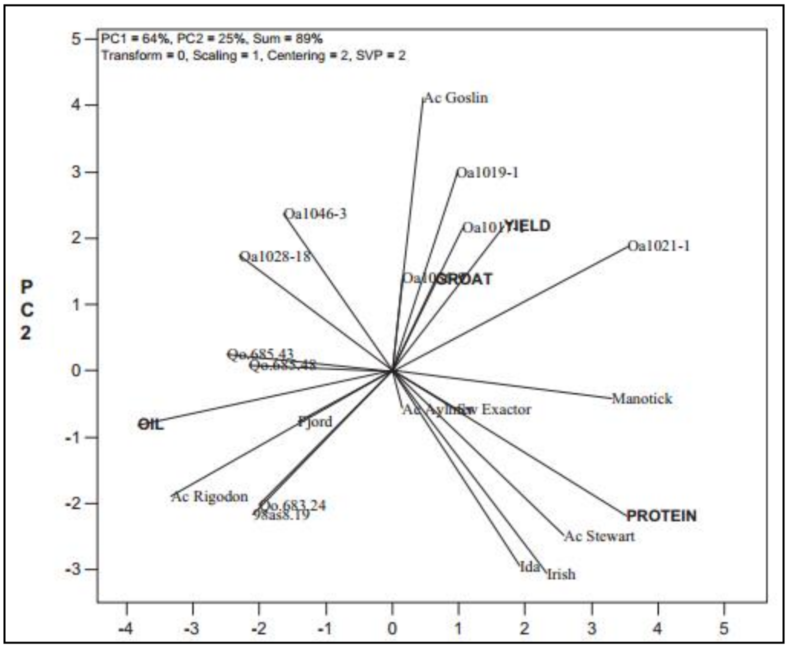

Figure 1.3: Yan and Tinker (2006), genotype by trait bi-plot. Bold text denotes parameters measured, lighter text denotes oat varieties analyzed.

Figure 1.4 is the environmental vector view in bi-plot that shows the relationship between genotype and environment noted by letters “G” and “E”, respectively. Following the same trend as the parameters in Figure 1.3 did, angles between the environments have a negative, positive or no correlation. In this case, all environments are positively correlated, except for a negative correlation between “E7” and “E8” and no correlation between “E5” and “E8”. The circles featured on the bi-plot represent the standard deviation of the environments—the further an environment is from the center of the circle, the higher the standard deviation (more variation in that environment). The environments “E7” and “E5” are the furthest from the center of the graph and therefore have the most variation. The remaining environments are closer towards the center of the graph, showing that there was less variation in those environments. The information located in the top left-hand corner of the figure discusses the experimental variation explained by the bi-plot; in this case, 78% of the experimental variation is explained. In their paper, Yan and Tinker (2006) suggest that environments with higher variation, such as “E7” and “E5”, should not be considered as test environments for further research, as they provide “little information on the genotypes”.

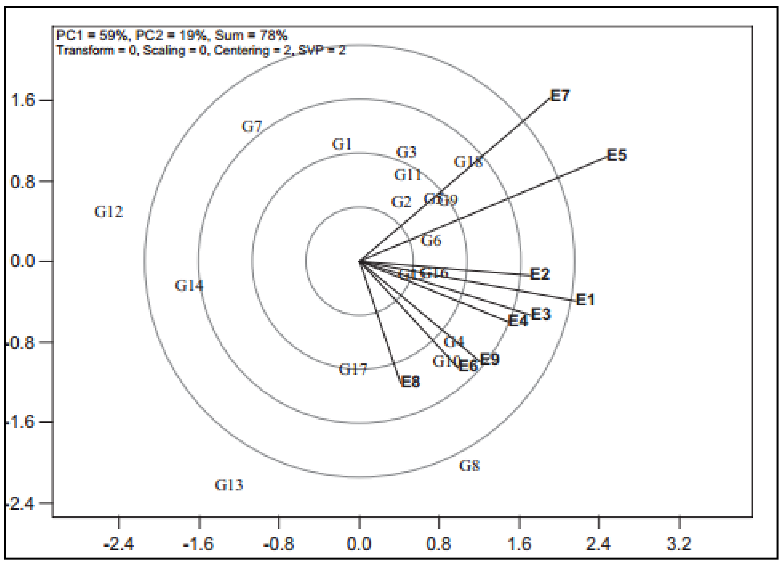

Figure 1.4: Yan and Tinker (2006), environment vector view in bi-plot. Concentric circles represent the standard deviation between environments. “G” denotes genotypes, “E” denotes environments.

The final bi-plot, Figure 1.5, shows the “which won where” analysis view. This type of analysis in bi-plot helps show how genotypes (G) performed across environment (E). Genotypes located on lines in the polygons either performed poorly or the best for a certain environment, with the genotypes in the corner either being the top performer or the worst. The genotype “G18” performed the best in environments “E5” and “E7”, while genotype “G8” performed best in all other environments. In addition, “G18” performed better at all locations than “G7”.

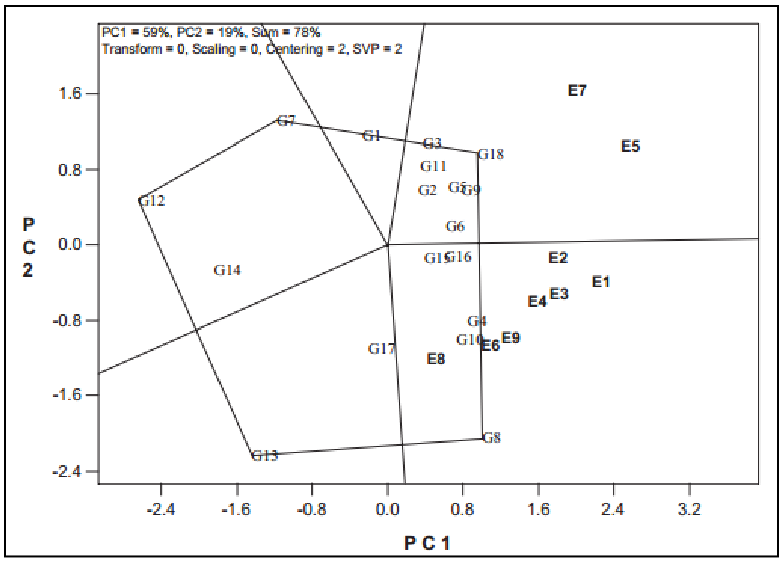

Figure 1.5: Yan and Tinker (2006), “which won where” view in bi-plot. This view shows which genotype (G) performed best in each environment (E).

Future of Barley Production in Texas

As the climate continues to change, more frequent and extreme drought events are expected to occur. In addition, temperatures will rise, causing less winter freeze injury and more heat stress, directly affecting crop growth habits and heading dates. With these changes, it will be important to update and improve current barley production practices and varieties. This may increase the adoption of drought-tolerant crops, such as barley, into cropping systems where it currently does not exist.

CHAPTER II

EVALUATION OF TCAP BARLEY LINES FOR YIELD AND QUALITY IN TEXAS ENVIRONMENTS

Introduction

Barley in Texas

Since the late 1500s, barley has been an important crop in Texas. Barley arrived in the state through El Paso from Mexico between 1598-1685 and through south and east Texas with the establishment of missions in the 1700s (Atkins, 1980). As the numbers of settlers and missionaries increased, the cultivation of barley slowly spread across the state.

Varieties grown in Texas depended on their path of entry. Coast-type barley, originating from northern Africa, traveled to Texas with missionaries. This spring type variety grew well in central and western areas of the state, but not in south Texas. Barley originating from Europe were mainly two-row spring types and came to Texas with settlers from northern and eastern states. Producers found winter barley was more successful versus spring due to its ability to withstand cooler temperatures, drought and disease (Atkins, 1980). The Texas Agriculture Census of 1887 showed that barley production covered 4,682 ha. Cotton (1,319,263 ha), corn (1,185,431 ha) and wheat (210,525 ha) were the top three field crops produced (Foster, 2001). Introduced barley lines from Tennessee increased planted acres to 36,017 ha in the 1920s and by 1961, harvested barley acres peaked at 170,372 ha (Atkins, 1980). After the 1960s, barley production began to decrease. The 1987 Texas Agriculture Census report showed that 5,434 ha of barley were harvested, in comparison to 1,476,739 ha of wheat harvested the same year. Today, barley is planted on less than 12,000 ha across the state and is mainly used as a dual-purpose grazing and grain source for cattle (~4,700 ha) (FSA, 2015).

Texas Agricultural Experiment stations played an important role in producing barley types that performed well across the state's different environments. Researchers found winter barley with prostrate growth habits (grow low to the ground) and high cold tolerance was well-adapted to the High Plains. Intermediate types of winter barley with upright growth habits, moderate cold tolerance and no vernalization requirement were best for pastureland in the Rolling Plains and East Texas. Some of the first barley varieties adapted to Texas were, 'Finley', 'Wintex' and 'Texan'. Over the years, more varieties were released including, 'Cordova' in 1938—a more disease-resistant and high quality grain and forage variety. 'Goliad' and 'Tunis', two varieties with good disease resistance and forage characteristics were also released (Atkins, 1980). More recently, Texas A&M Agriculture Experiment Station released two winter barley varieties for commercial use. The first, 'TAMbar 500', was released in 1991 and is ideal for production in the High Plains. It is a medium to late-maturing variety that has some resistance to Barley Yellow Dwarf Virus and complete resistance to powdery mildew and the leaf rust pathogen *Puccina hordei* (Marshall et al., 1993). The second, 'TAMbar 501', was released in 2001 and is commonly used as a feed-type barley in central, east and south Texas. This variety is early-maturing, has good winter hardiness and resistance to Barley Yellow Dwarf Virus (Marshall et al., 2003).

Malting and Craft Breweries in Texas

Beer is one beverage that has stood the test of time and has played an important role in Egyptian, Medieval and American Western eras. As defined by Helweg (2013), beer is “a beverage brewed, primarily from malted barley, hops, yeast and water”. Barley has remained a staple for beer production because it contains almost every ingredient required to make a high-quality beverage.

The Brewing Process

Four ingredients are typically needed when brewing: barley, hops, water and yeast. The first step, malting, allows enzymes to breakdown complex sugars in the kernel into simple sugars such as maltose and amino acids. The process of malting begins by soaking the barley kernels to induce germination (Helweg, 2013). Once the grain begins to sprout, the grain is heated to stop germination.

When malting is complete, the kernels are crushed, exposing the starch and soaked again. This process reactivates the enzymes which convert the newly exposed starch into sugar, producing the sugary liquid “wort”. Hops are incorporated into the wort to add bitterness to the beer. After this process, yeast is added and fermentation begins. The yeast consumes the sugars and through various cellular processes, ethanol and carbon dioxide is produced, giving the beer its alcohol content and carbonation (Helweg, 2013).

There are two main types of fermentation processes which influence the final beer produced. “Top fermenting yeast producers” are used to make ale. Ale is fermented at a higher temperature and has a higher alcohol content compared to lager. A lager is produced by “bottom fermenting yeast producers” at a cooler temperature for a longer period. The lager style beer is the most common beer consumed in the world (Helweg, 2013). The amount of barley needed to produce one barrel of beer varies depending on the type of beer being produced.

Desired Characteristics for Malt Barley

Malt analysis is an important aspect for maltsters and brewers, as it helps determine the type of barley they need to use. Analysis of barley is broken down into three main categories: physical analysis, wort analysis and chemical analysis (Bies and Roberts, 2012). Parameters tested in each category will be discussed further in this section.

Physical analysis is the physical make-up of the barley grain and includes assortment, bushel weight and moisture. Assortment, also known as “plumpness”, can help a brewer determine the amount of endosperm in the seed; a plumper seed has more endosperm. The plumper the seed, the lighter the color and higher yielding malt is to be expected. Ideally, barley being used for malt should contain 80% or greater of plump seeds. The second parameter in physical analysis is bushel weight. Although bushel weight is not as important for brewers when brewing beer, it is an important parameter to determine storage of barley. The last parameter, moisture, is important for brewing beer. A low moisture barley can result in breakage during the brewing process, while a high moisture barley can shorten the shelf life of the beer and affect the brewing process. The ideal moisture range for malt barley is 3-6%, but this can vary depending on the type of brew being produced (Bies and Roberts, 2012).

The second category, wort analysis, consists of color, malt extract, wort viscosity, soluble/total protein ration (S/T ratio) and free amino nitrogen (FAN). Malt extract measures the amount of fermentable sugars in a kernel. A higher malt extract increases the alcohol that can be produced. This parameter is measured by malting the grain and measuring the amount of soluble sugars in the wort, the liquid extracted during the mashing process (Trainor, 2016). The third parameter, wort viscosity, is the measure of the liquid's ability to resist flow through a capillary column (Bies and Roberts, 2012). Too high or too low viscosity malt can cause production issues in the brewhouse. An ideal range of viscosity for malt is between 1.45 and 1.60 centipose (Bies and Roberts, 2012). Wort contains sugars used by yeast during the fermentation process. Kernels with low viscosity will germinate more uniformly and will contain less cell wall material, while a high viscosity kernel contains more cell wall material, slowing down the germination process and affecting overall fermentation (Trainor, 2016). The S/T ratio is the ratio of the soluble protein and total protein in the malt. An S/T ratio of 30 is ideal; too high of protein can decrease the amount of extract and increase color. The last parameter in wort analysis is FAN, which measures how many free aminos are available to yeast during the fermentation process. Free amino nitrogen should ideally be ≥180 parts per million (ppm) (Bies and Roberts, 2012).

Chemical analysis, the last category of malt analysis, consists of alpha amylase and diastatic power. Alpha amylase indicates the ability of the malt to convert to mash properly (Bies and Roberts, 2012). Alpha amylase is an enzyme that breaks down starch into sugar for yeast to use during the fermentation process. An all barley mash needs an α-amylase level of at least 30, while a malt with other cereal grains needs a higher level (Bies and Roberts, 2012). Lastly, diastatic power measures the amount of α-amylase, β-amylase and limit-dextrinase in the kernel. These enzymes are critical to convert starch to sugar. Enzymatic activity is observed in the malt to measure this parameter—the lower the activity, the less potential for a high-quality malt extract, ultimately resulting in a lower quality beer (Trainor, 2006). For an all barley mash, a level of ≥50 is needed (Bies and Roberts, 2012).

In addition to these parameters, brewers also look for certain seed characteristics. This includes a 97% germination rate after 2-3 days, seed protein content between 9 and 11.5% and a water content of less than 13%. Aflatoxin and pesticide residues must also meet the national standards (Agribusiness Handbook, 2009).

The Texas Craft Beer Movement

A craft brewery is defined as a small privately-owned brewery that produces less than 6 million barrels of beer annually. In the United States, craft brewers tend to use spring type barleys for malting more than winter and/or facultative. Two-row spring barley is preferred for malting, as it is higher in extract and low in protein—ideal for producing lager. Two-row is grown in central MT, ID, WA and CO. Six-row spring barley can also be used for malting, but contains more enzymes which is not ideal for lager production. Six-row can be found growing in MN, ND and eastern MT (Bouckaer et al., 2016). There are currently 189 craft breweries in Texas, ranking 7th in the US. A "beer barrel" is defined as containing 117.3 liters (L) (31 gallons). Texas craft breweries produced 1,135,043 barrels of beer in 2015, which is the equivalent of 35,186.333

gallons (133,140,543.9 L) of beer. In 2014, craft brewery production in the state had a $3,770,000 impact on the economy (Craft Beer Sales by State, 2016).

For craft breweries to utilize locally grown barley, local malthouses are needed. In general, malt dealers prefer to contract with brewers producing greater than 20,000 barrels of beer each year (Bouckaer et al., 2016). Since Texas currently has one micro-malthouse, production is limited to the malthouse's capacity. From personal communication, malt production is expected to increase to 200 tons of barley consumed in 2017 and more malthouses are planning to be built across the state.

Statistical Approach of TCAP Yield and Quality Evaluations, Bi-plot Analysis

Bi-plot analysis is a statistical tool used to graphically show relationships between different factors at the same time. Figure 1.3, taken from Yan and Tinker (2006), is a representation of what bi-plot analysis looks like. This bi-plot shows the relationship between oat varieties and yield parameters including: yield, groat, oil and protein. The two parameters, yield and groat, are within proximity of each other. Since the angle between these two parameters is less than 90^o, they are positively correlated—an oat variety can have both a high yield and high groat. In contrast, the parameters oil and yield are not within proximity of each other. The angle between these two parameters is greater than 90^o meaning that they are more negatively correlated—an oat variety cannot have a high yield and a high oil content. Parameters that make a 90^o angle means that there is no correlation between them. Since the oat variety 'Ac Goslin' is closer to the parameters yield and groat, it would have both higher yield and groat, but a lower oil content because it is further from that parameter. The variety, 'Ac Rigodon' would have the opposite characteristics because it is closer to the oil parameter and further from both yield and groat.

Figure 1.4 is the environmental vector view in bi-plot. The letters “G” and “E” stand for genotype and environment, respectively. Following the same trend as the parameters in Figure 1.3 did, angles between the environments have a negative, positive or no correlation. In this case, all environments are positively correlated, except for a negative correlation between “E7” and “E8” and no correlation between “E5” and “E8”. The circles featured on the bi-plot represent the standard deviation of the environments—the further an environment is from the center of the circle, the higher the standard deviation (more variation in that environment). The environments “E7” and “E5” are the furthest from the center of the graph and therefore have the most variation. The remaining environments are closer towards the center of the graph, showing that there was less variation in those environments. The information located in the top left-hand corner of the figure discusses the variation explained by the bi-plot; in this case, 78% of the variation is explained. In their paper, Yan and Tinker (2006) suggest that environments with higher variation, such as “E7” and “E5”, should not be considered as test environments for further research, as they provide “little information on the genotypes”.

The final bi-plot, Figure 1.5, shows the “which won where” analysis view. This type of analysis in bi-plot helps show how genotypes (G) performed across environment (E). Genotypes located on the polygon either performed poorly or the best for a certain environment, with the genotypes in the corner either being the top performer or the worst. The genotype "G18" performed the best in environments "E5" and "E7", while genotype "G8" performed best in all other environments. In addition, "G18" performed better at all locations than "G7".

Conclusion

Although barley is a minor aspect of Texas agriculture, there are possibilities to use it as a feed and forage source for livestock and malting for local craft breweries. Acreage for barley has declined since the 1960s, but is currently planted on ~12,000 ha across the state. The release of 'TAMbar 500' in 1991 and 'TAMbar 501' in 2001 are two commercial barley varieties that have benefited livestock and grain producers across the state. More recently, the number of craft breweries and interest in local "Texas Beer" has had a significant impact on the state's economy—contributing approximately $3,700,000 in 2014.

As climate continues to change, more frequent and extreme drought events are expected to occur. In addition, temperatures will rise, causing less winter freeze injury and more heat stress, directly affecting crop growth habits and heading dates. With these changes, it will be important to update and improve current barley production practices and varieties. This may increase the adoption of more drought-tolerant crops, such as barley, into cropping systems where it currently does not exist.

Materials and Methods

For this project, barley lines were obtained from the Triticeae Coordinated Agricultural Project (TCAP) to screen advanced breeding material from barley breeding programs from Oregon State University, University of Minnesota and Oklahoma State

University. The TCAP consists of wheat and barley breeders from across the US with the goal of preserving and developing new varieties of wheat and barley (Director, Jorge Dubcovsky, jdubcovsky@ucdavis.edu). The first objective of this study was to evaluate and identify superior TCAP barley lines for yield and malt quality in Texas environments.

Harvest Year 2014

Headrows (HR) (1 m long, 0.4 m apart) of 463 spring (248 2-row, 215 6-row), 119 winter and 182 facultative TCAP lines (Appendix A-3 and A-4) were grown in two locations in central and south Texas, Castroville (CAS) and McGregor (MCG) in Harvest Year 2014. Table 2.1 and Figures 2.1 and 2.2 describe each location's environmental conditions, average monthly rainfall and temperature. Untreated barley seed was planted in a single replicated design (SRD) with repeated checks placed throughout. Checks were commercially available varieties and provided a yield comparison among TCAP breeding lines and commercial variety performance. Spring checks placed in the spring trial were: 'AC Metcalf', 'Conlon' and 'CDC Copeland'. Winter checks placed in the winter trial were: 'Alba', 'Maja' and 'Full Pint'. A Hege 1000 HR plot drill (76 cm long HD on a 38 cm row spacing), complete with automatic trip was used to plant. The CAS location had access to overhead irrigation and MCG was a dryland location.

Fertilizer was applied based on soil test recommendations. In CAS, no fertilizers of pesticides were applied. On February 14, 2014, 35.3 kg N ha^{-1} (UAN 32-0-0), 2.34 L ha^{-1} Dimethoate (ai: dimethoate) and a mixture of 1.75 L ha^{-1} Weedmaster (Nufarm, ai:

3,6-dichloro-o-anisic acid, 2,4-dichlorophenoxyacetic acid) and 0.0000025 L ml^{-1} of the surfactant LI 700 (Nufarm) was topdressed to the HRs at MCG.

In-field observations were taken during the growing season, as described in Table 2.4. Final field observations and plant height (cm) and plot quality were taken at harvest. In-field notes were taken on overall plant health and uniformity of each test plot before harvesting. If a plot had a great deal of lodging, bird damage, poor growth, etc. a rating of 1 would be given. A rating of 5 was given to plots that had uniform growth and no lodging or bird damage. All viable seedheads were hand harvested and placed into their respective sample bag for later processing.

In the lab, seedheads were counted, threshed (Model BT14E thresher, Almaco, Nevada, IA) to collect seed and cleaned (Model ABSO aspirator, Almaco, Nevada, IA) to remove foreign material. Table 2.4 describes the lab data that was collected after harvest. A double-screened method was used to determine kernel plumpness, a parameter used for malting characteristics. A 24 mm screen placed on a 20 mm screen all placed on a catch pan was shaken fifteen times clockwise and counterclockwise. Seed remaining on each screen was weighed (g) and divided into "plump" (>24 mm), "medium" (<24 mm and >20 mm) and "thin" (< 20 mm).

All field and lab data of TCAP lines and checks were compiled and statistically analyzed using the PROC CORR procedure in SAS (SAS Institute, 2009) to measure the association between yield and yield parameters (Appendix A-1). Prior to correlation analysis, yields of all entries were adjusted with repeating checks using the software program Agrobase (Agronomix Inc.). For this year, lines were not tested for malt quality and therefore the top yielding ~20% of winter, facultative and spring lines were replanted in small plots (1.5m x 4.5m) for Harvest Year 2015.

Table 2.1: Harvest year 2014 TCAP barley headrow location data.

Location	**McGregor, TX**	**Castroville, TX**
Date Planted	Winter: 11/14/13 Spring: 12/18/13	Winter: 11/12/13 Spring: 12/17/13
Coordinates	31ºN -97.5ºW	29.4ºN -98.8ºW
Irrigation Type & Amount Applied	Dryland 0 mm	Overhead 127 mm
Soil Type	Crawford Silty Clay	Lewisville Silty Clay
Date Harvested	06/05/14 206 Winter 169 Spring	05/15/14 184 Winter 149 Spring

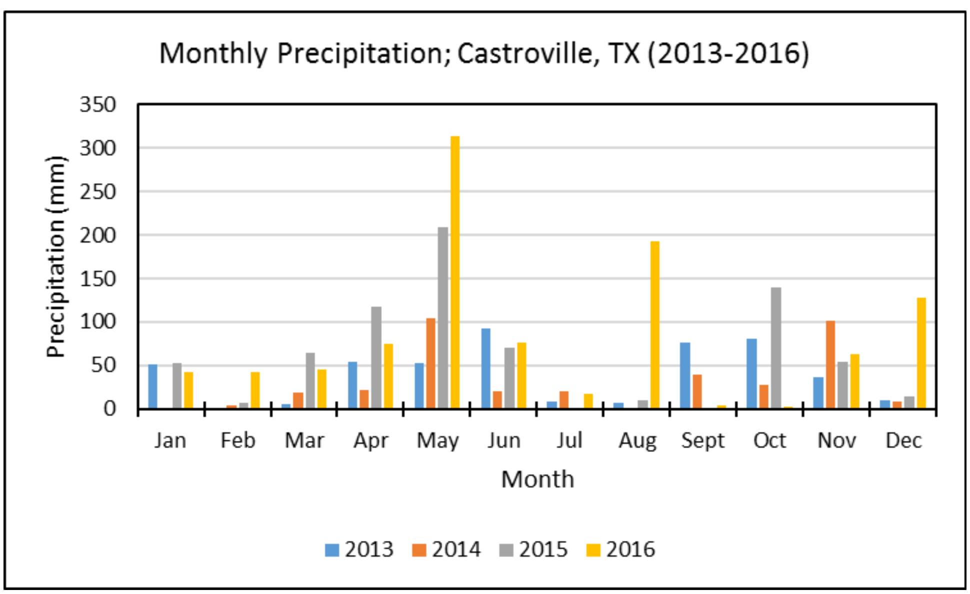

Figure 2.1: Monthly precipitation (mm) in Castroville, TX from January 2013 to December 2016.

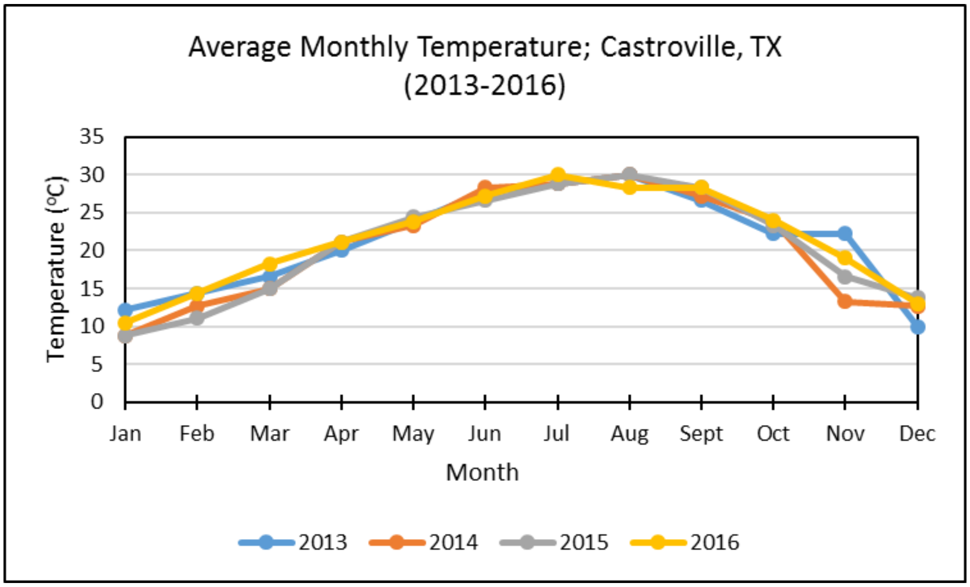

Figure 2.2: Average monthly temperature (ºC) in Castroville, TX from January 2013 to December 2016.

Harvest Year 2015

The top ~20% yielding lines from Harvest Year 2014 in larger test plots were further evaluated in Harvest Year 2015. 128 spring (64 2-row, 64 6-row), 23 winter and 45 facultative lines were planted in three locations in Texas: Dimmitt (DIM), CAS and MCG (Table 2.2, Figures 2.1-2.6). Dimmitt was planted with winter and facultative lines only, as fall planted spring barley reliability is limited in northern parts of Texas due to freeze injury from cold winter temperatures. The remaining locations, CAS and MCG were planted with winter, facultative and spring lines.

In this year, seed was treated with CruiserMaxx® Vibrance for Cereals (Syngenta, ai: Thiamethoxam, Mefenozam, Difenoconazole) and Cruiser® 5FS (Syngenta, ai: Thiamethoxam) to prevent fall insect infestation. 60 g (68 kg ha^{-1}) of each line were packaged in small envelopes for each location. If seed was limited (< 30 g, <

34 kg ha^{-1}), it was replaced with an alternative variety, 'P-919' or 'TAMbar 501' for winter and 'AC Metcalf', 'Conlon', 'CDC Copeland' or 'SY-Goliad' (wheat) for spring barley. Lines used this year were placed in a SRD with repeating checks placed throughout, same as Harvest Year 2014.

Small plots (1.5m x 4.5m) were planted using an eight-row (18 cm row spacing) planter. Two locations (DIM and CAS) had access to overhead irrigation while MCG was a dryland location. The same in-field observations were taken as Harvest Year 2014 (Table 2.4).

On January 29, 2015, in MCG, 50.4 kg N ha^{-1} (UAN 32-0-0) and a mixture of 1.55 L ha^{-1} MCPA Ester (Agri Star, ai: 2-ethylhexyl ester of 2-methyl-4-chlorophenoxyacetic acid) and recommended rate of the surfactant LI 700 was topdressed on all plots. In DIM, 70.6 kg N ha^{-1} (46-0-0) was applied on November 2, 2014 prior to planting. One week before planting, volunteer corn in the field was sprayed with Gramoxone (Syngenta, ai: paraquat dichloride) at a rate of 3.50 L ha^{-1}. Between late February and late March 2015, 3 applications of N (32-0-0) at the rate of 41.5 kg ha^{-1} was applied via fertigation.

During harvest, a Wintersteiger (Wintersteiger Ag, Ried, Austria) nursery combine (1.5 m header) was used. Due to the unseasonable amount of rain during May (harvest season), CAS was selectively hand harvested for seed increase only and was not included for statistical analysis. Harvested samples were processed in the lab and evaluated for yield components, same as Year 1 (Table 2.5). Subsamples of each line were packaged and sent to USDA Cereal Quality Testing Lab (Madison, WI) for malt quality testing including: kernel weight, color, malt extract, wort color and clarity, barley protein, wort protein and enzymes. All field and lab data of TCAP lines and checks were compiled and statistically analyzed using the PROC CORR and PROC GLM procedure in SAS (SAS Institute, 2009) to measure the association between yield, yield parameters and malt quality (Appendix A-1 and A-2). Values were designated significant at p-values less than or equal to 0.05 (*), 0.01 (**) and 0.001 (***), respectively. Any value greater than 0.05 was considered not significant (NS). Prior to correlation analysis, yields of all entries were adjusted with repeating checks using the software program Agrobase (Agronomix Inc.). Due to an unusually wet spring, barley yields were affected and therefore no lines were eliminated for Harvest Year 2016.

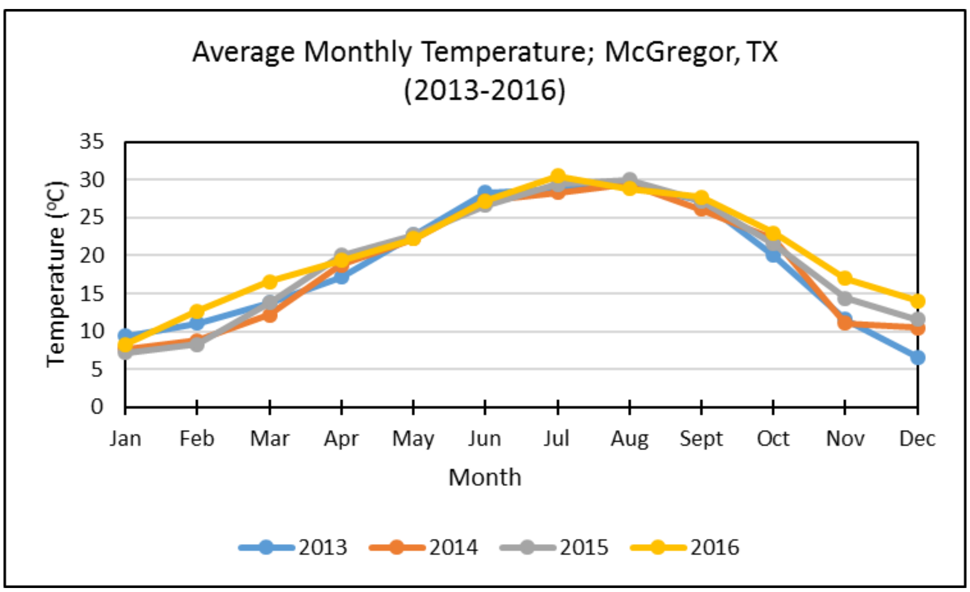

Figure 2.3: Monthly precipitation (mm) in McGregor, TX from January 2013 to December 2016.

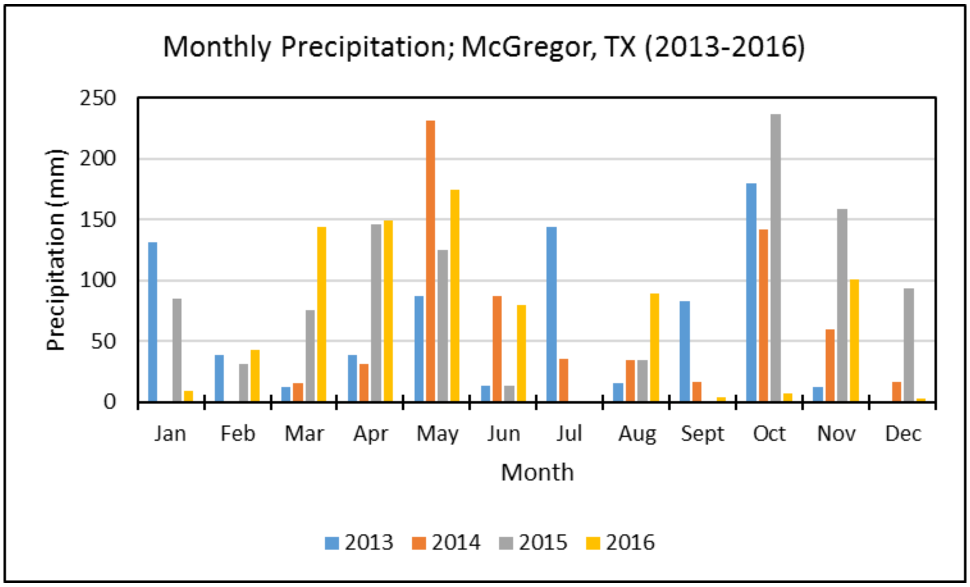

Figure 2.4: Average monthly temperature (°C) in McGregor, TX from January 2013 to December 2016.

Table 2.2: Harvest year 2015 TCAP barley small plot location data.

Location	McGregor, TX	Castroville, TX	Dimmitt, TX
Date Planted	Winter: 11/12/14 Spring: 12/09/14	Winter: 11/18/14 Spring: 12/17/14	Winter: 11/07/14
Coordinates	31°N -97.5°W	29.4°N -98.8°W	34.5°N -102.3°W
Irrigation Type & Amount Applied	Dryland 0 mm	Overhead 0 mm	Overhead 457 mm
Soil Type	Crawford Silty Clay	Lewisville Silty Clay	Pullman Clay Loam
Date Harvested	05/22/15 81 Winter 161 Spring	05/19/15 4 Winter 0 Spring	06/24/15 148 Winter

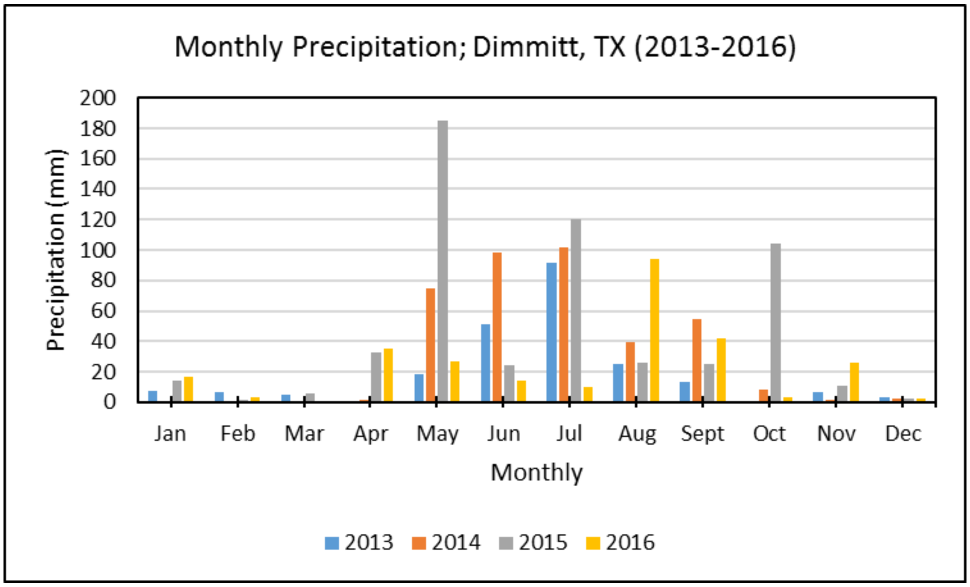

Figure 2.5: Monthly precipitation (mm) in Dimmitt, TX from January 2013 to December 2016.

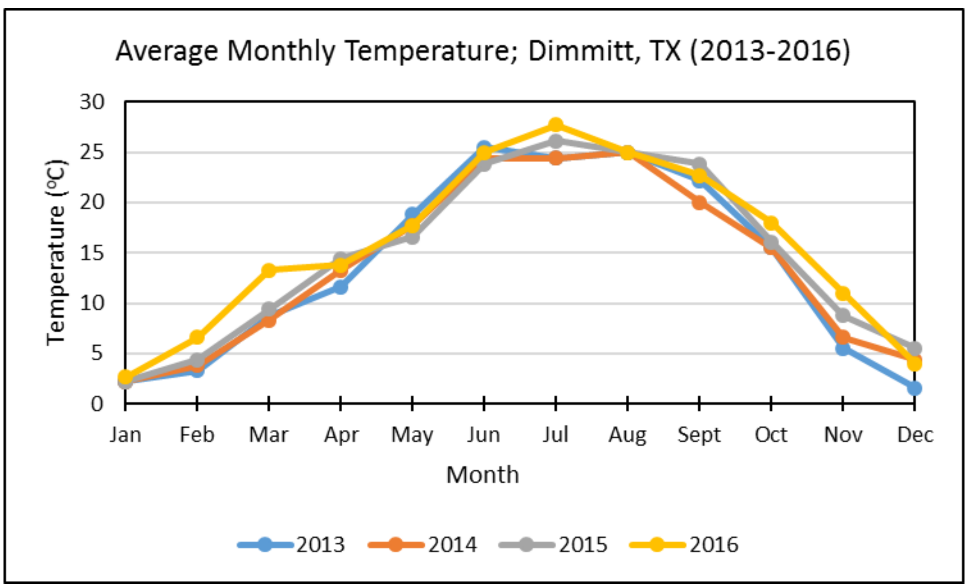

Figure 2.6: Average monthly temperature (°C) in Dimmitt, TX from January 2013 to December 2016.

Harvest Year 2016

In Harvest Year 2016, the same lines were used as the previous year in CAS, MCG and DIM (Table 2.3, Figures 2.1-2.6). 55 g (63 kg ha^{-1}) of each line was packaged for each location. Any seed envelope with less than 30 g (34 kg ha^{-1}) of barley was replaced with an alternative commercial variety, 'P-919', 'TAMbar 501' or 'TAM 304' (wheat) for winter trials and 'AC Metcalf', 'Conlon', 'CDC Copeland' or 'Expresso' (wheat) for spring trials. An alpha-lattice design containing two incomplete blocks was used with commercial checks placed within the trial. Checks were the same as the previous year, with the addition of 'TAM 304' (winter wheat) in the winter trial and 'Expresso' (spring wheat) in the spring trial. Wheat checks provided a direct comparison of barley yield in relation to a known crop with extensive yield history throughout the state. Barley was planted in small plots, using the same dimensions and equipment as in Harvest Year 2015. All locations, except for MCG had access to overhead irrigation.

In DIM, no herbicide or insecticide was applied to the field. On March 5, 2016, plots were topdressed via fertigation with 32.5 kg N ha^{-1} (32-0-0). In CAS, 599 kg ha^{-1} of fertilizer in the form of 12-8-5-2 was applied prior to planting on October 29, 2015. On March 3, 2016, a mixture of 0.87 L ha^{-1} of Dimethoate (ai: dimethoate) and 0.116 L ha^{-1} of Induce (Helena Chemical, ai: alkyl aryl polyozylkane ethers and free fatty acids) was topdressed to the plots. In MCG, a topdress application of 39 kg N ha^{-1} (32-0-0) was applied on January 27, 2016. On that same day, a mixture of 2.34 L ha^{-1} of MCPA

Ester (Agri Star, ai: 2-ethylhexyl ester of 2-methyl-4-chlorophenoxyacetic acid) and 36.5 mL ha^{-1} of the herbicide Amber (Syngenta, ai: triasulfuron) was applied.

Field maintenance, physiological notes, harvesting and yield component analysis procedures, including malt barley analysis/sampling were the same as Harvest Year 2015 (Table 2.4). Castroville was hand harvested for seedheads only due to wet field conditions prohibiting combine harvest. In addition to statistical analyses comparing yield and yield components of TCAP lines over years and locations, an economic analysis was completed to compare the profitability of barley and wheat. Bi-plot analysis was used to indicate similarities between lines grown, environment, yield components and malt quality (Appendix A-3). Data from all locations and years were analyzed based on yield (Mt ha^{-1}) test weight and malt quality score (Received from USDA Cereal Quality Testing Lab, Madison, WI). Winter, spring two-row and spring six-row were analyzed individually.

Table 2.3: Harvest year 2016 TCAP barley small plot location data.

Location	**McGregor, TX**	**Castroville, TX**	**Dimmitt, TX**
Date Planted	Winter: 11/24/15 Spring: 12/10/15	Winter: 11/11/15 Spring: 12/15/15	Winter: 12/22/15
Coordinates	31ºN -97.5ºW	29.4ºN -98.8ºW	34.5ºN -102.3ºW
Irrigation Type & Amount Applied	Dryland 0 mm	Overhead 0 mm	Overhead 178 mm
Soil Type	Crawford Silty Clay	Lewisville Silty Clay	Pullman Clay Loam
Date Harvested	05/24/16 280 Winter 312 Spring	05/17/16 280 Winter 312 Spring *(Seedheads only)*	06/28/16 280 Winter

Table 2.4: Field observations and lab evaluation data collected during this research.

In-Field Observations	**In-Lab Evaluations**
Stand Quality (0-5 scale, 0 = poor, 5 = excellent)	Seed yield (kg ha^{-1})
Growth/Maturity (Days to Heading)	Seed $spike^{-1}$ (# seeds counted)
Lodging (% plot affected)	Test weight (lbs bu^{-1})
Bird damage (0-5 scale, 0 = none, 5 = very damaged)	Moisture (%)
Insect/Disease (0-5 scale, 0 = low pressure, 5 = heavy pressure)	Single seed weight (g)
Cold damage (0-5 scale, 0 = none, 5 = very damaged)	Kernel plumpness (%)
Average height of plot at harvest (cm)	

Results

Environmental Effect on Trial Locations

During the second and third year of the research study, unusual amounts of rainfall caused significant lodging, seedhead sprouting and damage to certain locations. In

Harvest Year 2015, specific winter and spring lines in CAS were hand harvested for a seed increase only and were not evaluated. In Harvest Year 2016, CAS was hand harvested for seedheads, but was unharvestable by combine due to wet field conditions.

Facultative Barley

Figure 2.7 shows correlations of TCAP facultative barley grown in CAS, DIM and MCG from all harvest years (2014-2016). Parameters tested are shown in red, while TCAP facultative lines are shown in blue. Malt quality testing was not complete for DIM 2016 samples at the time of writing and therefore not included in analyses. Looking at each location individually, both negative and positive correlations were observed. In DIM, data was recorded for harvest years 2015 and 2016. A positive correlation between all parameters—yield (DIM_15_Y), test weight (DIM_15_TSTWT) and malt quality (DIM_15_MQ) was observed in 2015, while a highly negative correlation between yield (DIM_16_Y) and test weight (DIM_16_TSTWT) was observed in 2016. At MCG, data was recorded for harvest years 2014, 2015 and 2016. Yield in 2015 and 2016 (MCG_15_Y and MCG_16_Y) was positively correlated, but had little to no correlation with yield in 2014 (MCG_14_Y). Test weight (MCG_15_TSTWT and MCG_16_TSTWT) and malt quality (MCG_15_MQ and MCG_16_MQ) were positively correlated with each other and with yield within each respective year. A positive correlation between these two parameters could suggest that choosing TCAP barley lines with a high test weight could also select for high malt quality barley at this location. Yield in CAS was recorded for harvest year 2014 only (CAS_14_Y). A positive correlation between yield in CAS and yield in MCG 2015 and

2016 shows that TCAP facultative lines performed similarly at both locations. Yield at DIM in 2015 and yield in 2016 had a moderate negative correlated with yield in CAS. When comparing DIM and MCG locations, only DIM_16_Y and MCG_14_Y were positively correlated. All other site years were either negatively correlated or showed no correlation at all between the two locations, suggesting that TCAP facultative lines did not perform similarly for yield at both locations. One factor affecting yield performance could be the difference in irrigated (DIM) versus dryland (MCG) systems at each site. Similarly, MQ and TSTWT did not correlate well between the two sites, except for TSTWT in 2016. The standard deviation can be seen by looking at the circles located on the bi-plot. Test weight and yield in MCG in 2016 and malt quality and test weight in DIM in 2015 are the furthest from the center of the circle, showing that they are highly variable. The least variation was seen for yield in DIM in 2016. This analysis explained only 41.4% of the variation between these parameters. TCAP facultative lines, varied in their performance at all locations, as most of the lines are spread across the bi-plot. Lines located closer to the center of the bi-plot had less variation over environments, while lines further from the center had more variation.

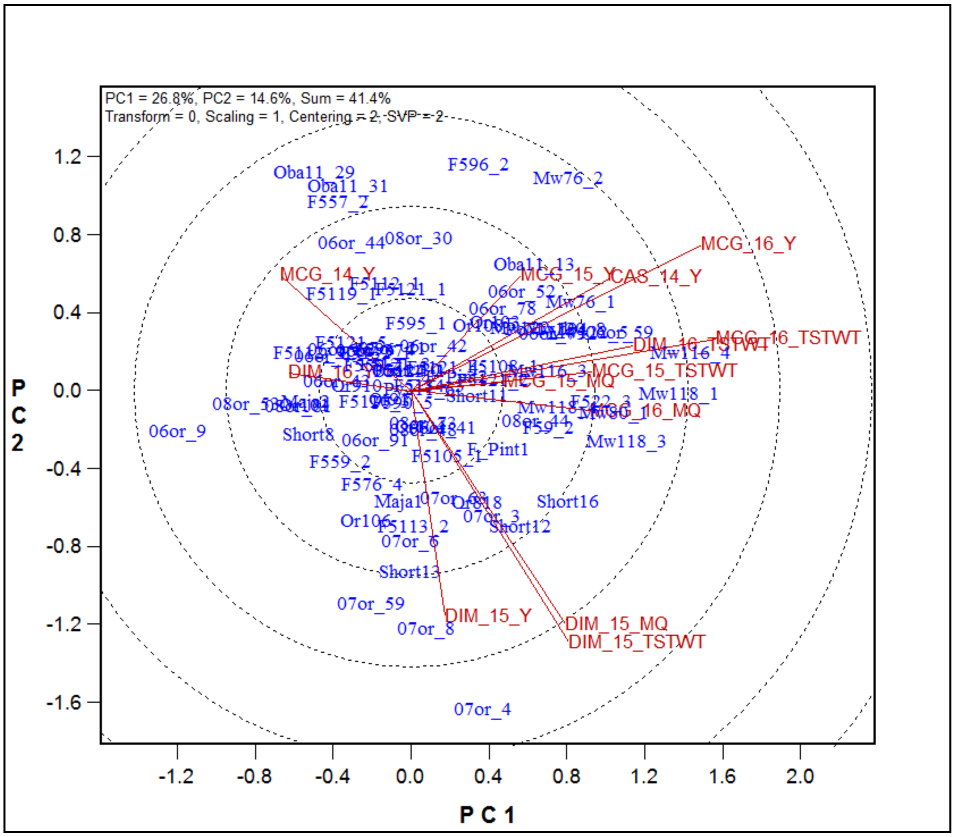

Figure 2.7: Relationship among yield parameters tested and malt quality (in red) and TCAP facultative barley lines (in blue) at all locations (CAS, DIM and MCG) from all harvest years (2014, 2015 and 2016).

Figure 2.8 is the “which won where” analysis of facultative lines and their performance at each location (CAS, DIM and MCG) over the course of the research. The TCAP line ‘07or_4’ performed best at DIM in 2015 for yield, malt quality and test weight compared to any other line tested. The line ‘06or_9’ performed the best at DIM for yield in 2016. TCAP line ‘Oba11_29’ was the highest yielding line at MCG in 2014. The TCAP line ‘Mw116_4’ was the superior line at MCG in 2015 and 2016 for test weight, malt quality and in DIM for test weight in 2016 and yield at CAS in 2014.

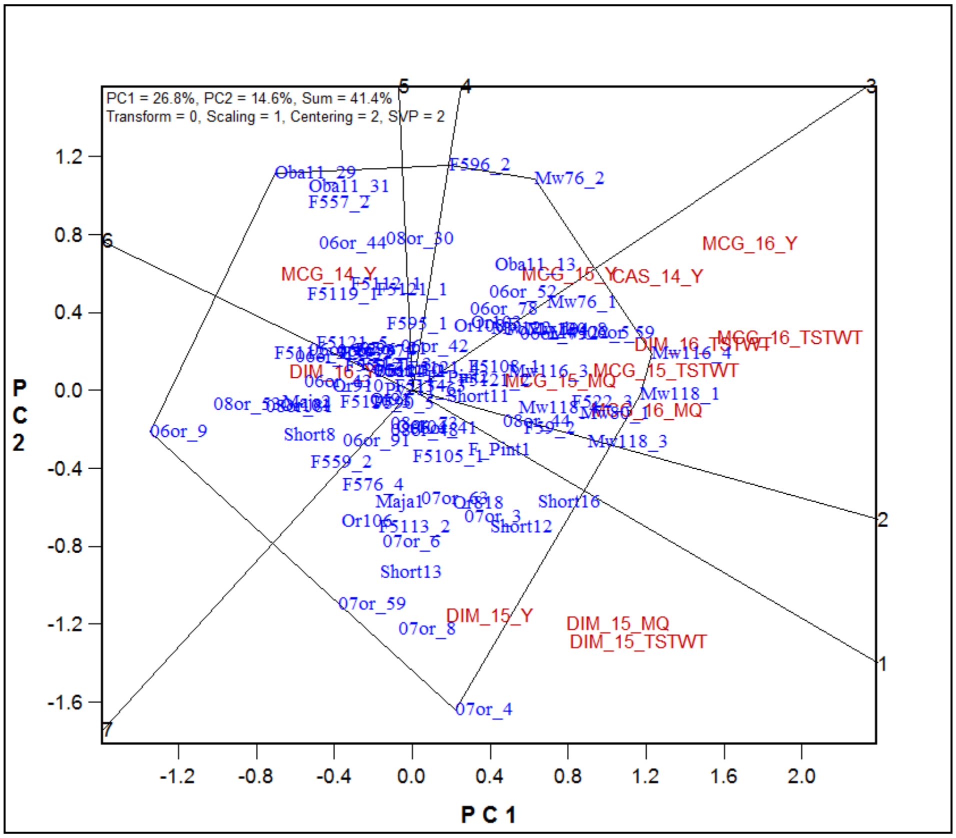

Figure 2.8: “Which won where” analysis of TCAP facultative barley lines (in blue) compared to yield parameters tested (in red) at all locations (CAS, DIM and MCG) from all harvest years (2014, 2015 and 2016).

Winter Barley

Figures 2.9 and 2.10 show bi-plot analysis between all locations where winter barley was grown (CAS, MCG and DIM) over all harvest years (2014-2016). When looking at DIM specifically, yield (DIM_16_Y and DIM_15_Y) were not correlated between years, while a positive correlation was seen between test weight over years (DIM_16_TSTWT and DIM_15_TSTWT). A positive correlation was seen between 2016 yield (DIM_16_Y) and DIM_16_TSTWT. In addition, test weight over years at DIM had a positive correlation with yield in 2015. There was no correlation between malt quality at DIM in 2015 (DIM_15_MQ) and 2016 yield and between DIM_15_MQ and DIM_16_TSTWT. A weak positive correlation existed between DIM_15_MQ and both DIM_15_TSTWT and DIM_15_Y. Negative correlations of TCAP winter barley performance at DIM may suggest that differences in cultural practices (fertilizer, irrigation, etc.) over years could have affected performance of lines. When comparing DIM yields to MCG, an extremely weak positive correlation was seen between 2016 DIM yield and yield at MCG across all years (MCG_14_Y, MCG_15_Y and MCG_16_Y). No correlation was found between 2015 DIM yield and MCG 2015 yield and a negative correlation between 2015 DIM yield and MCG 2014 and 2016 yields were seen. Yield of TCAP winter barley lines at MCG across all years were positively correlated, showing that performance of lines were fairly consistent; which was different from the performance of facultative barley at MCG. Malt quality, test weight and yield at MCG in 2015 were all positively correlated (MCG_15_MQ, MCG_15_TSTWT and MCG_15_Y). In contrast, the same parameters at MCG in 2016 were both positively and negatively correlated. Malt quality (MCG_16_MQ) and test weight (MCG_16_TSTWT) in at MCG in 2016 were positively correlated, however, each parameter was negatively correlated with yield (MCG_16_Y). When comparing yields at DIM and MCG over years with yield at CAS in 2014, MCG yield across all years was positively correlated. Both 2015 and 2016 yields at DIM were negatively correlated with CAS 2014 yield. Bi-plot analysis of winter TCAP lines at all locations only explained 45.6% of the variation seen. Dimmitt yield in 2016 and MCG yield in 2014 had the least variation, as they are closer to the center of the bi-plot.

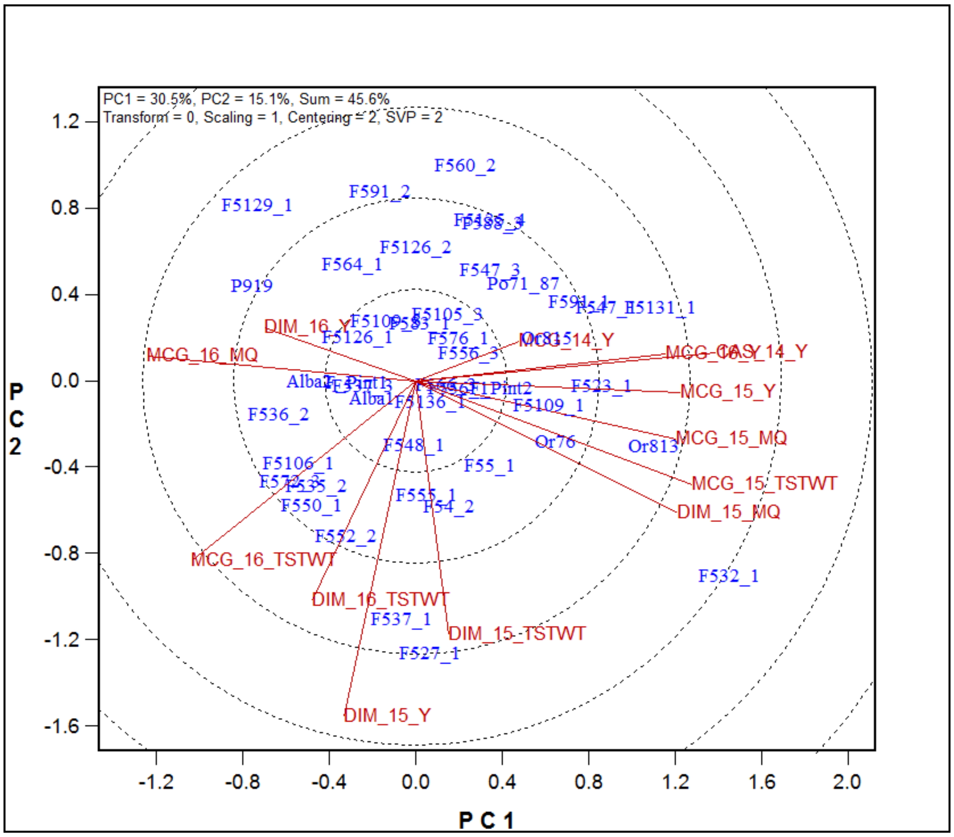

Figure 2.9: Relationship among yield parameters tested and malt quality (in red) and TCAP winter barley lines (in blue) at all locations (CAS, DIM and MCG) from all harvest years (2014, 2015 and 2016).

Figure 2.10, shows the “which won where” bi-plot analysis of winter TCAP lines tested at all locations (CAS, DIM and MCG) over all years (2014-2016). The TCAP winter line ‘F532_1’ performed best for yield, malt quality and test weight at MCG 2015, yield at MCG 2014, 2015 and 2016, yield in CAS 2014 and malt quality at DIM 2015. The winter line ‘F527_1’ performed best for yield in DIM 2015, test weight at DIM in 2015 and 2016 and test weight in 2016 at MCG. The best performing line for malt quality at MCG in 2016 and yield at DIM in 2016 was ‘F5129_1’. Lastly, the

TCAP line ‘F560_2’ did not perform well in any location, as there are no tested parameters located in that polygon.

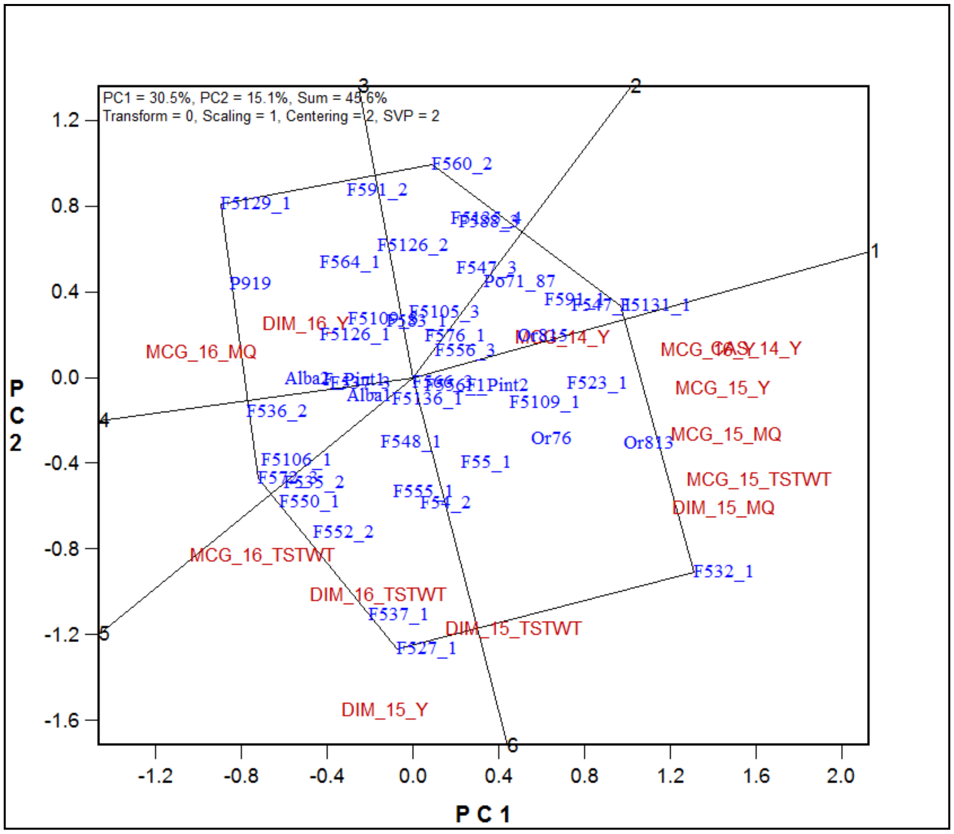

Figure 2.10: “Which won where” analysis of TCAP winter barley lines (in blue) compared to yield parameters tested (in red) at all locations (CAS, DIM and MCG) from all harvest years (2014, 2015 and 2016).

Spring Two-Row Barley

Spring two-row barley was grow in CAS (2014) and MCG (2014-2016). From the first bi-plot analysis shown in Figure 2.11, there was a positive correlation between yield at MCG in 2014, 2015 and 2016 (MCG_14_Y, MCG_15_Y and MCG_16_Y). A positive correlation between yield parameters in MCG over all three years suggests

TCAP spring two-row lines performed similarly across all variable environments. Test weight at MCG was positively correlated between 2015 (MCG_15_TSTWT) and 2016 (MCG_16_TSTWT) as well as a positive correlation between malt quality during those years (MCG_15_MQ and MCG_16_MQ). A positive correlation between these two parameters could show the potential for growing high-yielding and high malt quality TCAP spring 2-row barley in that location. Malt quality in 2016 had a strong positive correlation with MCG yield in 2016. Most of the spring two-row TCAP lines tested over the course of this study performed similarly in all locations, as shown by the blue cluster centrally located within the parameters in Figure 2.11. This bi-plot accounts for 56.3% of the variability in the test and the parameter MCG_15_MQ has the least variability compared to the others, as it is located closer to the center of the graph.

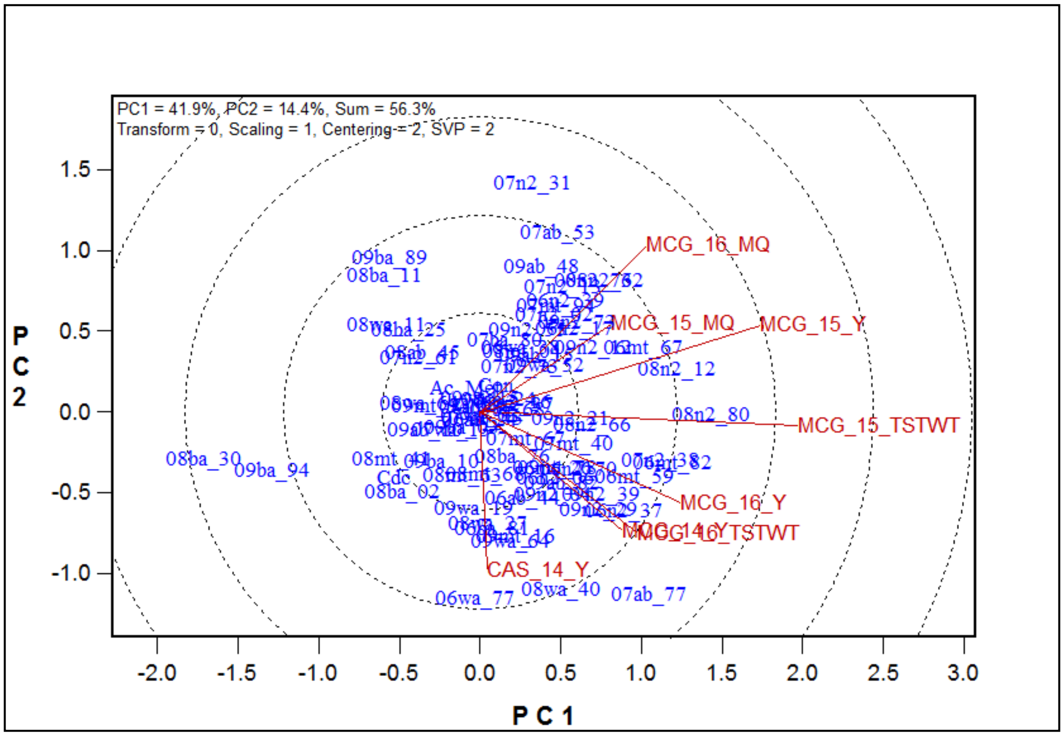

Figure 2.11: Relationship among yield parameters tested and malt quality TCAP spring two-row barley lines (in blue) at all locations (CAS and MCG) from all harvest years (2014, 2015 and 2016).

The “which won where” bi-plot analysis (Figure 2.12) shows that there are two main TCAP spring two-row lines that performed the best for certain locations and years. The TCAP line ‘08n2_80 performed best for malt quality at MCG 2015 and 2016, yield at MCG in 2015 and test weight at MCG in 2015. Lastly, the TCAP line ‘07ab_77’ performed best for yield in CAS 2014, MCG 2014 and MCG 2016 as well as test weight at MCG in 2016. Four other lines, ‘07n2_31’, ‘09ba_89’, ‘08ba_30’ and ‘06wa_77’ are not located in a polygon with parameters, indicating that they were not top-performing lines at any location over years.

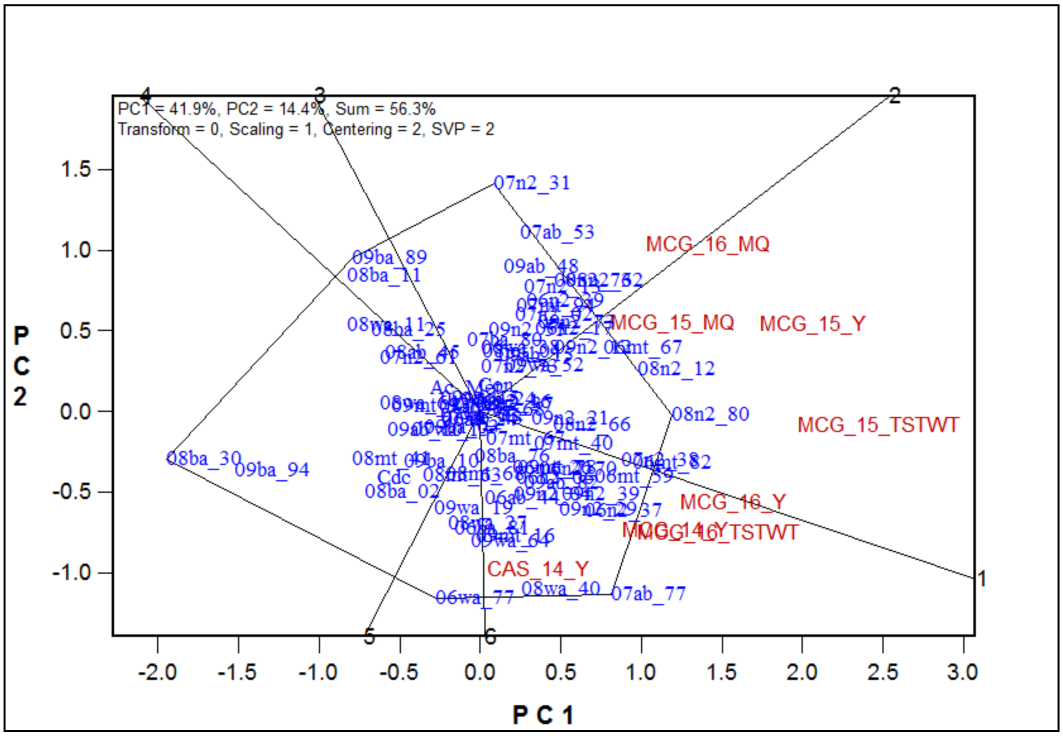

Figure 2.12: “Which won where” analysis of TCAP spring two-row barley lines (in blue) compared to yield parameters tested (in red) at all locations (CAS and MCG) from all harvest years (2014, 2015 and 2016).

Spring Six-Row Barley

Like spring two-row barley, six-row spring barley was grown in the same locations and same years. Six-row barley performed like two-row barley at all locations (Figure 2.13). Yield for all locations and years had a positive correlation. In addition, test weight at MCG in 2015 (MCG_15_TSTWT) and 2016 (MCG_16_TSTWT) had a positive correlation with yield at MCG in 2015 (MCG_15_Y) and 2016 (MCG_16_Y), respectively. Like the spring-two row, most of the TCAP barley lines performed similarly (clustered in the middle of the bi-plot), but there were some outliers. Outliers performed differently at each location and included ‘Stoneham’ (Stone), ‘Sidney’, '08n6_96' and '07ab_10'. This bi-plot analysis accounted for 54.1% of the variation in the data, with 2016 malt quality at MCG having the least variation (MCG_16_MQ).

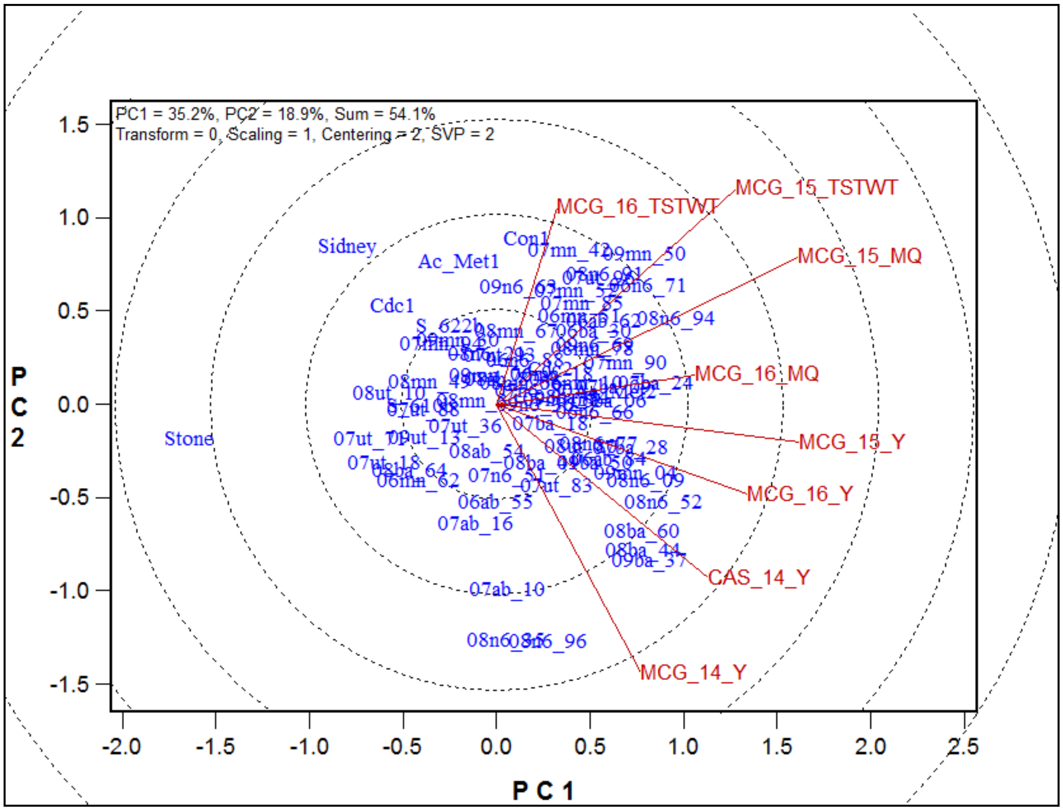

Figure 2.13: Relationship among yield parameters tested and malt quality TCAP spring six-row barley lines (in blue) at all locations (CAS and MCG) from all harvest years (2014, 2015 and 2016).

Figure 2.14, describing the "which won where" analysis of spring six-row barley at all locations over years, shows that TCAP line '09ba_37' was the top performing line for yield in CAS 2014 and MCG 2016, while '08n6_96' was the top performing line for yield in MCG 2014. The top line for malt quality at MCG in 2015 and 2016 was

‘08n6_94’. Lastly, the top TCAP line for test weight in MCG 2015 and 2016 was ‘09mn_50’. There was no top-performing TCAP line for yield in MCG 2016.

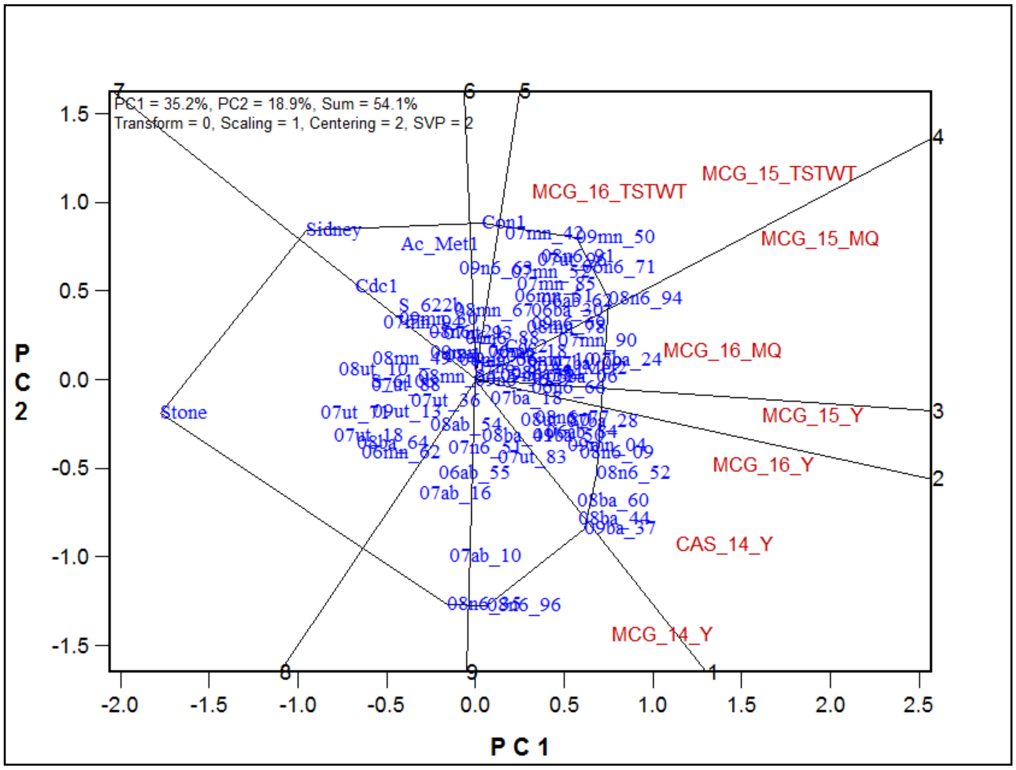

Figure 2.14: “Which won where” analysis of TCAP spring six-row barley lines compared to yield parameters tested at all locations (CAS and MCG) from all harvest years (2014, 2015 and 2016).

Superior TCAP Winter and Facultative Barley Lines, Dimmitt, TX

In 2015 and 2016, TCAP winter and facultative barley lines were tested in Dimmitt, TX. Dimmitt is in the High Plains, positioned 106 km south of Amarillo, TX and 136 km north of Lubbock, TX. Spring TCAP barley lines were not grown in DIM, as they are not as tolerant to cooler winter temperatures. Table 2.5 shows the ANOVA output for the statistical analysis completed. Table 2.6 shows an average yield (t ha^{-1}) of all TCAP winter and facultative barley lines tested in Dimmitt for years 2015 and 2016. Commercial checks in the table are denoted in bold ('P919', 'Alba', 'Full Pint' and 'Maja') and data is organized by yield (Mt ha^{-1}), from greatest to least. The column labeled "type" shows if the line is facultative (F) or winter (W). From the analysis, there are numerous TCAP lines that out-yielded the commercial varieties included in the study. There were no apparent differences in whether winter or facultative TCAP lines out-performed the other.

The CV for the analysis in Dimmitt, TX was 18.3%, which was higher than the desirable range for a trial such as this (6-8%). Because of the unexplained variability within the trial is higher than desired, results are less reliable compared to a data set with a lower CV. The trial LSD was 1.6 (5% confidence interval) indicating that the top 50 entries were statistically not different from each other and no different than the 'Maja' commercial check.

Superior TCAP Winter and Facultative Barley Lines Grown in Dimmitt and McGregor, TX

Table 2.5 and 2.6 describe the ANOVA output and superior yielding winter and facultative barley lines commonly grown in DIM and MCG during harvest years 2015 and 2016.

Table 2.5: ANOVA output from average yield (Mt ha^{-1}) of TCAP winter and facultative barley lines grown in Dimmitt, TX during harvest years 2015 and 2016.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Entry	120	106.01	0.88	1.39	0.03*
Year	1	154.99	154.99	244.16	<.0001

Table 2.6: Yield (Mt ha^{-1}) of TCAP winter (W) and facultative (F) barley lines in Dimmitt, TX averaged across harvest years 2015 and 2016. Commercial checks are highlighted in red.

TCAP Line	Type	Yield (t ha^{-1})	TCAP Line	Type	Yield (t ha^{-1})	TCAP Line	Type	Yield
F555_1	W	6.1	F523_1	W	4.6	F5108_1	F	4.0
F552_2	W	5.8	F566_3	W	4.6	OR91	F	4.0
F527_1	W	5.7	F583_1	W	4.6	F591_1	W	3.9
07OR_3	F	5.6	08OR_53	F	4.6	F560_2	W	3.9
F556_1	W	5.5	F5121_3	F	4.6	F5132_1	F	3.9
F537_1	W	5.5	F5109_1	W	4.6	08OR_81	F	3.8
F536_2	W	5.4	F5109_3	W	4.6	OBA11_2	F	3.8
F5120_3	F	5.4	F590_5	F	4.5	06OR_43	F	3.8
F522_3	F	5.3	F5105_1	F	4.5	F5112_1	F	3.8
F532_1	W	5.3	06OR_91	F	4.5	F547_1	W	3.8
07OR_4	F	5.2	MW122_5	F	4.5	F5134_3	F	3.8
F559_2	F	5.2	F5135_4	W	4.4	MW120_8	F	3.8
Short12	F	5.2	P919	W	4.4	PO71_104	F	3.8
F535_2	W	5.1	F537_3	W	4.4	F5136_1	W	3.7
F548_1	W	5.1	07OR_8	F	4.4	F5121_1	F	3.7
Maja	F	5.1	F5126_2	W	4.4	PO71_87	W	3.6
F550_1	W	5.0	MW116_4	F	4.4	OR813	W	3.6
Short16	F	5.0	F564_1	W	4.3	Full Pint	S 2R	3.6
F5131_1	W	5.0	07OR_6	F	4.3	06OR_10	F	3.6
07OR_59	F	5.0	F556_3	W	4.3	MW122_1	F	3.6
Short8	F	4.9	OBA11_13	F	4.3	08OR_30	F	3.5
F55_1	F	4.9	OR106	F	4.2	Alba	W	3.5
F5106_1	W	4.9	OBA11_29	F	4.2	OR103	F	3.5
F572_3	W	4.9	OR101	F	4.2	F5119_1	F	3.5
08OR_48	F	4.9	OR108	F	4.2	F576_1	W	3.4
08OR_73	F	4.9	MW076_2	F	4.2	06OR_41	F	3.4
MW118_3	F	4.9	08OR_44	F	4.2	MW116_3	F	3.4
F5113_2	F	4.8	F59_2	W	4.2	F591_2	W	3.3
F559_1	F	4.8	MW118_1	F	4.2	06OR_59	F	3.3
OBA11_31	F	4.8	MW118_4	F	4.1	06OR_52	F	3.3
Short13	F	4.8	F5126_1	W	4.1	OR910	F	3.3
F595_1	F	4.8	F5121_5	F	4.1	06OR_44	F	3.2
F5121_4	F	4.8	F557_2	F	4.1	06OR_37	F	3.1
OR818	F	4.7	F588_3	W	4.1	06OR_62	F	3.1
F576_4	F	4.7	F596_2	F	4.0	06OR_42	F	2.9
F54_2	W	4.7	OR815	W	4.0	06OR_45	F	2.8
PY211_6	F	4.7	F5121_2	F	4.0	06OR_78	F	2.7
F5105_3	W	4.7	F547_3	W	4.0	-	-	-
F5112_3	F	4.6	OR76	W	4.0	-	-	-
CV (%)	18.3	**LSD (0. 05)**	1.6					

Evaluation of TCAP Lines for Malt Barley Performance

Statistical Procedure and Analysis

The PROC CORR procedure in SAS was used to analyze and see if malt traits were correlated, either positive or negative, with yield evaluations (Appendix A-1). Values were designated significant at p-values greater or equal to 0.05 (*), 0.01 (**) and 0.001 (***), respectively. Any value greater than 0.05 was considered not significant (NS).

<u>*Winter and Facultative Barley Performance in Dimmitt, TX*</u>

Statistical analysis of winter and facultative barley lines for malt quality can be found in Table 2.7. A negative correlation was found between yield and kernel weight (-0.33***), while plumpness and kernel weight was positively correlated (0.53***). This means that kernel weight affects barley plumpness more than yield in this location. Barley protein had a slight negative correlation with yield (-0.14*), kernel weight (-0.14*) and plumpness (-0.26***) indicating that if a brewer desired a high-protein barley, choosing the highest yielding barley may not mean it is also a higher protein barley. Lastly, there was no significance between malt quality score and yield (0.01^{NS}).

Table 2.7: Pearson correlation analysis between malt analysis and yield data for winter and facultative barley averaged in Dimmitt, TX across harvest years 2015 and 2016.

	Yield (Mt ha^{-1})	**Kernel Weight (g)**	**Plumpness (6/64" screen)**	**Color**	**Malt Extract**	**Barley Protein**	**Wort Protein**	**S/T Ratio**	**Diastatic Power**	**Alpha Amylase**	**FAN**
Kernel Weight (g)	-0.33^{***} 269										
Plumpness (6/64" screen)	0.03^{NS} 269	0.53^{***} 274									
Color	-0.57^{***} 269	0.54^{***} 274	0.08^{NS} 274								
Malt Extract	-0.32^{***} 269	0.40^{***} 274	0.27^{***} 274	0.56^{***} 274							
Barley Protein	-0.14^{*} 269	-0.14^{*} 274	-0.26^{***} 274	-0.13^{*} 274	-0.35^{***} 274						
Wort Protein	0.15^{**} 269	-0.39^{***} 274	-0.14^{*} 274	-0.39^{***} 274	0.04^{NS} 274	0.22^{**} 274					
S/T Ratio	0.26^{***} 269	-0.29^{***} 274	0.04^{NS} 274	-0.31^{***} 274	0.26^{***} 274	-0.31^{***} 274	0.83^{***} 274				
Diastatic Power	0.03^{NS} 269	-0.34^{***} 274	-0.16^{**} 274	-0.13^{*} 274	0.01^{NS} 274	0.24^{***} 274	0.59^{***} 274	0.45^{***} 274			
Alpha Amylase	-0.07^{NS} 269	-0.06^{NS} 274	0.05^{NS} 274	0.06^{NS} 274	0.51^{***} 274	-0.17^{**} 274	0.66^{***} 274	0.75^{***} 274	0.46^{***} 274		
FAN	0.00^{NS} 269	-0.23^{**} 274	-0.09^{NS} 274	-0.10^{NS} 274	0.35^{***} 274	-0.02^{NS} 274	0.76^{***} 274	0.75^{***} 274	0.47^{***} 274	0.83^{***} 274	
Quality Score	0.01^{NS} 269	0.10^{NS} 274	0.28^{***} 274	0.11^{NS} 274	0.61^{***} 274	-0.48^{***} 274	0.46^{***} 274	0.73^{***} 274	0.35^{***} 274	0.79^{***} 274	0.64^{***} 274

Winter and Facultative Barley Performance in McGregor, TX

Winter and facultative barley analysis at MCG shows that there is a positive correlation between kernel weight and yield (0.36^{***}) (Table 2.8). Like DIM, barley protein at MCG had a negative correlation with yield (-0.16^{NS}), kernel weight (-0.28^{*}) and plumpness (-0.26^{*}). Malt extract had a strong positive correlation with plumpness (0.46^{***}), showing that plump barley has a higher malt extract and therefore could produce a higher quality brew. Malt quality score had a strong positive correlation with yield (0.26^{***}), kernel weight (0.43^{***}) and plumpness (0.37^{***}), but a strong negative correlation with barley protein (-0.61^{***}). In many brewing cases, an ideal barley is low in protein, therefore, further research on relationships between quality and protein content would be beneficial.

Table 2.8: Pearson correlation analysis between malt analysis and yield data for winter and facultative barley averaged in McGregor, TX across harvest years 2015 and 2016.

	Yield (Mt ha^{-1})	**Kernel Weight (g)**	**Plumpness (6/64” screen)**	**Color**	**Malt Extract**	**Barley Protein**	**Wort Protein**	**S/T Ratio**	**Diastatic Power**	**Alpha Amylase**	**FAN**
Kernel Weight (g)	0.36*** 111										
Plumpness (6/64” screen)	0.36*** 111	0.75*** 117									
Color	0.00^{NS} 111	0.01^{NS} 117	-0.09^{NS} 117								
Malt Extract	0.31** 111	0.50*** 117	0.46*** 117	0.22** 117							
Barley Protein	-0.16^{NS} 111	-0.28* 117	-0.26* 117	-0.22* 117	-0.71*** 117						
Wort Protein	-0.16^{NS} 111	-0.31* 117	-0.27* 117	-0.09^{NS} 117	-0.28** 117	0.58*** 117					
S/T Ratio	-0.01^{NS} 111	-0.02^{NS} 117	-0.02^{NS} 117	0.14^{NS} 117	0.49*** 117	-0.48*** 117	0.42*** 117				
Diastatic Power	0.02^{NS} 111	-0.09^{NS} 117	-0.09^{NS} 117	-0.23** 117	-0.28** 117	0.62*** 117	0.49*** 117	- 0.16^{NS} 117			
Alpha Amylase	0.06^{NS} 111	-0.13^{NS} 117	-0.24** 117	0.15^{NS} 117	0.33** 117	-0.21	0.36	0.61	0.01		
FAN	-0.08^{NS} 111	-0.10^{NS} 117	-0.02^{NS} 117	-0.04^{NS} 117	0.25** 117	0.07^{NS} 117	0.64*** 117	0.58*** 117	0.31** 117	0.61*** 117	
Quality Score	0.26** 111	0.43*** 117	0.37*** 117	0.11^{NS} 117	0.70*** 117	-0.61*** 117	-0.12^{NS} 117	0.56*** 117	-0.10^{NS} 117	0.46*** 117	0.33** 117

Spring Barley Performance in McGregor, TX

Spring two- and six-row barley was grown and evaluated in McGregor, TX during Harvest Year 2016. Tables 2.9 and 2.10 shows the correlation analysis for spring two-row and six-row barley, respectively,

Spring two-row barley (Table 2.9) had a strong positive correlation between yield and kernel weight (0.74***), while six-row (Table 2.10) had a strong negative correlation between the two parameters (-0.65***). A negative correlation in the six-row barley could potentially be due to the large amount of bird damage seen compared to the two-row. Plumpness in the six-row barley was also negatively correlated with yield (-0.47***), thus supporting the bird damage. Similar to winter and facultative barley in DIM and MCG, a negative correlation was found between barley protein and malt quality score for both spring barley types.

Table 2.9: Pearson correlation analysis between malt analysis and yield data for spring two-row barley averaged in McGregor, TX across harvest years 2015 and 2016..

	Yield (Mt ha^{-1})	**Kernel Weight (g)**	**Plumpness (6/64" screen)**	**Color**	**Malt Extract**	**Barley Protein**	**Wort Protein**	**S/T Ratio**	**Diastatic Power**	**Alpha Amylase**	**FAN**
Kernel Weight (g)	0.74*** 119										
Plumpness (6/64" screen)	-0.50*** 119	0.03^{NS} 124									
Color	0.65*** 119	0.75*** 124	0.09^{NS} 124								
Malt Extract	-0.91*** 119	-0.53*** 124	0.70*** 124	-0.42*** 124							
Barley Protein	-0.40*** 119	-0.64*** 124	-0.34*** 124	-0.65*** 124	0.10^{NS} 124						
Wort Protein	0.92*** 119	0.63*** 124	-0.62*** 124	0.52*** 124	-0.97*** 124	-0.20* 124					
S/T Ratio	0.54*** 119	0.40*** 124	-0.30** 124	0.37*** 124	-0.59*** 124	-0.30** 124	0.71*** 124				
Diastatic Power	-0.13^{NS} 119	-0.03^{NS} 124	0.21^{NS} 124	0.11^{NS} 124	0.18* 124	0.04^{NS} 124	-0.17^{NS} 124	-0.19* 124			
Alpha Amylase	0.02^{NS} 119	0.27* 124	0.20* 124	0.30** 124	0.07^{NS} 124	-0.35*** 124	0.02^{NS} 124	0.22* 124	0.41*** 124		
FAN	-0.39*** 119	-0.40*** 124	-0.03^{NS} 124	-0.34*** 124	0.16^{NS} 124	0.47*** 124	-0.11^{NS} 124	0.32** 124	0.06^{NS} 124	0.16^{NS} 124	
Quality Score	0.97*** 119	0.77*** 124	-0.50*** 124	0.66*** 124	-0.93*** 124	-0.40*** 124	0.96*** 124	0.60*** 124	-0.11^{NS} 124	0.10^{NS} 124	-0.33** 124

Table 2.10: Pearson correlation analysis between malt analysis and yield data for spring six-row barley averaged in McGregor, TX across harvest years 2015 and 2016.

	Yield (Mt ha^{-1})	Kernel Weight (g)	Plumpness (6/64" screen)	Color	Malt Extract	Barley Protein	Wort Protein	S/T Ratio	Diastatic Power	Alpha Amylase	FAN
Kernel Weight (g)	-0.65*** 131										
Plumpness (6/64" screen)	-0.47*** 131	0.82*** 133									
Color	-0.08^{NS} 131	0.12^{NS} 133	0.31** 133								
Malt Extract	-0.20* 131	0.43*** 133	0.58*** 133	0.53*** 133							
Barley Protein	0.08^{NS} 131	-0.28* 133	-0.42*** 133	-0.25* 133	-0.70*** 133						
Wort Protein	0.13^{NS} 131	-0.25* 133	-0.30** 133	-0.08^{NS} 133	-0.33*** 133	0.57*** 133					
S/T Ratio	0.11^{NS} 131		-0.01^{NS} 133	0.16^{NS} 133	0.22* 133	-0.15^{NS} 133	0.71*** 133				
Diastatic Power	0.17^{NS} 131	-0.11^{NS} 133	0.03^{NS} 133	0.30** 133	0.16^{NS} 133	0.14^{NS} 133	0.06^{NS} 133	-0.01^{NS} 133			
Alpha Amylase	-0.24* 131	0.30** 133	0.38*** 133	0.47*** 133	0.65*** 133	-0.45*** 133	-0.15^{NS} 133	0.25* 133	0.30** 133		
FAN	-0.14^{NS} 131	0.16^{NS} 133	0.21* 133	0.24* 133	0.28*** 133	0.06^{NS} 133	0.61*** 133	0.70*** 133	0.07^{NS} 133	0.43*** 133	
Quality Score	-0.18* 131	0.48*** 133	0.64*** 133	0.42*** 133	0.78*** 133	-0.61*** 133	-0.38*** 133	0.07^{NS} 133	0.22* 133	0.63*** 133	0.22* 133

Discussion and Conclusions

Environment had a large impact on performance of TCAP barley lines. Correlations among yield and quality parameters differed not only between locations, but also among years within each location. Much of the variation that occurred can be explained by variations in weather (temperature and precipitation), in addition to cultural and soil differences at each site. Castroville, TX is located 772 km southeast of Dimmitt, TX and 321 km southwest of McGregor, TX. Each location is in a different ecoregion as well. Castroville is in the South Texas Plains, where rainfall is low during the winter months and highest during the spring and fall. Dimmitt is in the High Plains, approximately 1000-1200 m above sea level. Rainfall in this region follows a similar pattern to rainfall in CAS, however, snow can commonly be seen in the winter months.

The last region, the Blackland Prairie, is where McGregor is located. The Blackland Prairie has fertile soils and high amounts of rainfall typically seen in the spring months. Each trial was located in a different ecoregion and therefore differences in performance of TCAP barley was likely and was evident in the bi-plot analysis. Figures 2.7 and 2.8 describe facultative barley parameter relationships and correlations with lines tested. Both bi-plots show positive and negative correlations between locations and across years. Slight positive correlations were found between most parameters at all locations across years, suggesting that TCAP facultative lines performed similarly across environments. Figures 2.9 and 2.10 describe winter barley parameter correlations and shows that there are some positive and negative correlations between locations. Like TCAP facultative barley performance, most parameters across years and locations have a slight positive correlation, despite differences in cultural practices.

From a spring barley perspective, MCG was the only location that had more than two years of data. Due to poor weather conditions in CAS in 2015 and 2016, plots were unharvestable. Both spring two- and six-row barley parameters were all positively correlated (Figures 2.11-2.14), a promising sign for producers, as it shows that yield of these barley types are more stable across a range of environments compared with winter and facultative barley types. From a breeding perspective, it may be easier to select a spring two-row line that performs well in all environments. A varietal release could potentially have adaptation in multiple regions across the state. 2015 and 2016 were unseasonably wet for Texas and drought occurs frequently, so a continuation of research considering environmental correlations over time is needed.

From a malt quality standpoint, both negative and positive correlations were found in all barley types in relation to yield. A negative correlation between malt quality and protein at DIM and MCG for all barley types (Tables 2.7-2.10) shows that selecting a high-quality barley does not automatically select for a high low protein type as well. While there are “ideal” parameters for malt barley, specialty brews vary from these ideal parameters. A barley producer could potentially find a barley line to grow that had moderate yield performance and good malt quality. While many producers’ goal is for high yields, private malting contracts with malthouses and/or brewers are significantly higher priced compared to feed grain ($ bushel^{-1}) and may offset lower yields. Malt contract pricing varies and therefore a producer would have to research and talk with local malthouses/breweries to negotiate pricing on a case-by-case basis.

Performance of some winter and facultative TCAP barley lines in DIM, did out-yield the commercial barley varieties used as checks in the field trials (Table 2.6). To have breeder lines out-perform commercially-available varieties is promising for producers, as a varietal release(s) could potentially improve barley yield potential in the High Plains. Therefore, barley could become more competitive with wheat production in that area. Both winter and facultative barley lines performed similarly with one another at this location.

Bi-plot analysis provided a visual description of the environmental similarities and differences of all TCAP trial locations evaluated. In this case, a visual description of the environmental similarities and differences of all TCAP trial locations was presented. Both negative and positive correlation were seen from analysis, between site years and locations. Differences between TCAP barley performance created negative correlations in yield, especially winter/facultative barley. This suggests that environmental conditions, cultural practices and soil type all had an impact in the performance of each location. Spring barley performed more consistently over years compared to winter/facultative barley at MCG and CAS. One main reason for this difference is the difference in distance between TCAP trial locations. Spring barley was grown in CAS and MCG only 321 km apart. While both temperature and precipitation may vary, there was a more consistent pattern of performance over years between the two. In contrast, the addition of a location in the Texas High Plains (DIM), created more variance in the performance of TCAP winter/facultative lines tested, ultimately changing correlations among locations. Weather in the Texas High Plains is much different than both central (MCG) and southern (CAS) regions of Texas. Despite this, more research should be continued to see how environment effects TCAP barley spring and winter yield and malt quality performance in those over the long term.

CHAPTER III

DETERMINING DESIRABLE CHARACTERISTICS OF BARLEY GROWN IN TEXAS ENVIRONMENTS

Introduction

Barley in Texas

Since the late 1500s, barley has been an important crop in Texas. Barley arrived in the state through El Paso from Mexico between 1598-1685 and through south and east Texas with the establishment of missions in the 1700s (Atkins, 1980). As the numbers of settlers and missionaries increased, the cultivation of barley slowly spread across the state.

Varieties grown in Texas depended on their path of entry. Coast-type barley, originating from northern Africa, traveled to Texas with missionaries. This spring type variety grew well in central and western areas of the state, but not in south Texas. Barley originating from Europe were mainly two-row spring types and came to Texas with settlers from northern and eastern states. Producers found winter barley was more successful versus spring due to its ability to withstand cooler temperatures, drought and disease (Atkins, 1980). The Texas Agriculture Census of 1887 showed that barley production covered 4,682 ha. Cotton (1,319,263 ha), corn (1,185,431 ha) and wheat (210,525 ha) were the top three field crops produced (Foster, 2001). Introduced barley lines from Tennessee increased planted acres to 36,017 ha in the 1920s and by 1961, harvested barley acres peaked at 170,372 ha (Atkins, 1980). After the 1960s, barley production began to decrease. The 1987 Texas Agriculture Census report showed that

5,434 ha of barley were harvested, in comparison to 1,476,739 ha of wheat harvested the same year. Today, barley is planted on less than 12,000 ha across the state and is mainly used as a dual-purpose grazing and grain source for cattle (~4,700 ha) (FSA, 2015).

Texas Agricultural Experiment stations played an important role in producing barley types that performed well across the state's different environments. Researchers found winter barley with prostrate growth habits (grow low to the ground) and high cold tolerance was well-adapted to the High Plains. Intermediate types of winter barley with upright growth habits, moderate cold tolerance and no vernalization requirement were best for pastureland in the Rolling Plains and East Texas. Some of the first barley varieties adapted to Texas were, 'Finley', 'Wintex' and 'Texan'. Over the years, more varieties were released including, 'Cordova' in 1938—a more disease-resistant and high quality grain and forage variety. 'Goliad' and 'Tunis', two varieties with good disease resistance and forage characteristics were also released (Atkins, 1980). More recently, Texas A&M Agriculture Experiment Station released two winter barley varieties for commercial use. The first, 'TAMbar 500', was released in 1991 and is ideal for production in the High Plains. It is a medium to late-maturing variety that has some resistance to Barley Yellow Dwarf Virus and complete resistance to powdery mildew and the leaf rust pathogen *Puccina hordei* (Marshall et al., 1993). The second, 'TAMbar 501', was released in 2001 and is commonly used as a feed-type barley in central, east and south Texas. This variety is early-maturing, has good winter hardiness and resistance to Barley Yellow Dwarf Virus (Marshall et al., 2003).

Common Barley Diseases in Texas

Barley is susceptible to many of the same diseases and viruses as wheat, including rust and barley yellow dwarf virus. The following subsections will discuss each further.

Rust

Historically, rust has been a problem in cereal crops since the time of the Romans and today can affect cereal crops grown across the US (Paulitz and Steffenson, 2011). Three types of rust commonly found on barley in Texas are: stripe, stem and leaf rust. The first documented case of stripe rust in the state occurred on barley research plots at the Texas A&M AgriLife Small Grain Breeding nursery in Uvalde, TX in April 1991 (Marshall and Sutton, 1995). Although barley is planted on a small amount of land in Texas, rust is still present and can potentially impact crop performance and yield if not controlled.

All rust types are caused by a fungus, belonging to the genus *Puccina* (Paulitz and Steffenson, 2011). With stripe rust specifically, the fungus *Puccina striiformis* sp. *hordei* affects barley, while *Puccina strifformis* sp. *tritici* affects wheat (Yan and Chen, 2006; Line, 2002). *Puccina graminia* sp. *tritici* causes stem rust and *Puccina recondita* sp. *tritici* causes leaf rust. Formation of rust pustules on the leaf blades, sheath or stem of the plant can occur in either warm or cool environments, depending on the type of rust causing the infection (Paulitz and Steffenson, 2011; DeWolf et al., 2010). Stripe rust prefers cooler temperatures, while stem and leaf rust prefer warmer temperatures. The color of the pustules varies from a light orange or yellow hue for stripe rust, to a brick red or brown color for stem and leaf rust. The pattern also varies, depending on the specific type of rust—stripe rust forms stripes on the leaf blades, leaf rust forms small oval pustules scattered randomly across infected leaf tissue and stem rust forms oval pustules that erupt in clusters on both sides of infected tissue (DeWolf et al., 2010).

In wheat breeding programs, all-stage (AS) and high-temperature adult-plant resistance (HTAP) have been researched. All-stage resistance begins at seedling stage and protects the wheat from a rust infection during all growth stages. The second resistance type, HTAP, protects adult plants against *Puccina* at high or low temperatures only (Chen, 2007).

Whether it is wheat or barley, growing resistant types of small grains is the best method of control for rust. In barley and wheat, all-stage (AS) and high-temperature adult-plant resistance (HTAP) have been researched. All-stage resistance begins at seedling stage and protects the wheat from a rust infection during all growth stages. The second resistance type, HTAP, protects adult plants against *Puccina* at high or low temperatures only (Chen, 2007). One disadvantage to AS resistance is that it is race specific, meaning it only protects the plant against certain strains of *Puccina*. In addition, AS is not considered "durable" because new races of *Puccina* can form and overcome the AS resistance. In contrast, HTAP resistance is both durable and not race specific (Yan and Chen, 2006).

Having both AS and HTAP resistance would be an ideal combination for protection against rust, but it is genetically difficult to do. The exact location of genes on the chromosome is still unknown (Yan and Chen, 2006). For example, through genetic testing, Chen and Line (2003) identified approximately 26 different genes in 18 barley genotypes for stripe rust resistance. They found that Grannenlose Zweizeillige, a two-row barley variety originating from Ethiopia, showed resistance to all races of barley stripe rust found in the US (Yan and Chen, 2006). Although this would be a good variety to incorporate into US barley breeding programs, identifying the resistance gene on the chromosome has been unsuccessful.

In addition to growing resistant and/or tolerant varieties, rust control with fungicides is also possible. In Texas, foliar application of fungicides increased barley grain yield by 41% and increased 1000-kernel weight by 33% when compared to fields without foliar applications (Chen, 2007). There are numerous registered fungicides available for rust control in barley. Some examples include: Quadris® (ai: azoxystrobin), Stratego® (ai: propiconazole, trifloxystrobin), Tilt® (ai: propiconazole), Headline® (ai: strobilurin) and Quilt® (ai: azoxystrobin, propiconazole).

Barley Yellow Dwarf Virus

Barley yellow dwarf virus (BYDV) can be found on most cereal grains in addition to barley. This disease is caused by viruses belonging to the genus *Luteoviridae* (Ingwell and Bosque-Pérez, 2015). Primarily transmitted by the vector, bird cherry-oat aphid (*Rhopalosiphum padi* L.), this virus enters the phloem of barley causing a range of problems such as dwarfing of the plant, failure to head and reduced grain yield (Ulrich, 2011; Ingwell and Bosque-Pérez, 2015; Bynum et al., 2012).

Unmanaged native grasses surrounding fertile cropland can host BYDV-infected aphids (Ingwell and Bosque-Pérez, 2015). Once a barley plant is infected, yellowing and stiffness of the leaves occur and the plant gradually ceases production. Yield losses can be a significant issue for producers. In the US, average yield losses in barley from this virus can range between 11 and 37%. In 1989, the US barley crop loss was valued at $48.5 million USD (Miller and Rashed, 1997). Cooler temperatures (15-18 ^{o}C) and a high light intensity are favorable conditions for continuing the BYDV cycle once it is established in the plant (D'Arcy and Domier, 2005).

Proper management and control measures are vital to prevent crop loss. Jones et al. (1970) found that most barley varieties originating from Ethiopia have higher tolerance to BYDV compared to other varieties. Proper planting dates are also important to reduce aphid infestations. Early fall plantings are less desirable because aphids are highly active during this time (Marshall and Rashed, 2014). If planting barley in the springtime, an earlier planting date is desirable because seedlings will have a chance to establish before aphid numbers increase. Lastly, insecticides, specifically seed treatments, can slow field infestations. Insecticides containing active ingredients imidaclopric or thiamethoxam are the best choices for protecting seedlings during the first 4-6 weeks post-planting. A producer can monitor aphid populations throughout the growing season and a foliar applied insecticide can be used, however, it is often not practical due to high costs (Marshall and Rashed, 2014). Insecticides are not 100% effective in clearing out an aphid population, but do have the potential to significantly reduce the infestations, thus lowering the risk of crop loss due to BYDV (D'Arcy and Domier, 2005).

Common Barley Pests in Texas

Like wheat and other small grains, barley is subject to much of the same pests. The following subsections will discuss aphids and Hessian fly as two possible pests of barley across the state.

Aphids

Aphids (*Aphidoidea*), are soft-bodied insects that affect small grains, ornamentals, trees and shrubs. Using their mouth, they pierce through a stem or leaf feeding on the plant's sugars located in the phloem. Aphids produce a sticky sap known as "honeydew". Honeydew is a favorable food source and environment for the fungus *Capnodium* to establish. This fungus produces a substance on leaves called "sooty mold" (Townsend, 2000). Sooty mold can block sunlight from reaching plant cells, thus reducing photosynthesis and overall productivity of the plant (Townsend, 2000; Drees, 1996). The three most common aphid types that affect barley in Texas are, Russian wheat aphid (*Diruaphis noxia*), greenbug (*Schizaphis graminum*) and bird cherry-oat aphid (Bynum et al., 2012).

One of the biggest concerns with aphids are the viruses they can potentially vector, especially BYDV, as described in the previous section. Early detection is important when controlling aphids, as they have an incredibly fast reproduction rate (Townsend, 2000). Insecticides can be used to control aphid populations; however, it is important to control infestations via seed treatments before populations have a chance to fully establish. There are some barley varieties that have resistance to aphids, specifically greenbug including 'Post 90' and 'STARS 1501B' (Armstrong et al., 2016).

Research conducted by the USDA Agriculture Research Service in Stillwater, Oklahoma have tested barley lines originating from Pakistan, Turkmenistan and Oklahoma for resistance against 14 known and unknown greenbug biotypes. Two genes, *Rsg1* and *Rsg2* are the only greenbug-resistance genes in barley. It has been found that all known barley varieties resistant to greenbug carry the gene *Rsg1* (Armstrong et al., 2016). Research is still on-going to find more barley lines and varieties that carry the *Rsg2* gene for greenbug resistance.

Hessian Fly

Hessian Fly (HF) (*Mayetiola destructor*), was first discovered in Russia, but traveled to the northeastern US in 1779 with Hessian troops fighting in the Revolutionary War. Over the next hundred years, HF spread across the US, reaching Texas around the 1880s. By 2005, more than 67 counties in Texas were dealing with HF infestations in their fields (Morgan et al., 2005).

Although HF prefers to infest wheat, barley can also be a host. During summer, HF remains inactive in a larval state on residual wheat/barley stubble in fields (Morgan et al., 2005). Adults emerge in late summer and early fall when temperatures cool and precipitation increases. One or more broods of larvae develop during the fall and reproduction then slows during the winter. As temperatures increase in late winter, adults become active once again and one or more broods of larvae will develop in the spring. Adults emerge for 2 days, during which they mate and lay eggs. Eggs hatch within 10 days and larvae begin to feed on barley (Morgan et al., 2005).

Hessian Fly can drastically affect the productivity and yield capabilities of the plant. In seedlings and tillering stages, HF can stunt growth and even kill the plant, while in mature plants, stem breakage can occur due to HF feeding. This leads to harvest losses from lodging and low grain yield because of poor nutrient delivery to the seedhead during kernel formation (Harris et al., 1996).

Once a field is infested with HF, there is no remedial control. Producers can prevent infestations with management practices such as, planting resistant varieties, delaying fall plant date and using seed treatments to suppress fall infestations. A study by Harris et al (1996) showed that in 1989, producers who planted HF-resistant barley cultivars in the US resulted in approximately 95% reduction in HF population—a savings of over $200 million USD. Another HF study conducted by Hill et al (1952) discovered that most of the HF-resistant barley varieties tested had origins tracing back to Egypt and northern Africa. Plant breeders may be able to take advantage of this information to continue to find highly HF-resistant barley cultivars.

Conclusion

Although barley is currently a minor crop in Texas, there are developing market opportunities for use as a livestock feed and forage source and malting for local craft breweries and distilling for whiskey production. Acreage for barley has declined since the 1960s and is currently planted on ~12,000 ha across the state. Barley is susceptible to some of the same diseases and pests as other small grains, including wheat, but most can be managed with appropriate farming practices. Rust can negatively impact yield and overall performance of barley, but research with AS and HTAP resistance is being conducted to find genomes in barley that can be used to create more tolerant and/or rust-resistant varieties. In addition to rust-resistance, research is on-going to find more aphid-resistant barley varieties. Aphids are vectors for various diseases, including BYDV, which can also have a negative impact on yield and overall performance of the barley plant. The last pest, Hessian fly, is more difficult to control, as there are no remedial methods, but seed treatments, tillage, crop rotation and resistant cultivars can all be used to suppress infestations.

Future climate models predict changes to local weather patterns and more frequent and extreme weather events, such as drought and flooding, are expected to occur. In addition, temperatures will rise, causing less winter freeze injury and more heat stress, directly affecting crop growth habits and heading dates. With these changes, it will be important to update and improve current barley production practices and varieties. This may increase the adoption of more drought-tolerant crops, such as barley, into cropping systems.

Materials and Methods

For this project, barley lines were obtained from the Triticeae Coordinated Agricultural Project (TCAP) to screen advanced breeding material from barley breeding programs within the US. This project identified suitable lines adapted for Texas climates that outperform current commercially available varieties for malting and feed grade purposes. The TCAP consists of wheat and barley breeders from across the US with the goal of preserving and developing new varieties of wheat and barley. The second objective of this research was to determine desirable phenotypic characteristics for barley grown in Texas.

Harvest Year 2014

Headrows (HR) (1 m long, 0.4 m apart) of 463 spring (248 2-row, 215 6-row), 119 winter and 182 facultative TCAP lines were grown in two locations in central and south Texas, Castroville (CAS) and McGregor (MCG) in Harvest Year 2014. Table 2.1 and Figures 2.1, 2.2, 2.3 and 2.4 describe each location's environmental conditions, average monthly rainfall and temperature. Untreated barley seed was planted in a single replicated design (SRD) with repeated checks placed throughout. Checks are commercially available varieties and provide a yield comparison among TCAP breeding lines and commercial variety performance. Spring checks placed in the spring trial were: 'AC Metcalf', 'Conlon' and 'CDC Copeland'. Winter checks placed in the winter trial were: 'Alba', 'Maja' and 'Full Pint'. A Hege 1000 HR plot drill (76 cm long HD on a 38 cm row spacing), complete with automatic trip was used to plant. The CAS location had access to overhead irrigation and MCG was a dryland location.

Fertilizer was applied based on soil test recommendations. In CAS, no chemicals were applied. On February 14, 2014, 35.3 kg N ha^{-1} (UAN 32-0-0), 2.34 L ha^{-1} Dimethoate (ai: dimethoate) and a mixture of 1.75 L ha^{-1} Weedmaster (Nufarm, ai: 3,6-dichloro-o-anisic acid, 2,4-dichlorophenoxyacetic acid) and 0.0000025 L ml^{-1} of the surfactant LI 700 (Nufarm) was topdressed to the HRs at MCG.

In-field observations were taken during the growing season, as described in Table 2.4. Final field observations and plant height (cm) and plot quality were taken at harvest. In-field notes taken on plot quality, rated plots based on the overall plant health and uniformity of each test plot before harvesting. If a plot had a great deal of lodging, bird damage, poor growth, etc. a rating of 1 would be given. A rating of 5 was given to plots that had uniform growth and no lodging or bird damage. Viable seedheads were hand harvested and placed into their respective sample bag for later processing.

In the lab, seedheads were counted, threshed (Model BT14E thresher, Almaco, Nevada, IA) to collect seed and cleaned (Model ABSO aspirator, Almaco, Nevada, IA) to remove foreign material. Table 2.5 describes the lab data that was collected after harvest. A double-screened method was used to determine kernel plumpness, a parameter used for malting characteristics. A 24 mm screen placed on a 20 mm screen all placed on a catch pan was shaken fifteen times clockwise and counterclockwise. Seed remaining on each screen was weighed (g) and divided into “plump” (>24 mm), “medium” (<24 mm and >20 mm) and “thin” (< 20 mm).

All field and lab data of TCAP lines and checks were compiled and statistically analyzed using the PROC CORR procedure in SAS (SAS Institute, 2009) to measure the association between yield and yield parameters (Appendix A-1). Prior to correlation analysis, yields of all entries were adjusted with repeating checks using the software program Agrobase (Agronomix Inc.). The top yielding 20% of winter and spring lines were replanted in small plots (1.5m x 4.5m) for Harvest Year 2015.

Harvest Year 2015

The top 20% yielding lines from Harvest Year 2014 in larger test plots were further evaluated in Harvest Year 2015. 128 spring (64 2-row, 64 6-row), 23 winter and

45 facultative lines were planted in three locations in Texas: Dimmitt (DIM), CAS and MCG (Table 2.2, Figures 2.1, 2.2, 2.3, 2.4, 2.5 and 2.6). Dimmitt was planted with winter and facultative lines only, as fall planted spring barley reliability is limited in northern parts of Texas due to freeze injury from cold winter temperatures. The remaining locations, CAS and MCG were planted with winter and spring lines.

In this year, seed was treated with CruiserMaxx® Vibrance for Cereals (Syngenta, ai: Thiamethozam, Mefenozam, Difenoconazole) and Cruiser® 5FS (Syngenta, ai: Thiamethozam) to prevent fall insect infestation. 60 g (68 kg ha^{-1}) of each line were packaged in small envelopes for each location. If seed was limited (< 30 g, < 34 kg ha^{-1}), it was replaced with an alternative variety, 'P-919' or 'TAMbar 501' for winter and 'AC Metcalf', 'Conlon', 'CDC Copeland' or 'SY-Goliad' (wheat) for spring barley. Lines used this year were placed in a SRD with repeating checks placed throughout, same as Harvest Year 2014.

Small plots (1.5m x 4.5m) were planted using an eight-row (18 cm row spacing) planter. Two locations (DIM and CAS) had access to overhead irrigation while MCG was a dryland location. The same in-field observations were taken as Harvest Year 2014 (Table 2.4).

On January 29, 2015, in MCG, 50.4 kg N ha^{-1} (UAN 32-0-0) and a mixture of 1.55 L ha^{-1} MCPA Ester (Agri Star, ai: 2-ethylhexyl ester of 2-methyl-4-chlorophenoxyacetic acid) and recommended rate of the surfactant LI 700 was topdressed on all plots. In DIM, 70.6 kg N ha^{-1} (46-0-0) was applied on November 2, 2014 prior to planting. One week before planting, volunteer corn in the field was sprayed with Gramoxone (Syngenta, ai: paraquat dichloride) at a rate of 3.50 L ha^{-1}. Between late February and late March 2015, 3 applications of N (32-0-0) at the rate of 41.5 kg ha^{-1} was applied via fertigation.

During harvest, a Wintersteiger (Wintersteiger Ag, Ried, Austria) nursery combine (1.5 m header) was used. Due to the unseasonable amount of rain during May (harvest season), CAS was selectively hand harvested for seed increase only and was not included for statistical analysis. Harvested samples were processed in the lab and evaluated for yield components, same as Year 1 (Table 2.5). Subsamples of each line were packaged and sent to USDA Cereal Quality Testing Lab (Madison, WI) for malt quality testing including: kernel weight, color, malt extract, wort color and clarity, barley protein, wort protein and enzymes. All field and lab data of TCAP lines and checks were compiled and statistically analyzed using the PROC CORR and PROC GLM procedures in SAS (SAS Institute, 2009) to measure the association between yield, yield parameters and malt quality (Appendix A-1 and A-2). Values were designated significant at p-values greater than or equal to 0.05 (*), 0.01 (**) and 0.001 (***), respectively. Any value greater than 0.05 was considered not significant (NS). Prior to correlation analysis, yields of all entries were adjusted with repeating checks using the software program Agrobase (Agronomix Inc.).

Harvest Year 2016

In Harvest Year 2016, the same lines were used the previous year in CAS, MCG and DIM (Table 2.3, Figures 2.1, 2.2, 2.3, 2.4, 2.5 and 2.6). 55 g (63 kg ha^{-1}) of each line was packaged for each location. Any seed envelope with less than 30 g (34 kg ha^{-1})

of barley was replaced with an alternative commercial variety, ‘P-919’, ‘TAMbar 501’ or ‘TAM 304’ (wheat) for winter trials and ‘AC Metcalf’, ‘Conlon’, ‘CDC Copeland’ or ‘Expresso’ (wheat) for spring trials. An alpha-lattice design containing two incomplete blocks was used with commercial checks placed within the trial. Checks were the same as the previous year, with the addition of ‘TAM 304’ (winter wheat) in the winter trial and ‘Expresso’ (spring wheat) in the spring trial. Wheat checks provided a direct comparison of barley yield in relation to a known crop with extensive yield history throughout the state. Barley was planted in small plots, using the same dimensions and equipment as in Harvest Year 2015. All locations, except for MCG had access to overhead irrigation.

In DIM, no herbicide or insecticide was applied to the field. On March 5, 2016, plots were topdressed via fertigation with 32.5 kg N ha^{-1} (32-0-0). In CAS, 599 kg ha^{-1} of fertilizer in the form of 12-8-5-2 was applied prior to planting on October 29, 2015. On March 3, 2016, a mixture of 0.87 L ha^{-1} of Dimethoate (ai: dimethoate) and 0.116 L ha^{-1} of Induce (Helena Chemical, ai: alkyl aryl polyozylkane ethers and free fatty acids) was topdressed to the plots. In MCG, a topdress application of 39 kg N ha^{-1} (32-0-0) was applied on January 27, 2016. On that same day, a mixture of 2.34 L ha^{-1} of MCPA Ester (Agri Star, ai: 2-ethylhexyl ester of 2-methyl-4-chlorophenoxyacetic acid) and 36.5 mL ha^{-1} of the herbicide Amber (Syngenta, ai: triasulfuron) was applied.

Field maintenance, physiological notes, harvesting and yield component analysis procedures, including malt barley analysis/sampling were the same as Harvest Year 2015 (Tables 2.4 and 2.5). Castroville was hand harvested for seedheads only due to wet field conditions a combine could not handle. In addition to statistical analyses comparing yield and yield components of TCAP lines over years and locations, an economic analysis was completed to compare the profitability of barley and wheat. Bi-plot analysis was also used to indicate similarities between lines grown, environment, yield components and malt quality (Appendix A-3).

Results

Environmental Effect on Trial Locations

During the second and third year of the study, unusual amounts of rainfall caused significant lodging, seedhead sprouting and damage to certain locations. In Harvest Year 2015, specific winter and spring lines in CAS were hand harvested for a seed increase only and were not evaluated. In Harvest Year 2016, CAS was hand harvested for seedheads, but was unharvestable by combine due to wet field conditions.

Statistical Procedure and Analysis

The PROC CORR procedure in SAS was used to analyze correlations among phenotypic traits observed in the field and in-lab evaluations (Appendix A-1). Values were designated significant at p-values greater or equal to 0.05 (*), 0.01 (**) and 0.001 (***), respectively. Any value greater than 0.05 was considered not significant (NS).

TCAP Barley Performance and Location Effect

All Locations

Table 3.1 shows the Pearson correlation analysis from the TCAP barley trial of winter, facultative, spring two- and spring six-row types grown in CAS, DIM and MCG across all years of the study. In general, biotic and abiotic environmental factors had a negative correlation with yield. Yield loss from bird damage (-0.32***) was observed as seeds began to emerge from the seedhead. An above normal rainfall at all locations during harvest years 2015 and 2016 in comparison to 2013 and 2014, caused a great deal of lodging in the field plots. Lodging resulted in barley seedheads laying on the ground, rendering them unharvestable. In addition, aphid pressure, found only in Harvest Year 2014, was negatively correlated with yield (-0.20***). As previously mentioned in the introduction, aphids are vectors for various viruses (barley yellow dwarf virus) and they can negatively affect yield. When aphids produce honeydew, the fungus *Capnodium* establishes causing sooty mold to form. Sooty mold can block photosynthetic processes in the plant, ultimately interrupting production and yield (Townsend, 2000; Drees, 1996). Freeze damage was negatively correlated to yield (-0.57***) and was found in both CAS and MCG in Harvest Year 2014 only. The cold snap occurred after barley was planted, in November and December 2013 at only CAS and MCG. In CAS, temperatures dropped to an average of 10^{o}C in December, after an unusually warm November (~22^{o}C). In MCG, temperatures dropped to an average of 10^{o}C. Barley that was affected from freeze injury had brown, shriveled tillers. From analysis, plot quality was negatively correlated with yield (-0.30***). A negative correlation between yield and plot quality emphasizes the impact that environmental factors such as insect/disease pressure, lodging and bird damage all have on barley performance. Each of these environmental factors negatively impacted the test plot, resulting in a poor plot quality rating. The other parameters: heading (0.38***), height (0.57***), seedhead weight (0.53***) and test weight (0.40***) were positively correlated with yield. The malt quality parameter was negatively correlated with yield (-0.16***), but positively correlated with stand quality (0.37***). Looking at malt quality, heading date had a negative correlation (-0.50***). Malt quality was also negatively correlated with height (-0.29***), bird damage (-0.20***) and seed moisture (-0.20***). Plumpness had a strong positive correlation with malt quality (0.50***).

<u>*Castroville, TX*</u>

Winter, facultative, spring two- and spring six-row barley data was collected from Castroville, TX from 2014-2016. In 2015, field plots were not harvested due to poor field conditions, however, in-field data was collected throughout the growing season and was included in analysis. In 2016, poor field conditions prevented plots from being mechanically harvested, however, seedheads from all plots were collected and evaluated in-lab.

Table 3.2 shows the correlations between in-field and lab-data collected at this location. Similar to the trend with yield at all locations (Table 3.1), environmental conditions had a negative impact. Lodging (-0.32**), leaf rust (-0.09**) and bird damage (-0.14***) were all negatively correlated with yield, however, aphid pressure (-0.04) was not significant. Height (0.27***) was positively correlated with yield. Unlike the correlation including all locations, heading was negatively correlated with yield (-0.26***). A negative correlation with heading suggests that a later heading date has a negative effect on yield production. Grain fill could occur too early and yield loss from bird damage or lodging could affect those TCAP lines sooner and for a longer duration of time compared to TCAP lines that headed later in the growing season.

While malt quality was not assessed on barley TCAP lines in CAS, plumpness, another malting characteristic, was evaluated. When brewing beer, maltsters prefer a plumper seed. From data collected, yield was positively correlated with plump seed (0.09^{*}) and negatively correlated with medium (-0.28^{***}) and thin (-0.17^{***}) seed. In MCG, plump seed was positively correlated with malt quality and thus may serve as a surrogate for malt quality evaluation (Table 3.3).

McGregor, TX

Winter, facultative, spring two- and spring six-row barley data was collected from McGregor, TX from 2014-2016. Table 3.3 describes the correlations between in-field and lab data collected. Trends for correlations between yield and other data collected were like CAS. Environmental conditions including freeze (-0.19^{***}), bird damage (-0.10^{*}) and aphid pressure (-0.29^{***}) had a significant negative correlation to yield performance. Plot quality was negatively correlated to yield (-0.35^{***}) and height (-0.30^{***}). A poor stand, that had significant lodging or bird damage would be tougher to harvest and therefore lead to a poor yield. When looking at height, some TCAP barley types may have not handled wetter conditions in 2015 and 2016 and grew poorly, resulting in lower yields. In wet conditions, taller barley could have potentially been affected more by rainfall and had high lodging. In contrast, there was a positive correlation (0.37^{***}) between plot and malt quality. A higher quality plot, with little to no environmental damage (lodging, bird and/or insect damage) would be able to produce a higher-quality barley stand compared to a lower quality plot. There was no significance between malt quality and yield at MCG, unlike DIM. There was a negative correlation between yield and medium (-0.32***) and thin (-0.28***) seed. This trend was similar for correlations between malt quality and medium (-0.57***) and thin (-0.53***) seed.

Dimmitt, TX

Only winter TCAP barley lines were grown in Dimmitt, TX between 2015 and 2016. Table 3.4 shows the correlations between in-field observations and lab evaluations. Disease, insect pressure and bird damage at DIM each year was below detectable levels, as the Texas High Plains commonly do not encounter those disease and insect pressures as much as central and southern regions of the state. Lodging had a negative correlation with yield (-0.33***), mainly because as lodging increases, it becomes more difficult to mechanically harvest the crop.

When observing malt quality, there was a positive correlation between malt quality and yield (0.21*). A high-yielding and good malt quality barley could potentially be grown in the High Plains. Like the malt quality trend in MCG, a positive correlation between malt quality and plump seed was found (0.17*). There was no significance in the correlation between malt quality and medium or thin seed, respectively. There was a negative correlation between height and plump seed (-0.25***). A negative correlation between height and plump seed shows that as a barley plant grows taller, less of its nutrients and energy are going to seed production, which ultimately causes more medium and thin-sized seeds on the seedhead. Lastly, stand quality had a positive correlation (0.50***) with height. A positive correlation between these two parameters could be due to the lack of lodging seen at this location, thus reducing the amount of poor stands found in the field.

Discussion and Conclusions

Variations in climate, precipitation and temperature across different growing regions have both negative and positive effects on barley production. Environmental conditions such as aphid, freeze and bird damage had negative impacts in relation to yield production (Tables 3.2 and 3.3). In Harvest Year 2015 and 2016, conditions were wetter than ideal during harvest season. Because barley does not tolerate wet conditions well, excessive rainfall and constant soil saturation caused damage to the crop. In locations such as MCG and CAS, that are higher rainfall regions in Texas, standability is an important trait for selecting lines to be produced in those areas. A barley line that has good standability would be able to withstand rainfall and still be able to produce a good yielding crop.

When statistically analyzed, plot quality played a significant role in yield performance, a high-quality plot was positively associated with a higher yield. This trend was similar for malt quality as well. Despite excessive rainfall during the growing season, most the barley plots achieved an “excellent” plot rating. While it may seem practical to select top-performing lines visually, a high-quality plot during the growing season does not necessarily mean it will be a high-yielding plot during harvest. From a personal standpoint, some barley lines that had excellent vegetative growth, matured too early and either lodged or lost seed from bird damage.

Malt quality is an important parameter when looking at barley for beer production. Table 3.1 shows that malt quality is negatively correlated with yield performance, but when looking at each location individually, it is not significant at MCG (Table 3.3) and positively correlated at DIM (Table 3.4). Due to the differences in correlations between yield and malt at the two locations, more research is needed to determine if these parameters seem to be more negatively or positively correlated.

From PROC CORR analysis, regional differences were evident when comparing in-field data to yield evaluations in-lab. Insect and disease pressure is more evident in central and southern regions of Texas and have a negative impact on the quality and performance of barley throughout the growing season. Little insect and disease pressure is found in the Texas High Plains and therefore no negative impacts were seen and recorded during the growing season. Dimmitt, TX is one of the more ideal locations for barley production compared to other areas of the state, MCG and CAS included. The main reason for this is that with a lower monthly precipitation and cooler temperatures, barley can grow more efficiently—with less heat stress, insect/disease and excessive precipitation. Pivot irrigation systems are common in the High Plains and regulated water applications are applied to crops when needed. Barley, under irrigation, would be able to grow and produce grain, even if a dry-spell were to affect precipitation.

While three years of research in different regions across the state has been beneficial, more research is needed to discover trends in production over a longer time. More data, especially about the relationship between high yield and malt quality, is needed as well. A high-yielding and high malt quality barley may be an ideal combination for a producer looking to supply to both the feed grain and malt industries.

Table 3.1: Pearson correlation analysis between in-field and lab data collected from all locations (CAS, DIM and MCG) and all barley types from 2014-2016.

	Single seed weight (g)	**Number of Seeds**	**Plump Seed**	**Medium Seed**	**Thin Seed**	**Yield (kg ha^{-1})**	**Seed Moisture**	**Test Weight (lbs bu^{-1})**	**Seedhead Weight (g)**	**Heading (Julian Day)**	**Height (cm)**	**Lodging**	**Bird Damage**	**Freeze (03/10/14)**	**Plot Quality**
Plump Seed	0.33^{***} 2676	-0.03^{NS} 2675													
Medium Seed	-0.42^{***} 2680	-0.02^{NS} 2680	0.42^{***} 2936												
Thin Seed	-0.47^{***} 2680	0.02^{NS} 2680	-0.13^{***} 2936	0.53^{***} 2941											
Yield (kg ha^{-1})	0.26^{***} 2659	-0.20^{***} 2659	0.02^{NS} 2915	-0.22^{***} 2919	-0.15^{***} 2919										
Moisture	-0.01^{NS} 1001	-0.23^{***} 1001	-0.16^{***} 1245	0.11^{***} 1245	0.20^{***} 1245	-0.13^{***} 1245									
Test Weight (lbs bu^{-1})	0.30^{***} 942	0.46^{***} 942	0.30^{***} 1185	-0.35^{***} 1185	-0.12^{***} 1185	0.40^{***} 1185	-0.09^{**} 1184								
Seedhead Weight (g)	0.04^{NS} 1561	0.98^{***} 1561	0.29^{***} 1009	-0.35^{***} 1009	-0.09^{*} 1009	0.53^{***} 1009	-0.25^{***} 1001	0.53^{***} 942							
Heading (Julian Day)	-0.12^{***} 2236	-0.59^{***} 2233	-0.04^{NS} 2483	0.17^{***} 2487	0.13^{***} 2487	0.38^{***} 2466	0.83^{***} 817	0.11^{**} 757	-0.29^{***} 587						
Height (cm)	0.17^{***} 3123	0.02^{NS} 3131	0.03^{NS} 2818	-0.27^{***} 2823	-0.18^{***} 2823	0.57^{***} 2802	0.28^{***} 1245	0.12^{***} 1185	0.08^{***} 1564	-0.21^{***} 2393					
Lodging	-0.05^{*} 1455	-0.33^{***} 1460	-0.15^{***} 1127	0.13^{***} 1127	0.08^{**} 1127	-0.01^{NS} 1126	0.20^{***} 940	-0.20^{***} 880	-0.37^{***} 1281	0.19^{***} 985	0.02^{NS} 1681				
Bird Damage	0.06^{*} 1559	-0.36^{***} 1555	-	-0.01^{NS} 1073	-0.01^{NS} 1073	-0.32^{***} 1073	-0.10^{*} 533	-0.12^{**} 485	-0.42^{***} 1030	-0.31^{***} 1086	0.26^{***} 1531	0.50^{***} 1079			
Freeze (03/10/14)	-0.07^{**} 1673	-0.56^{***} 1669	0.01^{NS} 1679	0.13^{***} 1684	0.09^{***} 1684	-0.57^{***} 1663	-	-	-	0.84^{***} 1679	-0.75^{***} 1585	-0.40^{***} 182	-0.08^{*} 543		
Plot Quality	-0.13^{***} 3094	0.53^{***} 3086	-	0.08^{***} 2550	0.12^{***} 2550	-0.30^{***} 2529	-0.16^{***} 854	0.43^{***} 794	0.50^{***} 1413	-0.28^{***} 2271	-0.29^{***} 3003	-0.71^{***} 1317	-0.53^{***} 1573	-0.37^{***} 1711	
Aphid Pressure	0.15^{***} 618	-0.27^{***} 620	0.09^{*} 626	-0.11^{**} 629	-0.08^{*} 629	-0.20^{***} 628	-	-	-	0.20^{***} 611	-0.22^{***} 595	-0.15^{NS} 95	-	0.36^{***} 635	0.04^{NS} 635
Malt Quality	0.33^{***} 408	-0.20^{***} 408	0.50^{***} 640	-0.51^{***} 640	-0.47^{***} 640	-0.16^{***} 640	-0.20^{***} 640	0.08^{*} 626	-0.13^{*} 408	-0.50^{***} 493	-0.29^{***} 642	-0.27^{***} 618	-0.20^{**} 236	-	0.37^{***} 261

Table 3.2: Pearson correlation analysis between in-field and lab data collected from all barley types in Castroville, TX, 2014-2016.

	Single Seed Weight (g)	Number of Seeds	Plump Seed	Medium Seed	Thin Seed	Yield (kg ha^{-1})	Heading (Julian Day)	Height (cm)	Lodging	Leaf Rust	Bird Damage	Stand Quality
Number of Seeds	-0.14*** 1371											
Plump Seed	0.39*** 832	0.05^{NS} 837										
Medium Seed	-0.64*** 834	-0.14*** 840	-0.39*** 848									
Thin Seed	-0.52*** 834	-0.05^{NS} 840	-0.51*** 848	0.69*** 851								
Yield (kg ha^{-1})	0.13*** 833	0.81*** 839	0.09* 847	-0.28*** 850	-0.17*** 850							
Heading (Julian Day)	-0.21*** 816	-0.30*** 818	-0.37*** 827	0.42*** 829	0.26*** 829	-0.26*** 828						
Height (cm)	0.15*** 1326	-0.19*** 1333	0.49*** 786	-0.53*** 789	-0.36*** 789	0.27*** 788	-0.47*** 780					
Lodging	-0.04^{NS} 646	-0.33*** 651	-0.09^{NS} 105	0.12^{NS} 105	0.06^{NS} 105	-0.32** 104	-0.08^{NS} 106	0.01^{NS} 653				
Leaf Rust	-0.20*** 835	-0.04^{NS} 840	-0.16*** 848	0.17*** 851	0.12*** 851	-0.09** 850	-0.02^{NS} 843	-0.11** 802	0.06^{NS} 107			
Bird Damage	0.08* 1014	-0.67*** 1010	0.05^{NS} 533	-0.11** 533	-0.12** 533	-0.14*** 533	0.06^{NS} 543	0.15*** 986	0.20*** 535	0.11* 543		
Stand Quality	-0.12*** 1381	0.67*** 1386	-0.08* 848	-0.01^{NS} 851	0.04^{NS} 851	0.09* 850	-0.07* 843	-0.33*** 1348	-0.46*** 653	0.01^{NS} 865	-0.68*** 1028	
Aphid Pressure	-0.05^{NS} 300	-0.03^{NS} 308	-0.04^{NS} 308	0.05^{NS} 311	0.03^{NS} 311	-0.04^{NS} 310	0.05^{NS} 293	-0.14* 297	0.13^{NS} 57	-	-	0.09^{NS} 315
Stripe Rust	0.08^{NS} 302	0.14* 310	-0.03^{NS} 310	-0.07^{NS} 313	0.01^{NS} 313	0.19*** 312	0.05^{NS} 295	0.02^{NS} 299	0.11^{NS} 57	-0.15** 317	-	0.05^{NS} 317

Table 3.3: Pearson correlation analysis between in-field and lab data collected from all barley types in McGregor, TX, 2014-2016.

	Single Seed Weight (g)	**Number of Seeds**	**Plump Seed**	**Medium Seed**	**Thin Seed**	**Yield (kg ha^{-1})**	**Test Weight (lbs bu^{-1})**	**Head m^{-2}**	**Seeds hd^{-1}**	**Heading (Julian Day)**	**Height (cm)**	**Lodging**	**Freeze (3/10/14)**	**Plot Quality**
Number of Seeds	-0.45***													
	1420													
Plump Seed	0.37***	-0.10***												
	1418	1412												
Medium Seed	-0.36***	0.27***	0.50***											
	1420	1414	1661											
Thin Seed	-0.47***	0.25***	-0.12***	0.48***										
	1420	1414	1661	1663										
Yield (kg ha^{-1})	0.35***	-0.35***	0.03^{NS}	-0.32***	-0.28***									
	1400	1394	1641	1642	1642									
Test Weight (lbs bu$^{=1}$)	0.51***	0.16***	0.42***	-0.47***	-0.34***	0.07*								
	516	516	758	758	758	758								
Head m^{-2}	0.04^{NS}	-0.21***	-0.02^{NS}	0.03^{NS}	-0.02^{NS}	0.37***	-0.30***							
	1415	1410	1412	1414	1414	1394	516							
Seeds hd^{-1}	-0.29***	0.62***	-0.07**	-	0.08**	-0.11***	0.15***	-0.49***						
	1414	1415	1406		1408	1388	516	1410						
Heading (Julian Day)	-0.22***	0.21***	-0.03^{NS}	0.04^{NS}	0.05*	0.17***	0.11**	-0.10***	0.02^{NS}					
	1420	1415	1656	1658	1658	1638	757	1414	1409					
Height (cm)	0.33***	-0.34***	0.03^{NS}	-0.29***	-0.29***	0.75***	-0.08*	0.27***	-0.12***	0.20***				
	1370	1371	1605	1607	1607	1587	758	1363	1365	1613				
Lodging	-0.19***	-0.20***	-0.15***	0.13***	0.08*	0.10**	-0.21***	0.17***	-0.20***	0.26***	0.11**			
	662	662	874	874	874	874	732	658	662	879	880			
Bird Damage	-0.13**	-0.15***	-0.38***	0.39***	0.40***	-0.10*	-0.16***	0.06^{NS}	-0.16***	0.28***	-0.09*	0.15***		
	544	544	539	539	539	539	484	539	544	543	544	544		
Freeze (03/10/14)	0.43***	-0.33***	0.09**	-0.41***	-0.37***	-0.19***	-	-0.28***	-0.10**	0.01^{NS}	0.24***	0.33**		
	838	829	831	833	833	813		833	823	836	783	75		
Plot Quality	-0.17***	0.44***	-0.01^{NS}	0.18***	0.19***	-0.35***	0.38***	-0.17***	0.26***	0.20***	-0.30***	-0.90***	-0.24***	
	1434	1421	1419	1421	1421	1401	516	1420	1415	1428	1376	664	846	
Aphid Pressure	0.44***	-0.34***	0.40***	-0.42***	-0.19***	-0.29***	-	-0.34***	-0.04^{NS}	-0.09^{NS}	0.06^{NS}	-0.18^{NS}	0.30***	0.04^{NS}
	318	312	318	318	318	318		319	311	318	298	38	320	320
Malt Quality	0.35***	0.30***	0.56***	-0.57***	-0.53***	0.01^{NS}	0.20***	-0.33***	0.30***	-0.50***	-0.24***	-0.34***	-	0.37***
	261	261	492	492	492	492	478	259	261	493	494	470		261

Table 3.4: Pearson correlation analysis between in-field and lab data collected from winter and facultative barley in Dimmitt, TX, 2015-2016.

	Single Seed Weight (g)	**Plump Seed**	**Medium Seed**	**Thin Seed**	**Yield (kg ha^{-1})**	**Moisture**	**Test Weight (lbs bu^{-1})**	**Head m^{-2}**	**Seeds hd^{-1}**	**Height (cm)**
Number of Seeds	-0.17*** 427									
Plump Seed	0.29*** 426									
Medium Seed	-0.37*** 426	-0.71*** 427								
Thin Seed	-0.38*** 426	-0.58*** 427	0.67*** 427							
Yield (kg ha^{-1})	-0.29*** 426	-0.08^{NS} 427	0.06^{NS} 427	0.30*** 427						
Moisture	-0.26*** 426	-0.16*** 427	0.18*** 427	0.58*** 427	0.58*** 427					
Test Weight (lbs bu^{-1})	-0.01^{NS} 426	0.17*** 427	-0.19*** 427	-0.15** 427	0.23*** 427	0.08^{NS} 427				
Head m^{-2}	-0.41*** 426	-0.19*** 426	0.19*** 426	0.28*** 426	0.73*** 426	0.40*** 426	0.02^{NS} 426			
Seeds hd^{-1}	-0.17*** 427	0.05^{NS} 426	-0.06^{NS} 426	0.08^{NS} 426	0.30*** 426	0.20*** 426	0.23*** 426	-0.34*** 426		
Height (cm)	-0.32*** 427	-0.25*** 427	0.29*** 427	0.68*** 427	0.67*** 427	0.86*** 427	0.13** 427	0.44*** 426	0.29*** 427	
Lodging	-0.06^{NS} 147	-0.25** 148	0.24** 148	0.25** 148	-0.33*** 148	0.10^{NS} 148	-0.15^{NS} 148	-0.17* 147	-0.22** 147	-0.08^{NS} 148
Stand Quality	0.07^{NS} 279	-0.03^{NS} 278	-0.22*** 278	0.11* 278	0.30*** 278	0.06^{NS} 278	-0.08^{NS} 278	0.20** 278	-0.06^{NS} 279	0.50*** 279
Malt Quality	0.03^{NS} 147	0.17* 148	-0.16^{NS} 148	-0.16^{NS} 148	0.21* 148	-0.09^{NS} 148	0.38*** 148	0.06^{NS} 147	0.14^{NS} 147	0.10^{NS} 148

CHAPTER IV

AN EVALUATION OF ECONOMIC FEASIBILITY OF BARLEY IN TEXAS

Introduction

Barley from a Global Perspective

A significant amount of barley is grown on almost every continent in the world and it plays an important role in many people's lives. Since the 1990s, annual worldwide production of barley has decreased from 178 million metric tons (MMT) to 144 MMT in 2014. Over 78% of the world's barley is grown in Europe and Asia combined. In 2014, Russia (20,444,258 metric tons), France (11,770,682 metric tons) and Germany (11,562,800 metric tons) were the top 3 barley-producing countries in the world. North America contributed approximately 11% (FAOSTAT, 2016)

The Food and Agriculture Organization (FAO) indicates that from 2000 to 2005, world trade of barley grain was worth \$3 billion US dollars per year (USD yr^{-1}) and world trade of barley for malt purposes was \$2 billion USD yr^{-1}. Germany, United Kingdom, France and Belgium use barley mainly for malt production. Ulrich (2011) stated 94% of barley from the countries previously mentioned is used for beer, 4% for distillation for whiskey and 2% for food use. An increase in consumption of beer has increased the use and production of barley as a malt product over the past few years.

Barley is the fifth most popular crop produced worldwide and the fourth most produced cereal grain on a dry weight basis. At one point in the 1980s, barley production was twice as much as soybean (*Glycine max*) production, but has since declined by 12% (Ulrich, 2011). Technological limits, government regulations, higher-profiting crops and climate are some factors having affected barley production over the years.

Barley in the United States

Barley is believed to have entered the United States (US) in two ways: to New England and the Atlantic coast with colonists from Europe and to the southwest with the Spaniards (Atkins, 1980). After the 1800s, settlers began to move west and barley traveled with them. It was soon discovered barley grew better in fertile Midwest soils versus sandy coastal-type areas.

While the epicenter of barley production in the US is based in five states, it can be found growing in the Eastern and Southwestern parts of the country as well (Figure 1.1). Each region in the US varies in production and type(s) of barley grown. Idaho, Minnesota, Montana, North Dakota and Washington are the top barley-producing states in the US, planting approximately 82% of the total barley acreage in the 2015 planting season (WASDE, 2016).

In the US, 23% of barley is used for animal feed and 77% is used for food, seed and industrial purposes. In contrast, 83% of wheat produced is used for animal feed and 17% is used for food and seed (WASDE, 2016). Table 1 describes the land use and production trend for both barley and wheat between the years 2014 and 2016. In 2000, the country's demand for malt was 14.97 MMT (Brown et al., 2001). Figure 1.2 shows the price trends compiled by USDA of barley grain, malt barley, wheat and corn grain on a \$ metric ton^{-1} (\$ Mt^{-1}) from 2000-2016.

Barley in Texas

Since the late 1500s, barley has been an important crop in Texas. Barley arrived in the state through El Paso from Mexico between 1598-1685 and through south and east Texas with the establishment of missions in the 1700s (Atkins, 1980). As the numbers of settlers and missionaries increased, the cultivation of barley slowly spread across the state.

Varieties grown in Texas depended on their path of entry. Coast-type barley, originating from northern Africa, traveled to Texas with missionaries. This spring type variety grew well in central and western areas of the state, but not in south Texas. Barley originating from Europe were mainly two-row spring types and came to Texas with settlers from northern and eastern states. Producers found winter barley was more successful versus spring due to its ability to withstand cooler temperatures, drought and disease (Atkins, 1980). The Texas Agriculture Census of 1887 showed that barley production covered 4,682 ha. Cotton (1,319,263 ha), corn (1,185,431 ha) and wheat (210,525 ha) were the top three field crops produced (Foster, 2001). Introduced barley lines from Tennessee increased planted acres to 36,017 ha in the 1920s and by 1961, harvested barley acres peaked at 170,372 ha (Atkins, 1980). After the 1960s, barley production began to decrease. The 1987 Texas Agriculture Census report showed that 5,434 ha of barley were harvested, in comparison to 1,476,739 ha of wheat harvested the same year. Today, barley is planted on less than 12,000 ha across the state and is mainly used as a dual-purpose grazing and grain source for cattle (~4,700 ha). Table 4.1 shows the breakdown of 2015 barley production in the state (FSA, 2015).

Texas Agricultural Experiment stations played an important role in producing barley types that performed well across the state's different environments. Researchers found winter barley with prostrate growth habits (grow low to the ground) and high cold tolerance was well-adapted to the High Plains. Intermediate types of winter barley with upright growth habits, moderate cold tolerance and no vernalization requirement were best for pastureland in the Rolling Plains and East Texas. Some of the first barley varieties adapted to Texas were, 'Finley', 'Wintex' and 'Texan'. Over the years, more varieties were released including, 'Cordova' in 1938—a more disease-resistant and high quality grain and forage variety. 'Goliad' and 'Tunis', two varieties with good disease resistance and forage characteristics were also released (Atkins, 1980). More recently, Texas A&M Agriculture Experiment Station released two winter barley varieties for commercial use. The first, 'TAMbar 500', was released in 1991 and is ideal for production in the High Plains. It is a medium to late-maturing variety that has some resistance to Barley Yellow Dwarf Virus and complete resistance to powdery mildew and the leaf rust pathogen *Puccina hordei* (Marshall et al., 1993). The second, 'TAMbar 501', was released in 2001 and is commonly used as a feed-type barley in central, east and south Texas. This variety is early-maturing, has good winter hardiness and resistance to Barley Yellow Dwarf Virus (Marshall et al., 2003).

Table 4.1: 2015 Farm Service Agency; barley use breakdown in Texas.

Use	*Land Area (ha)*
Grazing & Grain	4,653
Grain only	3,503
Grazing only	1,424
Forage only	1,176
Cover crop only	338
Seed only	49.4
Left standing	0.81
Total (2015)	11,144.21

Texas Dairy Industry

Texas is home to over 400 dairy farms located mainly in the Central and High Plains of the state. On average, a Texas dairy raises 1,076 head of milking cattle, producing over 9.9 million kg of milk $year^{-1}$. Annually, the Texas dairy industry contributes $9.5 million to the state's economy (Economics, 2014).

Dairy cattle are commonly fed corn silage, as it is palatable and contains a proper ratio of nutrients and energy requirements that are needed by a lactating cow. Small grains, such as wheat and grasses such as annual ryegrass can also be utilized. Forage crops are harvested at a higher moisture when being used for silage versus dry hay. The ensiling process has two main steps—an aerobic (with oxygen) and an anaerobic (without oxygen) process. In the first step, aerobic bacteria release carbon dioxide (CO_2) and heat and consume the oxygen in the silo where the silage is stored. The temperature of the forage increases to 26-37^{o}C. Once oxygen has been depleted, anaerobic bacteria take over and begin to produce both lactic and acetic acid (Ball, Hoveland and Lacefield, 2007). The final product has a pH between 3.5-4.5. Silage is a desirable feed for livestock, including dairy cattle, because it is palatable and if ensiled and stored correctly, it has a good "shelf life". In recent years, barley has been an increasingly popular crop grown by dairy producers in the Texas High Plains for use as both a silage and grain for cattle (personal communication).

The National Research Council (NRC), helps to evaluate nutrient content of various feedstuff that livestock consume. Table 4.2 describes the nutrient content of barley silage (headed), corn silage (normal heading) and wheat silage (early headed). Data was taken from the NRC computer program. Total digestible nutrients (TDN, % dry matter) a measure of energy and considers the amount of digestible fiber, carbohydrates, protein and fats in a feedstuff. The higher the percentage of TDN in a feedstuff, the more energy can be utilized by the animal consuming it. The second parameter, digestible energy (DE, Mcal kg^{-1}) is directly related to TDN. This parameter describes the amount of energy that is digested by the animal. Dry Matter (DM, % as fed), refers to the feed that is remaining once moisture is removed during analysis. Neutral detergent fiber (NDF, % DM), measures the hemicellulose, cellulose and lignin content. This parameter is associated with DM intake; the higher the NDF percentage, the lower the animal's intake of feed. Acid detergent fiber (ADF, % DM) is associated with DM digestibility and measures the indigestible content of the feedstuff—cellulose and lignin. Acid detergent fiber is negatively correlated with digestibility; as it increases, the less digestible the feedstuff is (Ball, Hoveland and Lacefield, 2007). Crude protein (CP, % DM) is derived from the nitrogen content, both true protein (amino acids) and non-protein nitrogen sources (urea). For a high-producing lactating dairy cow (30-39 kg milk day^{-1}), rations should contain ~16% CP. The last parameter, fat, is considered an energy source and is measured as a percent of the dry matter content.

When looking at table 4.2, TDN is the highest in corn silage, in addition to having the highest DE. Barley silage has the highest digestible energy, which is beneficial for lactating dairy cattle, as they need energy to produce milk. For NDF, it is the highest in wheat silage, which indicates that the animal's intake would be lower compared to feeding both barley and corn silage. Acid detergent fiber is also the highest for wheat silage, indicating that it is a less digestible feedstuff compared to barley and corn silage. Crude protein content is consistent between barley and wheat silage (12.00 % DM) and lower in corn silage (8.80 % DM). Silage with a higher CP would be more beneficial for lactating dairy cattle. The last parameter, fat, is consistent between barley, corn and wheat silage.

Table 4.2: National Research Council (NRC) nutrient content of barley silage (headed), corn silage (normal) and wheat silage (early headed).

	Barley Silage, Headed	**Corn Silage, Normal**	**Wheat Silage, Early Headed**
TDN (% DM)	60.16	68.79	57.40
DE (Mcal kg^{-1})	2.67	2.99	2.56
DM (% As Fed)	35.50	35.10	33.30
NDF (% DM)	56.30	45.00	59.90
ADF (% DM)	34.50	28.10	37.60
CP (% DM)	12.00	8.80	12.00
Fat (% DM)	3.50	3.20	3.20

The Texas Craft Beer Movement

A craft brewery is defined as a small privately-owned brewery that produces less than 6 million barrels of beer annually. In the United States, craft brewers tend to use spring type barleys for malting more than winter and/or facultative. Two-row spring barley is preferred for malting, as it is higher in extract and low in protein—ideal for producing lager. Two-row is grown in central MT, ID, WA and CO. Six-row spring barley can also be used for malting, but contains more enzymes which is not ideal for lager production. Six-row can be found growing in MN, ND and eastern MT (Bouckaer et al., 2016). There are currently 189 craft breweries in Texas, ranking 7th in the US. A "beer barrel" is defined as containing 117.3 liters (L) (31 gallons). Texas craft breweries produced 1,135,043 barrels of beer in 2015, which is the equivalent of 35,186.333 gallons (133,140,543.9 L) of beer. In 2014, craft brewery production in the state had a $3,770,000 impact on the economy (Craft Beer Sales by State, 2016).

For craft breweries to utilize locally grown barley, local malthouses are needed. In general, malt dealers prefer to contract with brewers producing greater than 20,000 barrels of beer each year (Bouckaer et al., 2016). Since Texas currently has one micro-malthouse, production is limited to the malthouse's capacity. From personal communication, malt production is expected to increase to 200 tons of barley consumed in 2017 and more malthouses are planning to be built across the state.

Materials and Methods

For this project, barley lines were obtained from the Triticeae Coordinated Agricultural Project (TCAP) to screen advanced breeding material from barley breeding programs within the US. This project identified suitable lines adapted for Texas climates that outperform current commercially available varieties for malting and feed grade purposes. The TCAP consists of wheat and barley breeders from across the US with the goal of preserving and developing new varieties of wheat and barley. The third objective of this study was to evaluate the economic feasibility of barley production in Texas. An evaluation of wheat grown within the same plots and/or in the same field as the barley trials was used to help make a comparison between wheat and barley grown under similar field conditions, treatments, etc. between all harvest years (2014-2016) at MCG and DIM only.

Harvest Year 2014

Headrows (HR) (1 m long, 0.4 m apart) of 463 spring (248 2-row, 215 6-row), 119 winter and 182 facultative TCAP lines were grown in two locations in central and south Texas, Castroville (CAS) and McGregor (MCG) in Harvest Year 2014. Table 2.1 and Figures 2.1 and 2.2 describe each location's environmental conditions, average monthly rainfall and temperature. Untreated barley seed was planted in a single replicated design (SRD) with repeated checks placed throughout. Checks are commercially available varieties and provide a yield comparison among TCAP breeding lines and commercial variety performance. Spring checks placed in the spring trial were: 'AC Metcalf', 'Conlon' and 'CDC Copeland'. Winter checks placed in the winter trial were: 'Alba', 'Maja' and 'Full Pint'. A Hege 1000 HR plot drill (76 cm long HD on a 38 cm row spacing), complete with automatic trip was used to plant. The CAS location had access to overhead irrigation and MCG was a dryland location.

Fertilizer was applied based on soil test recommendations. In CAS, no chemicals were applied. On February 14, 2014, 35.3 kg N ha^{-1} (UAN 32-0-0), 2.34 L ha^{-1} Dimethoate (ai: dimethoate) and a mixture of 1.75 L ha^{-1} Weedmaster (Nufarm, ai: 3,6-dichloro-o-anisic acid, 2,4-dichlorophenoxyacetic acid) and 0.0000025 L ml^{-1} of the surfactant LI 700 (Nufarm) was topdressed to the HRs at MCG.

In-field observations were taken during the growing season, as described in Table 2.4. Final field observations and plant height (cm) and plot quality were taken at harvest. In-field notes taken on plot quality, rated plots based on the overall plant health and uniformity of each test plot before harvesting. If a plot had a great deal of lodging, bird damage, poor growth, etc. a rating of 1 would be given. A rating of 5 was given to plots that had uniform growth and no lodging or bird damage. Viable seedheads were hand harvested and placed into their respective sample bag for later processing.

In the lab, seedheads were counted, threshed (Model BT14E thresher, Almaco, Nevada, IA) to collect seed and cleaned (Model ABSO aspirator, Almaco, Nevada, IA) to remove foreign material. Table 2.4 describes the lab data that was collected after harvest. A double-screened method was used to determine kernel plumpness, a parameter used for malting characteristics. A 24 mm screen placed on a 20 mm screen all placed on a catch pan was shaken fifteen times clockwise and counterclockwise. Seed remaining on each screen was weighed (g) and divided into “plump” (>24 mm), “medium” (<24 mm and >20 mm) and “thin” (< 20 mm).

All field and lab data of TCAP lines and checks were compiled and statistically analyzed using the PROC CORR procedure in SAS (SAS Institute, 2009) to measure the association between yield and yield parameters (Appendix A-1). Prior to correlation analysis, yields of all entries were adjusted with repeating checks using the software program Agrobase (Agronomix Inc.). The top yielding 20% of winter and spring lines were replanted in small plots (1.5m x 4.5m) for Harvest Year 2015.

Harvest Year 2015

The top 20% yielding lines from Harvest Year 2014 were further evaluated in larger test plots in Harvest Year 2015. 128 spring (64 2-row, 64 6-row), 23 winter and 45 facultative lines were planted in three locations in Texas: Dimmitt (DIM), CAS and MCG (Table 2.2, Figures 2.1, 2.2, 2.3, 2.4, 2.5 and 2.6). Dimmitt was planted with winter and facultative lines only, as fall planted spring barley reliability is limited in northern parts of Texas due to freeze injury from cold winter temperatures. The remaining locations, CAS and MCG were planted with winter and spring lines.

In this year, seed was treated with CruiserMaxx® Vibrance for Cereals (Syngenta, ai: Thiamethozam, Mefenozam, Difenoconazole) and Cruiser® 5FS (Syngenta, ai: Thiamethozam) to prevent fall insect infestation. 60 g (68 kg ha^{-1}) of each line were packaged in small envelopes for each location. If seed was limited (< 30 g, < 34 kg ha^{-1}), it was replaced with an alternative variety, 'P-919' or 'TAMbar 501' for winter and 'AC Metcalf', 'Conlon', 'CDC Copeland' or 'SY-Goliad' (wheat) for spring barley. Lines used this year were placed in a SRD with repeating checks placed throughout.

Small plots (1.5m x 4.5m) were planted using an eight-row (18 cm row spacing) planter. Two locations (DIM and CAS) had access to overhead irrigation while MCG was a dryland location. The same in-field observations were taken as Harvest Year 2014 (Table 2.5).

On January 29, 2015, in MCG, 50.4 kg N ha^{-1} (UAN 32-0-0) and a mixture of 1.55 L ha^{-1} MCPA Ester (Agri Star, ai: 2-ethylhexyl ester of 2-methyl-4-chlorophenoxyacetic acid) and a recommended rate of the surfactant LI 700 was topdressed on all plots. In DIM, 70.6 kg N ha^{-1} (46-0-0) was applied on November 2, 2014 prior to planting. One week before planting, volunteer corn in the field was sprayed with Gramoxone (Syngenta, ai: paraquat dichloride) at a rate of 3.50 L ha^{-1}. Between late February and late March 2015, three applications of N (32-0-0) at the rate of 41.5 kg ha^{-1} was applied via fertigation.

During harvest, a Wintersteiger (Wintersteiger Ag, Ried, Austria) nursery combine (1.5 m header) was used. Due to the unseasonable amount of rain during May (harvest season), CAS was selectively hand harvested for seed increase only and was not included for statistical analysis. Harvested samples were processed in the lab and evaluated for yield components (Table 2.7). Subsamples of each line were packaged and sent to USDA Cereal Quality Testing Lab (Madison, WI) for malt quality testing including: kernel weight, color, malt extract, wort color and clarity, barley protein, wort protein and enzymes.

Harvest Year 2016

In 2015-2016, the same lines were used as the previous year in CAS, MCG and DIM (Table 2.3, Figures 2.1, 2.2, 2.3, 2.4, 2.5 and 2.6). 55 g (63 kg ha^{-1}) of each line was packaged for each location. Any seed envelope with less than 30 g (34 kg ha^{-1}) of barley was replaced with an alternative commercial variety, ‘P-919’, ‘TAMbar 501’ or ‘TAM 304’ (wheat) for winter trials and ‘AC Metcalf’, ‘Conlon’, ‘CDC Copeland’ or ‘Expresso’ (wheat) for spring trials. An alpha-lattice design containing two incomplete blocks was used with commercial checks placed within the trial. Checks were the same as the previous year, with the addition of ‘TAM 304’ (winter wheat) in the winter trial and ‘Expresso’ (spring wheat) in the spring trial. Wheat checks provided a direct comparison of barley yield in relation to a known crop with extensive yield history throughout the state. Barley was planted in small plots, using the same dimensions and equipment as in Harvest Year 2015. All locations, except for MCG had access to overhead irrigation.

In DIM, no herbicide or insecticide was applied to the field. On March 5, 2016, plots were topdressed via fertigation with 32.5 kg N ha^{-1} (32-0-0). In CAS, 599 kg ha^{-1} of fertilizer in the form of 12-8-5-2 was applied prior to planting on October 29, 2015. On March 3, 2016, a mixture of 0.87 L ha^{-1} of Dimethoate (ai: dimethoate) and 0.116 L ha^{-1} of Induce (Helena Chemical, ai: alkyl aryl polyozylkane ethers and free fatty acids) was topdressed to the plots. In MCG, a topdress application of 39 kg N ha^{-1} (32-0-0) was applied on January 27, 2016. On that same day, a mixture of 2.34 L ha^{-1} of MCPA Ester (Agri Star, ai: 2-ethylhexyl ester of 2-methyl-4-chlorophenoxyacetic acid) and 36.5 mL ha^{-1} of the herbicide Amber (Syngenta, ai: triasulfuron) was applied.

Results

Winter TCAP Barley Lines

Winter barley was harvested at MCG 2014, 2015 and 2016 and in DIM 2015 and 2016. Despite an unusual amount of rainfall during springtime of both years, the yield of both barley and wheat were near average for each respective region. Table 4.3 shows the yield data and averages, in metric ton ha^{-1} (Mt ha^{-1}) from DIM and MCG winter barley trials for all harvest years.

In DIM, yields were lower in 2016 compared to 2015, largely due to a later planting date in 2015. There were no common top-performing TCAP winter lines at DIM during both years. The top five performing TCAP tested lines in 2015 yielded approximately 2-3 Mt ha^{-1} more than the commercial barley checks in 2015. The top five TCAP lines tested in 2015 averaged 7.50 Mt ha^{-1} compared to the top five hard red winter wheat (HRWW) varieties (7.11 Mt ha^{-1}) grown in another field located in DIM under similar environmental growing conditions. In 2016, the addition of a wheat commercial check ('TAM 304') allowed for a more accurate comparison of performance between the two small grains under the same field conditions and environment. The average yield of the top five TCAP barley lines tested in DIM (4.38 Mt ha^{-1}) was greater than the top five average HRWW yield (3.63 Mt ha^{-1}) at a trial in Hereford, TX, approximately 34 km from the barley trial site. The TCAP line 'F532_1' was a top-performing line at DIM and MCG in 2015. Yields of winter barley at DIM were higher over both years (2015 and 2016) compared to yields at MCG. Cultural practices including irrigation, coupled with a drier environment (less disease and pest pressure) are some contributors to these yield differences.

Data from winter barley grown at MCG was collected during harvest years 2014, 2015 and 2016 (Table 4.3). Yields in 2014 were much lower compared to harvest years 2015 and 2016 due to plot size (headrows vs. small plots). In 2014, yields of the top five TCAP lines (0.39 Mt ha^{-1}) out-yielded all three commercial checks. At MCG in 2015, the top five winter barley TCAP lines outperformed the commercial checks by approximately 1.50 Mt ha^{-1}. The top five TCAP lines yielded higher (3.52 Mt ha^{-1}) than the average of the top five HRWW at a variety trial in Hillsboro, TX which is 77 km away (2.38 Mt ha^{-1}). Winter TCAP barley line 'F523_1' was the top-yielding line at MCG across all years. This TCAP line was also a top-performing line in DIM 2016. At MCG in 2016, the average yield for the top five TCAP lines (3.32 Mt ha^{-1}) was superior to all barley commercial checks for yield. In addition, the top five performing TCAP lines out-performed the wheat check 'TAM 304' (2.81 Mt ha^{-1}), which was the number one HRWW planted in the region in 2015 (NASS, 2015). The top five TCAP lines in 2016 also outperformed the HRWW (3.70 Mt ha^{-1}) grown in a trial adjacent to the barley trial site in McGregor, TX. There were no TCAP lines that made the top five ranking more than a single year at MCG.

Table 4.3: Winter barley yield results from Dimmitt and McGregor, TX (2014-2016).

Location & Type	Harvest Year 2014 Entry	Harvest Year 2014 Yield (Mt ha^{-1})	Harvest Year 2015 Entry	Harvest Year 2015 Yield (Mt ha^{-1})	Harvest Year 2016 Entry	Harvest Year 2016 Yield (Mt ha^{-1})
Dimmitt, TX Winter Barley	**Commercial Checks**		**Commercial Checks**		**Commercial Checks**	
	-	-	Maja	5.42	Full Pint	3.59
	-	-	TAMbar 501	4.89	Alba	3.49
	-	-	P919	4.35	Maja	3.32
	-	-	-	-	TAM 304 (wheat)	2.63
	Top 5 Performing TCAP Lines		**Top 5 Performing TCAP Lines**		**Top 5 Performing TCAP Lines**	
	-	-	F527_1	8.01	OK216	4.49
	-	-	F555_1	7.88	OK248	4.43
	-	-	F537_1	7.59	F523_1	4.34
	-	-	F552_2	7.31	F552_2	4.33
			F532_1	6.98	F535_2	4.33
McGregor, TX Winter Barley	**Commercial Checks**		**Commercial Checks**		**Commercial Checks**	
	Alba	0.26	Alba	2.31	Full Pint	2.97
	Maja	0.22	Maja	2.26	Alba	2.06
	Full Pint	0.05	Full Pint	1.56	Maja	1.43
	-	-	-	-	TAM 304 (wheat)	2.81
	Top 5 Performing TCAP Lines		**Top 5 Performing TCAP Lines**		**Top 5 Performing TCAP Lines**	
	PO71_87	0.56	F532_1	3.78	F523_1	3.72
	F555_1	0.42	F523_1	3.68	F55_1	3.51
	F5126_1	0.37	F583_1	3.62	F591_1	3.20
	F523_1	0.32	F548_1	3.46	F547_3	3.19
	F537_3	0.32	F588_3	3.07	F54_2	3.02

Facultative TCAP Barley Lines

Facultative barley was grown at MCG during harvest years 2014, 2015 and 2016 and was grown in DIM during harvest years 2015 and 2016. Like the yield differences of the winter barley at DIM in 2015 vs. 2016, yield of facultative barley was also lower in 2016 due to a later planting date (Table 4.4).

At DIM, there were no similarities between top-performing lines across years, however, the top-performing TCAP line ‘F591_2’ in DIM 2016, was a top-performing line at MCG in 2015. Yield of the top-performing TCAP lines out-performed the commercial checks over both years. In 2016, the top TCAP lines also out-performed the wheat check 'TAM 304' (2.63 Mt ha^{-1}). In 2015, the average of the top 5 lines (6.87 Mt ha^{-1}) did not out-yield the average of the top five average HRWW grown in Hereford, TX (7.11 Mt ha^{-1}), but was still competitive. In contrast, the average of the top five facultative TCAP barley grown in 2016 (4.54 Mt ha^{-1}) did out-yield the top five average HRWW (3.63 Mt ha^{-1}). There was varied performance between winter and facultative lines, as neither was consistently higher yielding than the other. Facultative barley performance was higher at DIM compared to MCG in 2015 and 2016. Cooler climate, less humidity, disease and pest pressure are contributing factors to DIM having better yields.

In MCG, TCAP facultative line 'MW76_2' was a top-yielding line across all years (Table 4.4). In 2014, the average of the top-performing facultative lines (0.45 Mt ha^{-1}) out-performed all the commercial checks. A similar trend between top-performing TCAP lines out-yielding commercial checks in 2015 and 2016 was also seen. In 2015, the average of the top TCAP lines (3.37 Mt ha^{-1}) was higher than the average of the top five HRWW lines (2.38 Mt ha^{-1}) grown in the variety trial at Hillsboro, TX. Lastly, in 2016, the average of the top TCAP lines (4.07 Mt ha^{-1}) was also higher than the average of the top five HRWW lines (3.70 Mt ha^{-1}) grown in the variety trial at McGregor, TX.

Table 4.4: Facultative barley yield results from Dimmitt and McGregor, TX (2014-2016).

Location & Type	Harvest Year 2014 Entry	Harvest Year 2014 Yield (Mt ha^{-1})	Harvest Year 2015 Entry	Harvest Year 2015 Yield (Mt ha^{-1})	Harvest Year 2016 Entry	Harvest Year 2016 Yield (Mt ha^{-1})
Dimmitt, TX Facultative Barley	**Commercial Checks**		**Commercial Checks**		**Commercial Checks**	
	-	-	Maja	5.42	Full Pint	3.59
	-	-	TAMbar 501	4.89	Alba	3.49
	-	-	P919	4.35	Maja	3.32
	-	-	-	-	TAM 304 (wheat)	2.63
	Top 5 Performing TCAP Lines		**Top 5 Performing TCAP Lines**		**Top 5 Performing TCAP Lines**	
	-	-	07OR_3	7.40	F5112_3	4.64
	-	-	07OR_4	6.86	F5131_1	4.56
	-	-	Short16	6.83	F595_1	4.37
	-	-	Short12	6.64	F591_2	4.35
			MW118_3	6.62	F5120_3	4.25
McGregor, TX Facultative Barley	**Commercial Checks**		**Commercial Checks**		**Commercial Checks**	
	Alba	0.26	Alba	2.31	Full Pint	2.97
	Maja	0.22	Maja	2.26	Alba	2.06
	Full Pint	0.05	Full Pint	1.56	Maja	1.43
	-	-	-	-	TAM 304 (wheat)	2.81
	Top 5 Performing TCAP Lines		**Top 5 Performing TCAP Lines**		**Top 5 Performing TCAP Lines**	
	F557_2	0.52	OBA11_31	3.77	MW80_1	4.38
	F5121_5	0.47	OBA11_13	3.44	MW118_4	4.21
	MW76_2	0.44	F591_2	3.29	MW118_1	4.18
	OBA11_29	0.42	MW76_2	3.23	MW76_2	4.08
	F5121_1	0.41	F5121_3	3.14	F596_2	3.51

Spring Six-Row TCAP Barley Lines

Spring six-row barley was grown in MCG 2014, 2015 and 2016. Yield evaluations from all years and comparisons to commercial checks can be found in Tables 4.5. Like the winter barley trials, top-performing spring six-row TCAP lines out-yielded the commercial checks across years. In 2014, barley was planted in headrows and therefore yields are much lower compared to small plot data from 2015 and 2016. The average of the top five TCAP lines in 2014 (0.31 Mt ha^{-1}) out-yielded the commercial checks by double. In 2015, the average yield of the top five TCAP lines (3.92 Mt ha^{-1}) out-performed HRWW (2.38 Mt ha^{-1}) in Hillsboro, TX. In 2016, the addition of a spring wheat commercial variety 'Expresso' was incorporated into the barley trial to serve as a wheat check within the trial, similar to the purpose of 'TAM 304' in the winter trials. The top five performing TCAP lines (2.50 Mt ha^{-1}) and the trial average (1.78 Mt ha^{-1}) were lower than the top five HRWW varieties (3.70 Mt ha^{-1}). The TCAP line '08N6_94' was a top yielding line in 2015 and 2016.

Table 4.5: Spring six-row barley yield results from McGregor, TX (2014-2016).

	Harvest Year 2014		**Harvest Year 2015**		**Harvest Year 2016**	
Location & Type	**Entry**	**Yield (Mt ha^{-1})**	**Entry**	**Yield (Mt ha^{-1})**	**Entry**	**Yield (Mt ha^{-1})**
McGregor, TX Spring 6-Row	**Commercial Checks**		**Commercial Checks**		**Commercial Checks**	
	Conlon	0.18	CDC Copeland	2.04	Conlon	1.81
	AC Metcalf	0.13	Conlon	1.93	AC Metcalf	1.74
	CDC Copeland	0.12	AC Metcalf	1.83	CDC Copeland	1.50
	-	-	-	-	Expresso (wheat)	1.29
	Top 5 Performing TCAP Lines		**Top 5 Performing TCAP Lines**		**Top 5 Performing TCAP Lines**	
	08N6_35	0.35	07N6_80	4.14	08N6_94	2.63
	08N6_96	0.34	08N6_94	4.09	08N6_52	2.60
	08N6_90	0.33	08N6_91	3.92	09MN_04	2.50
	08BA_60	0.33	06AB_84	3.82	08N6_77	2.44
	08BA_44	0.30	06N6_66	3.76	08BA_41	2.33

Spring Two-Row TCAP Barley Lines

Spring two-row barley was harvested at MCG in 2014, 2015 and 2016. Yield evaluations across years can be found in Table 4.5. The top spring two-row barley lines grown in 2014 were not similar to lines grown in years 2015 and 2016. The TCAP line

‘09N2_21’ was a top-yielding line in both 2015 and 2016. Across all years, the average yield of TCAP lines (2014, 0.31 Mt ha^{-1}; 2015, 4.31 Mt ha^{-1}; 2016, 3.17 Mt ha^{-1}) out-performed their respective commercial checks. In 2015, TCAP top five performing lines (4.30 Mt ha^{-1}) out-performed the average of the top five HRWW yield (2.38 Mt ha^{-1}) in Hillsboro, TX. In 2016, yields were less than the previous year, however, the top five TCAP lines (3.17 Mt ha^{-1}) still out-yielded the commercial barley and wheat checks. The spring two-row barley did not out-yield the average of the top five HRWW (3.70 Mt ha^{-1}) grown in McGregor, TX in 2016.

When comparing six-row versus two-row barley performance at MCG, performance was nearly identical in 2014. In years 2015 and 2016 however, two-row barley out-yielded the six-row. A possible contributing factor could be from a higher amount of bird damage in the six-row barley. More in-depth field observations are needed to determine if birds affect six-row barley more than two-row.

Table 4.6: Spring two-row barley yield results from McGregor, TX (2014-2016).

	Harvest Year 2014		Harvest Year 2015		Harvest Year 2016	
Location & Type	**Entry**	**Yield (Mt ha^{-1})**	**Entry**	**Yield (Mt ha^{-1})**	**Entry**	**Yield (Mt ha^{-1})**
McGregor, TX Spring 2-Row	**Commercial Checks**		**Commercial Checks**		**Commercial Checks**	
	CDC Copeland	0.14	CDC Copeland	2.37	Conlon	2.33
	Conlon	0.14	Conlon	1.97	AC Metcalf	2.00
	AC Metcalf	0.13	AC Metcalf	1.77	CDC Copeland	1.84
	-	-	-	-	Expresso (wheat)	1.78
	Top 5 Performing TCAP Lines		**Top 5 Performing TCAP Lines**		**Top 5 Performing TCAP Lines**	
	09N2_39	0.33	06MT_49	4.52	06MT_59	3.57
	07AB_77	0.33	07N2_13	4.46	07MT_40	3.19
	09N2_29	0.31	06MT_67	4.35	06MT_82	3.15
	09N2_04	0.30	09N2_21	4.12	09N2_21	2.98
	09MT_16	0.29	08N2_62	4.09	07N2_38	2.97

Economic Feasibility

One of the most important decisions a producer must make for their enterprise is determining whether a risk is worth the reward. Budget analysis can help determine how certain decisions could positively or negatively affect an operation. The Texas A&M AgriLife Extension creates yearly budgets for different commodities for each district across the state (Districts 1-12). The following tables in this section are a compilation of yield data from this research project, variable and fixed costs from Extension Budgets District 8 for MCG (Johnson, 2015) and 10 for DIM (Hogan, 2016) and malt and feed prices from the National Ag Statistics Service. Each table describes budget breakdowns for winter, facultative, spring two- and six-row barley grown in DIM and MCG in Harvest Year 2016.

Budget Estimations for Dimmitt, TX

Table 4.7 shows the winter barley feed and malt budget for DIM 2016. Looking specifically at the average of the top five TCAP winter lines, more revenue was gained for selling as malt ($217.36) versus feed (-$194.41). TCAP winter lines not only out-yielded the commercial checks, they also created more total revenue for malt purposes ($217.36 TCAP lines, $7.99 commercial checks). Both TCAP winter lines (-$194.41) and commercial checks (-$318.44) for feed purposes did not generate any total revenue in this budget analysis. Compared to dryland barley grown in MCG, irrigation costs (energy, repairs, depreciation and equipment investment) were all costs associated with this location, which increased both total and variable costs.

Table 4.7: Malt and feed barley budget estimations for 2016 winter barley produced in Dimmitt, TX. Yield data is compiled from research project, prices compiled from National Ag Statistics Service and costs are compiled from Texas A&M Extension Budgets (District 10).

	Quantity	\$ unit^{-1}	Avg. Top 5 TCAP (WIN) Malt	Avg. Commercial Checks, Malt	Avg. Top 5 TCAP (WIN) Feed	Avg. Commercial Checks, Feed
Yield (Mt ha^{-1})			4.38	3.47	4.38	3.47
Malt Price (\$ Mt^{-1})			\$230.36	\$230.36	-	-
Feed Price (\$ Mt^{-1})			-	-	\$136.29	\$136.29
Total Revenue			**\$1,008.98**	**\$799.35**	**\$596.95**	**\$472.93**
Seed	61.7 kg ha^{-1}	\$1.76	\$108.59	\$108.59	\$108.59	\$108.59
Fertilizer						
32-0-0	0.0325 Mt ha^{-1}	\$262.00	\$8.52	\$8.52	\$8.52	\$8.52
Crop Insurance	1 ha	\$66.67	\$66.67	\$66.67	\$66.67	\$66.67
Barley Overhead	1 ha	\$9.88	\$9.88	\$9.88	\$9.88	\$9.88
Irrigation						
Energy Costs	390 kWh	\$0.17	\$66.30	\$66.30	\$66.30	\$66.30
Labor	0.02 hr	\$11.00	\$0.22	\$0.22	\$0.22	\$0.22
Machinery Labor	0.62 hr	\$12.00	\$7.44	\$7.44	\$7.44	\$7.44
Diesel Fuel	1.45 L	\$0.57	\$0.83	\$0.83	\$8.03	\$0.83
Gasoline	1 ha	\$72.69	\$72.69	\$72.69	\$72.69	\$72.69
Repairs						
Pick-up	1 ha	\$16.59	\$16.59	\$16.59	\$16.59	\$16.59
Irrigation	1 ha	\$10.22	\$10.22	\$10.22	\$10.22	\$10.22
Tractors	1 ha	\$7.56	\$7.56	\$7.56	\$7.56	\$7.56
Implements	1 ha	\$8.27	\$8.27	\$8.27	\$8.27	\$8.27
Total Variable Costs			**\$383.77**	**\$383.77**	**\$383.77**	**\$383.77**
Machinery Depreciation						
Pick-up	1 ha	\$62.22	\$62.22	\$62.22	\$62.22	\$62.22
Irrigation	1 ha	\$119.83	\$119.83	\$119.83	\$119.83	\$119.83
Tractors	1 ha	\$24.37	\$24.37	\$24.37	\$24.37	\$24.37
Implements	1 ha	\$10.02	\$10.02	\$10.02	\$10.02	\$10.02
Equipment Investment						
Pick-up	6.50%	\$168.02	\$10.92	\$10.92	\$10.92	\$10.92
Irrigation	6.50%	\$727.97	\$47.32	\$47.32	\$47.32	\$47.32
Tractors	6.50%	\$112.13	\$7.29	\$7.29	\$7.29	\$7.29
Implements	6.50%	\$33.28	\$2.16	\$2.16	\$2.16	\$2.16
Irrigated Land Rent	1 ha	\$123.46	\$123.46	\$123.46	\$123.46	\$123.46
Total Fixed Costs			**\$407.59**	**\$407.59**	**\$407.59**	**\$407.59**
Total Specified Costs			**\$791.36**	**\$791.36**	**\$791.36**	**\$791.36**
Returns Above Specified Costs			**\$217.36**	**\$7.99**	**(\$194.41)**	**(\$318.44)**
Breakeven Price (Mt^{-1})			**\$180.68**	**\$228.06**	**\$180.68**	**\$228.06**

Yields for facultative and winter barley grown in DIM for Harvest Year 2016 were comparable and so was total revenue generated. Budget estimations for facultative barley grown in DIM can be found in Table 4.8. The same variable costs, fixed costs and malt and feed barley prices were used and were taken from the Texas A&M AgriLife Extension budget for District 10 (irrigatied conditions). Similar to the trend as in the winter barley budget (Table 4.7), TCAP barley for malt purposes generated the highest total revenue ($208.40), while commercial checks for feed purposes generated the least (-$318.14). From the budget estimations for DIM for both winter and facultative barley, it shows that growing barley for malt purposes could potentially be more cost effective compared to growing for feed use.

Table 4.8: Malt and feed barley budget estimations for 2016 facultative barley produced in Dimmitt, TX. Yield data is compiled from research project, prices compiled from National Ag Statistics Service and costs are compiled from Texas A&M Extension Budgets (District 10).

	Quantity	$ unit^{-1}	Avg. Top 5 TCAP (FAC), Malt	Avg. Commercial Checks, Malt	Avg. Top 5 TCAP (FAC), Feed	Avg. Commercial Checks, Feed
Yield (Mt ha^{-1})			4.34	3.47	4.34	3.47
Malt Price ($ Mt^{-1})			$230.36	$230.36	-	-
Feed Price ($ Mt^{-1})			-	-	$136.29	$136.29
Total Revenue			**$999.76**	**$799.35**	**$591.50**	**$472.93**
Seed	61.7 kg ha^{-1}	$1.73	$108.59	$108.59	$108.59	$108.59
Fertilizer						
32-0-0	0.0325 Mt ha^{-1}	$262.00	$8.52	$8.52	$8.52	$8.52
Crop Insurance	1 ha	$66.67	$66.67	$66.67	$66.67	$66.67
Barley Overhead	1 ha	$9.88	$9.88	$9.88	$9.88	$9.88
Irrigation						
Energy Costs	390 kWh	$0.17	$66.30	$66.30	$66.30	$66.30
Labor	0.02 hr	$11.00	$0.22	$0.22	$0.22	$0.22
Machinery Labor	0.62 hr	$12.00	$7.44	$7.44	$7.44	$7.44
Diesel Fuel	1.45 L	$0.57	$0.83	$0.83	$0.83	$0.83
Gasoline	1 ha	$72.69	$72.69	$72.69	$72.69	$72.69
Repairs						
Pick-up	1 ha	$16.59	$16.59	$16.59	$16.59	$16.59
Irrigation	1 ha	$10.22	$10.22	$10.22	$10.22	$10.22
Tractors	1 ha	$7.56	$7.56	$7.56	$7.56	$7.56
Implements	1 ha	$8.27	$8.27	$8.27	$8.27	$8.27
Total Variable Costs			**$383.77**	**$383.77**	**$383.77**	**$383.77**
Machinery Depreciation						
Pick-up	1 ha	$62.22	$62.22	$62.22	$62.22	$62.22
Irrigation	1 ha	$119.83	$119.83	$119.83	$119.83	$119.83
Tractors	1 ha	$24.37	$24.37	$24.37	$24.37	$24.37
Implements	1 ha	$10.02	$10.02	$10.02	$10.02	$10.02
Equipment Investment						
Pick-up	6.50%	$168.02	$10.92	$10.92	$10.92	$10.92
Irrigation	6.50%	$727.97	$47.32	$47.32	$47.32	$47.32
Tractors	6.50%	$112.13	$7.29	$7.29	$7.29	$7.29
Implements	6.50%	$33.28	$2.16	$2.16	$2.16	$2.16
Irrigated Land Rent	1 ha	$123.46	$123.46	$123.46	$123.46	$123.46
Total Fixed Costs			**$407.59**	**$407.59**	**$407.59**	**$407.59**
Total Specified Costs			**$791.36**	**$791.36**	**$791.36**	**$791.36**
Returns Above Specified Costs			**$208.40**	**$7.99**	**($199.86)**	**($318.14)**
Breakeven Price (Mt^{-1})			**$182.34**	**$228.06**	**$182.34**	**$228.06**

Budget Estimations for McGregor, TX

Facultative and winter barley grown in DIM 2016 out-yielded winter and facultative barley grow in MCG, however, did not generate as much income. Table 4.9

describes the malt and feed barley budget estimations for barley produced in MCG. Variable and total costs for this location were taken from the Texas A&M AgriLife Budget for District 8. Yield for winter TCAP barley lines versus commercial checks was higher and therefore generated a higher total revenue than commercial checks for both malt and feed purposes ($340.20 and $26.95, respectively). Winter TCAP lines in MCG ($26.95) for feed purposes generated a higher total revenue than winter barley in DIM (-$194.41).

Table 4.9: Malt and feed barley budget estimations for 2016 winter barley produced in McGregor, TX. Yield data is compiled from research project, prices compiled from National Ag Statistics Service and costs are compiled from Texas A&M Extension Budgets (District 8).

	Qty.	$ unit^{-1}	Avg. Top 5 TCAP (WIN), Malt	Avg. Commercial Checks, Malt	Avg. Top 5 TCAP (WIN), Feed	Avg. Commercial Checks, Feed
Yield (Mt ha^{-1})			3.33	2.15	3.33	2.15
Malt Price ($ Mt^{-1})			$230.36	$230.36	-	-
Feed Price ($ Mt^{-1})			-	-	$136.29	$136.29
Total Revenue			**$767.10**	**$495.27**	**$453.85**	**$293.02**
Seed	61.7 kg ha^{-1}	$1.76	$108.59	$108.59	$108.59	$108.59
Fertilizer						
32-0-0	0.039 Mt ha^{-1}	$262.00	$10.22	$10.22	$10.22	$10.22
MCPA	2.34 L ha^{-1}	$0.01	$0.02	$0.02	$0.02	$0.02
Amber	36.5 mL ha^{-1}	$0.34	$12.41	$12.41	$12.41	$12.41
Crop Insurance	1 ha	$66.67	$66.67	$66.67	$66.67	$66.67
Barley Overhead	1 ha	$9.88	$9.88	$9.88	$9.88	$9.88
Machinery Labor	0.91 hr	$10.00	$6.20	$6.20	$6.20	$6.20
Diesel Fuel	22.6 L	$0.70	$15.82	$15.82	$15.82	$15.82
Repairs						
Tractors	1 ha	$23.56	$23.56	$23.56	$23.56	$23.56
Implements	1 ha	$30.59	$30.59	$30.59	$30.59	$30.59
Total Variable Costs			**$283.96**	**$283.96**	**$283.96**	**$283.96**
Machinery Depreciation						
Tractors	1 ha	$24.35	$24.35	$24.35	$24.35	$24.35
Implements	1 ha	$35.90	$35.90	$35.90	$35.90	$35.90
Equipment Investment						
Tractors	6.00%	$76.78	$4.61	$4.61	$4.61	$4.61
Implements	6.00%	$66.80	$4.01	$4.01	$4.01	$4.01
Dryland Rent	1 ha	$74.07	$74.07	$74.07	$74.07	$74.07
Total Fixed Costs			**$142.94**	**$142.94**	**$142.94**	**$142.94**
Total Specified Costs			**$426.90**	**$426.90**	**$426.90**	**$426.90**
Returns Above Specified Costs			**$340.20**	**$68.38**	**$26.95**	**($133.87)**
Breakeven Price (Mt^{-1})			**$128.19**	**$198.56**	**$128.19**	**$198.56**

Facultative barley grown in MCG generated a much higher total revenue than winter barley at the same location (Table 4.10). The average of the top five TCAP lines generated $510.67, approximately $170.00 more than winter barley found in Table 4.9) In addition, approximately $100.00 more in total revenue was produced with facultative TCAP lines for feed ($127.80) compared to winter TCAP lines ($26.95). Commercial checks did not generate a higher total revenue than TCAP lines, showing that lines tested from this research project could potentially be more cost effective to produce than varieties currently available to producers.

Table 4.10: Malt and feed barley budget estimations for 2016 facultative barley produced in McGregor, TX. Yield data is compiled from research project, prices compiled from National Ag Statistics Service and costs are compiled from Texas A&M Extension Budgets (District 8).

	Qty.	**$ unit^{-1}**	**Avg. Top 5 TCAP (FAC), Malt**	**Avg. Commercial Checks, Malt**	**Avg. Top 5 TCAP (FAC), Feed**	**Avg. Commercial Checks, Feed**
Yield (Mt ha^{-1})			4.07	2.15	4.07	2.15
Malt Price ($ Mt^{-1})			$230.36	$230.36	-	-
Feed Price ($ Mt^{-1})			-	-	$136.29	$136.29
Total Revenue			**$937.57**	**$495.27**	**$554.70**	**$293.02**
Seed	61.7 kg ha^{-1}	$1.76	$108.59	$108.59	$108.59	$108.59
Fertilizer						
32-0-0	0.039 Mt ha^{-1}	$262.00	$10.22	$10.22	$10.22	$10.22
MCPA	2.34 L ha^{-1}	$0.01	$0.02	$0.02	$0.02	$0.02
Amber	36.5 mL ha^{-1}	$0.34	$12.41	$12.41	$12.41	$12.41
Crop Insurance	1 ha	$66.67	$66.67	$66.67	$66.67	$66.67
Barley Overhead	1 ha	$9.88	$9.88	$9.88	$9.88	$9.88
Machinery Labor	0.91 hr	$10.00	$6.20	$6.20	$6.20	$6.20
Diesel Fuel	22.6 L	$0.70	$15.82	$15.82	$15.82	$15.82
Repairs						
Tractors	1 ha	$23.56	$23.56	$23.56	$23.56	$23.56
Implements	1 ha	$30.59	$30.59	$30.59	$30.59	$30.59
Total Variable Costs			**$283.96**	**$283.96**	**$283.96**	**$283.96**
Machinery Depreciation						
Tractors	1 ha	$24.35	$24.35	$24.35	$24.35	$24.35
Implements	1 ha	$35.90	$35.90	$35.90	$35.90	$35.90
Equipment Investment						
Tractors	6.00%	$76.78	$4.61	$4.61	$4.61	$4.61
Implements	6.00%	$66.80	$4.01	$4.01	$4.01	$4.01
Dryland Rent	1 ha	$74.07	$74.07	$74.07	$74.07	$74.07
Total Fixed Costs			**$142.94**	**$142.94**	**$142.94**	**$142.94**
Total Specified Costs			**$426.90**	**$426.90**	**$426.90**	**$426.90**
Returns Above Specified Costs			**$510.67**	**$68.38**	**$127.80**	**($133.87)**
Breakeven Price (Mt^{-1})			**$104.89**	**$198.56**	**$104.89**	**$198.56**

Spring two- and six-row barley was grown in MCG only for Harvest Year 2016. Table 4.11 and 4.12 are budget estimations for spring two- and six-row barley, respectively. Both malt and feed prices are budgeted, like previous tables. Spring two-row yields were higher than six-row, mainly due to a higher amount of bird damage found in six-row plots. In Table 4.11, spring TCAP two-row lines for malt, generated $303.34 in total revenue, compared to the commercial checks which generated $47.65. Yields for spring two-row barley were less than MCG facultative and winter barley, thus, less revenue was generated. Comparing spring two-row barley to both winter and facultative barley production in DIM, spring barely yields were comparable, but generated more income for both malt and feed purposes.

Table 4.11: Malt and feed barley budget estimations for 2016 spring two-row barley produced in McGregor, TX. Yield data is compiled from research project, prices compiled from National Ag Statistics Service and costs are compiled from Texas A&M Extension Budgets (District 8).

	Qty.	$ unit^{-1}	Avg. Top 5 TCAP (2R), Malt	Avg. Commercial Checks, Malt	Avg. Top 5 TCAP (2R), Feed	Avg. Commercial Checks, Feed
Yield (Mt ha^{-1})			3.17	2.06	3.17	2.06
Malt Price ($ Mt^{-1})			$230.36	$230.36	-	-
Feed Price ($ Mt^{-1})			-	-	$136.29	$136.29
Total Revenue			**$730.24**	**$474.54**	**$432.04**	**$280.76**
Seed	61.7 kg ha^{-1}	$1.76	$108.59	$108.59	$108.59	$108.59
Fertilizer						
32-0-0	0.039 Mt ha^{-1}	$262.00	$10.22	$10.22	$10.22	$10.22
MCPA	2.34 L ha^{-1}	$0.01	$0.02	$0.02	$0.02	$0.02
Amber	36.5 mL ha^{-1}	$0.34	$12.41	$12.41	$12.41	$12.41
Crop Insurance	1 ha	$66.67	$66.67	$66.67	$66.67	$66.67
Barley Overhead	1 ha	$9.88	$9.88	$9.88	$9.88	$9.88
Machinery Labor	0.91 hr	$10.00	$6.20	$6.20	$6.20	$6.20
Diesel Fuel	22.6 L	$0.70	$15.82	$15.82	$15.82	$15.82
Repairs						
Tractors	1 ha	$23.56	$23.56	$23.56	$23.56	$23.56
Implements	1 ha	$30.59	$30.59	$30.59	$30.59	$30.59
Total Variable Costs			**$283.96**	**$283.96**	**$283.96**	**$283.96**
Machinery Depreciation						
Tractors	1 ha	$24.35	$24.35	$24.35	$24.35	$24.35
Implements	1 ha	$35.90	$35.90	$35.90	$35.90	$35.90
Equipment Investment						
Tractors	6.00%	$76.78	$4.61	$4.61	$4.61	$4.61
Implements	6.00%	$66.80	$4.01	$4.01	$4.01	$4.01
Dryland Rent	1 ha	$74.07	$74.07	$74.07	$74.07	$74.07
Total Fixed Costs			**$142.94**	**$142.94**	**$142.94**	**$142.94**
Total Specified Costs			**$426.90**	**$426.90**	**$426.90**	**$426.90**
Returns Above Specified Costs			**$303.34**	**$47.65**	**$5.14**	**($146.14)**
Breakeven Price (Mt^{-1})			**$134.67**	**$207.23**	**$134.67**	**$207.23**

Spring barley budget six-row estimations in Table 4.12 show that two-row barley generated more total revenue for both malt and feed purposes. Total revenue generated by TCAP lines for feed (-$86.17) is much lower compared to malt ($149.00). The average of the top five TCAP two-row barley generated a higher income ($303.34) compared to the average of the top five TCAP six-row barley ($149.00). Like the other budgets, TCAP lines tested generated more income than commercial checks evaluated for the same purposes.

Table 4.12: Malt and feed barley budget estimations for 2016 spring six-row barley produced in McGregor, TX. Yield data is compiled from research project, prices compiled from National Ag Statistics Service and costs are compiled from Texas A&M Extension Budgets (District 8).

	Quantity	**$ unit^{-1}**	**Avg. Top 5 TCAP (6R), Malt**	**Avg. Commercial Checks, Malt**	**Avg. Top 5 TCAP (6R), Feed**	**Avg. Commercial Checks, Feed**
Yield (Mt ha^{-1})			2.50	1.68	2.50	1.68
Malt Price ($ Mt^{-1})			$230.36	$230.36	-	-
Feed Price ($ Mt^{-1})			-	-	$136.29	$136.29
Total Revenue			**$575.90**	**$387.00**	**$340.73**	**$228.97**
Seed	61.7 kg ha^{-1}	$1.76	$108.59	$108.59	$108.59	$108.59
Fertilizer						
32-0-0	0.039 Mt ha^{-1}	$262.00	$10.22	$10.22	$10.22	$10.22
MCPA	2.34 L ha^{-1}	$0.01	$0.02	$0.02	$0.02	$0.02
Amber	36.5 mL ha^{-1}	$0.34	$12.41	$12.41	$12.41	$12.41
Crop Insurance	1 ha	$66.67	$66.67	$66.67	$66.67	$66.67
Barley Overhead	1 ha	$9.88	$9.88	$9.88	$9.88	$9.88
Machinery Labor	0.91 hr	$10.00	$6.20	$6.20	$6.20	$6.20
Diesel Fuel	22.6 L	$0.70	$15.82	$15.82	$15.82	$15.82
Repairs						
Tractors	1 ha	$23.56	$23.56	$23.56	$23.56	$23.56
Implements	1 ha	$30.59	$30.59	$30.59	$30.59	$30.59
Total Variable Costs			**$283.96**	**$283.96**	**$283.96**	**$283.96**
Machinery Depreciation						
Tractors	1 ha	$24.35	$24.35	$24.35	$24.35	$24.35
Implements	1 ha	$35.90	$35.90	$35.90	$35.90	$35.90
Equipment Investment						
Tractors	6.00%	$76.78	$4.61	$4.61	$4.61	$4.61
Implements	6.00%	$66.80	$4.01	$4.01	$4.01	$4.01
Dryland Rent	1 ha	$74.07	$74.07	$74.07	$74.07	$74.07
Total Fixed Costs			**$142.94**	**$142.94**	**$142.94**	**$142.94**
Total Specified Costs			**$426.90**	**$426.90**	**$426.90**	**$426.90**
Returns Above Specified Costs			**$149.00**	**($39.89)**	**($86.17)**	**($197.93)**
Breakeven Price (Mt^{-1})			**$170.76**	**$254.10**	**$170.76**	**$254.10**

The Use of Barley

Figure 4.1 shows the change in use of barley from 1980 to 2016/17 in the US. While food, seed and industrial use of barley is declining, it is not declining as rapidly as barley for feed and residual use is. The decline in feed and residual use of barley is directly related to the current surplus of feed grain in the markets. This surplus has been and still is decreasing the price ($ bushel^{-1}). As production costs to grow feed grain (fuel, fertilizer, seed, etc.) continue to increase, while grain prices decrease, growing barley and other small grains for feed use is becoming less attractive.

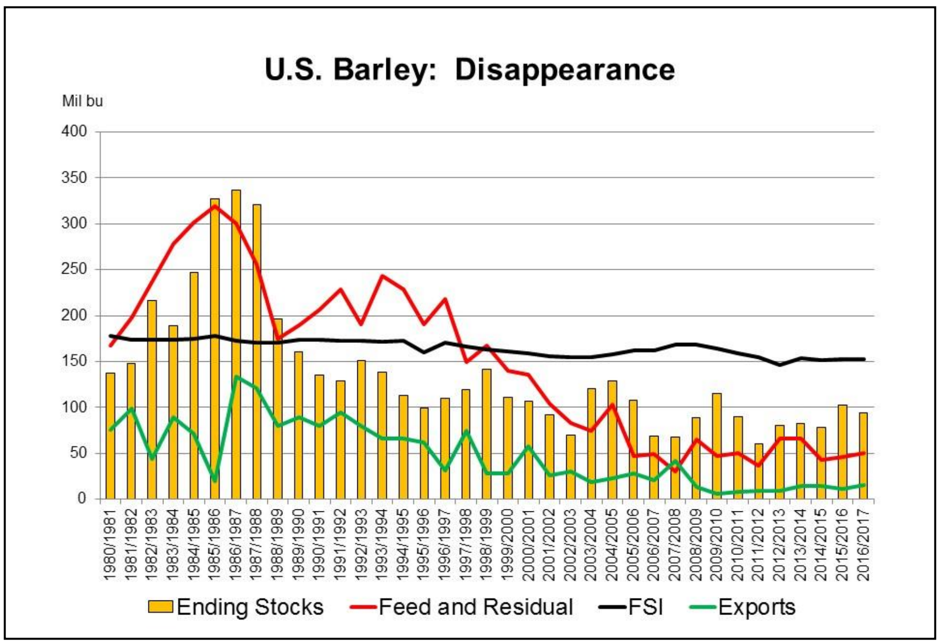

Figure 4.1: US barley disappearance chart (USDA FAS, September 2016).

Discussion and Conclusions

Based on two years of results comparing wheat and barley performance under similar environments, barley appears to have a yield advantage over wheat in both locations. Winter and facultative barley grown in DIM yielded higher than winter and facultative barley in MCG as well as spring six- and two-row grown in MCG. Producers in the High Plains more commonly use irrigated conditions when growing their crops. That, coupled with lower disease and pest pressure, means that environmental and cultural practices are more desirable for barley production in that region of the state. In addition, a high population of dairy cattle near DIM may encourage producers to grow winter and/or facultative barley lines for forage, grain and/or for silage purposes and market it to dairy farms in the surrounding area. From personal communication, grain elevators in the High Plains are equipped to handle and store harvested barley grain.

From a budgeting perspective, producing and selling barley for malt has a greater advantage over selling barley for feed purposes. At DIM and MCG during Harvest Year 2016, barley grown for malt purposes had a higher revenue compared to feed barley (Tables 4.7-4.12). A trend at all locations and years shows that the average of the top five TCAP barley lines have an additional advantage in price for both malt and feed purposes when compared to average of the commercial checks. A varietal release of a TCAP line(s) could enhance yield potential and generate additional income compared to commercially available barley varieties already on the market that are not bred and adapted for Texas environments.

Producers could begin to take advantage of the malt barley market and create private malt contracts directly with breweries and/or maltsters, which could prove beneficial for producers in the long-run by offering contracts for a high value crop and diversifying cropping systems. In general, prices for malt barley are significantly higher than feed barley. Malt prices do vary from brewery to brewery and therefore determining a general baseline price for malt is difficult. Potential malt barley producers would need to explore contract options on a case-by-case basis with the malthouse.

While growing barley for malt may seem advantageous over feed barley, producers need to consider potential higher prices for transportation costs of malt to malthouses located in the state. In addition, there are not many malthouses located across Texas currently and so the market for malt barley is still small, creating challenges to producers wanting to grow and contract their barley. A promising sign is that the number of craft breweries in the state continues to increase, ultimately increasing the demand of barley malt to meet the public's consumption needs.

Although barley has become a less popular crop in the state, there are some economic advantages to produce it. With an overflow of grain in the market, prices are decreasing, making it hard for producers to breakeven on their input costs accrued during the growing season. Niche markets, such as craft breweries, could be ideal for producers to explore as feed prices decline. Private contracts with malt and/or brewing companies would have more lucrative incentives over feed barley. Since each producer has different incomes, abilities and factors affecting their budget, individual research by the producer himself is needed before making operational changes.

CHAPTER V`

SUMMARY AND CONCLUSIONS

As the climate continues to change, more frequent and extreme drought events are expected to occur. In addition, temperatures will rise, causing less winter freeze injury and more heat stress, directly affecting crop growth habits and heading dates. With these changes, it will be important to update and improve current barley production practices and varieties. This may increase the adoption of drought-tolerant crops, such as barley, into cropping systems where it currently does not exist.

Barley has the potential to be a profitable crop in Texas. It has and still is being grown in a commercial setting by producers across the state (~12,000 ha). Locations for this TCAP barley research stretched from the High Plains, to southern and central locations in the state of Texas. Despite environmental hardships and occasional field losses, barley was successfully grown at each trial location. Although environmental conditions differed each year, similarities between yield parameters and malt quality were seen. In addition, statistical analysis showed that winter and facultative TCAP lines tested in DIM could out-perform commercial checks—indicating the potential for a new variety release.

While environment did alter the performance and productivity of barley in some locations, overall, barley could produce average yield and malt quality. Negative correlations between bird damage and freeze damage with yield shows that more research is needed to find ways to remedy these issues—either through resistance for insect and freeze damage or budget-friendly ways to prevent excessive bird damage. resistance to some of these issues.

From an economic standpoint, TCAP winter, spring two- and six-row barley lines out-yielded commercial barley and wheat checks and nearby HRWW trials in some locations (Hillsboro and Dimmitt locations). When comparing gross income ($ Mt^{-1}), the top TCAP lines were more desirable compared to the commercial checks, wheat checks and HRWW for both malt and feed purposes. As prices decline with and overabundance in the feed grain market, producers may begin to look to alternative, niche markets to sell their grain. With an increase in local craft breweries across the state, producers may find that growing barley and privately contracting it to these breweries/malthouses may be more desirable than producing for the feed grain market. However, producers must analyze their budgets and decide if the risk of trying a new crop is worth the potential income advantage.

While each location tested over the three years of research could grow barley, the High Plains of Texas seem to be the most desirable location to produce barley. Compared to other locations (CAS and MCG), DIM has a lower humidity and cooler night as well as lower insect and pest pressure. In addition, most farmed acres in that region are under pivot irrigation and so water can be applied to the plants as needed, reducing the risk of field loss from possible drought(s). Lastly, with a large population of dairy cattle in the area, barley is in high demand for use as a feedstuff, which provides another market option. With a high CP%, feed barley is an ideal grain to be incorporated in a lactating cow's ration. It is difficult to feed cattle malt barley, as it typically contains a low protein content and therefore, dairy producers would have to supplement more protein into a ration. This may ultimately cost more money and be less practical.

More research is needed to help fine tune best management practices for barley in Texas to promote acreage increases. Adding research locations across more eco-regions of the state would help to improve the current evaluations of barley performance in the state. Barley is known to be more salt and drought-tolerant compared to wheat and other small grains. High-salinity soils located in far West Texas may provide one area where barely could be readily adopted in Texas, since many other crops cannot be successfully grown there. Barley may be a minor crop in Texas agriculture currently, but with its ability to be used as a feed, forage and malting source, opportunity for acreage expansion is expected in the future.

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APPENDIX

A-1: PROC CORR procedure for statistical analysis. This code was used in SAS, data was copied from excel and pasted into the code.

```
ods html close;
DM log "OUT;CLEAR;LOG;CLEAR;" log continue;
DM log 'next results; clear; cancel;' whostedit continue;
ods html newfile=none;
data TCAP;
input
        (parameters inserted here);
cards;
(Data inserted here)
;
proc print;
proc corr pearson;
        (parameters inserted here);
run;
proc sort; by Type;
proc corr pearson; by Type;
        (parameters inserted here);
run;
proc sort; by LOC;
proc corr pearson; by LOC;
        (parameters inserted here);
run;
```

A-2: PROC GLM procedure for statistical analysis. This code was used in SAS, data was copied from excel and pasted into the code.

```
ods html close;
DM log "OUT;CLEAR;LOG;CLEAR;" log continue;
DM log ' next results; clear; cancel;' whostedit continue;
ods html newfile=none;
data TCAP;
input
        Year Loc$ Type$ Entry$ Yield;
cards;
(Data inserted here)
;
proc glm;
```

```
class Year Entry;
model Yield = Entry Year;
means Entry /lsd lines;
run;
```

A-3: Bi-plot procedure for statistical analysis. This code was used in SAS, data was copied from excel and pasted into the code. Input varied between comparisons (spring 2-row, spring 6-row, winter/facultative).

```
ods html close;
DM log "OUT;CLEAR;LOG;CLEAR;" log continue;
DM log ' next results; clear; cancel;' whostedit continue;
ods html newfile=none;
data TCAP;
input
        (parameters inserted here);
cards;
(Data inserted here)
;
proc print data=TCAP;
proc prinqual data=TCAP mdpref;
id name;
transform monotone (parameters inserted here);
run;
```

A-3: TCAP Barley lines and commercial check pedigrees and yield evaluations (F= facultative, W= winter, S2= spring two-row, S6= spring six-row).

			Yield (Mt ha^{-1})						Test Weight (kg bu^{-1})				Malt Quality		
			2016		2015		2014		2016		2015		2016	2015	
Line/Variety	Type	Pedigree	DIM	MCG	DIM	MCG	MCG	CAS	DIM	MCG	DIM	MCG	MCG	DIM	MCG
P919	F	.	3.3	2.4	4.1	3.3	5.6	6.8	21.32	16.05	21.66	19.75	.	21	17
06OR_10	F	Maja/Kab 50	3.3	2.2	3.7	.	1.7	3.7	20.48	16.16	21.61	.	.	26	.
06OR_37	F	Stab 47/Kab 51	3.2	1.9	2.8	.	2.3	2.3	20.48	16.30	21.47	.	36	26	.
06OR_41	F	StabBC 42	2.6	1.8	4.2	1.8	2.5	3.8	20.61	16.89	21.61	19.34	34	38	23
06OR_42	F	Stab 7/Kab 41	2.7	2.0	2.9	.	1.7	4.9	20.82	15.89	21.29	.	.	31	.
06OR_43	F	Stab 47/Kab 51	3.8	2.0	3.7	2.1	2.5	1.5	20.38	.	21.16	18.21	33	30	21
06OR_44	F	StabBC 42	3.7	2.6	2.5	.	2.3	3.7	19.84	.	18.98	.	.	32	.
06OR_45	F	Stab 47/Kab 51	2.6	1.5	3.3	2.1	3	3.0	19.82	16.12	20.75	18.16	.	30	21
06OR_52	F	Stab 47/Excel//Stab 47	3.3	3.1	3.6	.	3.1	7.3	20.61	17.16	21.97	.	.	32	.
06OR_59	F	Kab51/Excel//Stab 47/Excel	3.3	3.1	3.5	.	1	4.7	21.47	19.25	21.61	.	34	38	.
06OR_62	F	Kold/88Ab536	3.2	1.2	3.2	1.8	3.2	1.4	20.57	16.75	20.88	18.89	.	26	26
06OR_75	F	Stab 47/Excel//Stab 47	3.3	2.7	3.3	.	2.3	6.9	20.68	17.82	22.11	.	.	38	.
06OR_78	F	Stab 47/Excel//Stab 47	2.8	2.4	2.4	.	2.4	6.3	20.34	.	21.47	.	.	38	.
06OR_9	F	Stab 47/Kab 51	4.0	.	.	0.6	2.2	1.4	.	.	.	17.84	.	.	.
06OR_91	F	Stab 47/Excel//Stab 47	3.4	1.7	5.6	.	1.7	4.4	19.70	17.23	20.61	.	24	35	.
07OR_21	F	Stab 47/Kab 51	3.6	1.8	4.9	2.9	4	4.1	20.59	16.50	21.02	18.66	.	32	26
07OR_3	F	Bu 27/Stab 47/3/Maja/Stab 47	4.4	2.6	7.4	.	1.9	5.1	20.82	16.64	21.20	.	45	47	.
07OR_4	F	Bu 27/Stab 47/3/Maja/Stab 47	3.4	1.6	6.9	1.3	2.5	3.0	20.48	.	23.74	19.07	.	63	24
07OR_59	F	CC99A	3.5	1.1	6.4	.	2.6	3.1	19.64	.	22.97	.	38	42	.
07OR_6	F	Bu 27/Stab 47/3/Maja/StabBC 42	3.7	1.7	4.9	1.9	2.5	2.7	20.48	.	21.75	19.02	31	59	21
07OR_63	F	CC99A	2.9	2.3	5.7	.	1.8	1.8	19.84	18.07	22.25	.	30	36	.
07OR_8	F	Bu 27/Stab 47/3/Maja/StabBC	3.0	1.1	5.9	1.8	2.7	2.9	20.70	.	23.20	18.52	.	53	19
08OR_30	F	StabBC 42/Stab 7	2.9	2.9	4.1	1.7	2.8	5.1	19.70	17.03	17.80	19.70	40	35	18
08OR_44	F	StabBC 42/3/Kab 51/Legacy//Kab 51	2.9	2.4	5.4	.	2.3	6.2	20.95	17.21	22.70	.	.	31	.
08OR_48	F	StabBC 50/Maja	4.0	2.2	5.9	.	2.2	5.1	21.07	15.89	22.02	.	.	27	.
08OR_53	F	StabBC 50/Maja	4.2	0.6	5.1	.	2.1	3.5	20.16	.	20.34	.	.	19	.
08OR_73	F	Kab 51/Excel//Maja/3/J2	3.9	1.8	5.8	.	2.3	5.5	20.57	.	20.48	.	.	39	.
08OR_81	F	Maja/L//Maja/3/Stab 47/Kab 51	3.1	1.0	4.6	0.6	1.6	3.4	19.75	16.12	18.48	19.48	.	33	.
F5105_1	F	Stab 47/Kab 51//StabBC 42	.	.	.	.	.	.	22.79	.	.	.	.	.	.
F5108_1	F	Stab 47/Kab 51//StabBC 42	3.6	1.2	6.5	1.6	2.1	2.9	20.95	.	21.79	16.84	.	35	21
F5112_1	F	Stab 47/Kab 51//StabBC 42-14	3.9	2.6	5.3	.	2	2.8	20.07	.	21.70	.	40	19	.
F5112_3	F	Stab 47/Kab 51//StabBC 42	3.7	2.5	4.1	2.7	2.9	5.5	20.02	15.98	20.02	18.34	36	31	24
F5113_2	F	Stab 47/Kab 51//StabBC 50	4.4	2.0	4.6	.	2.2	3.4	20.20	.	19.98	.	28	28	.
F5119_1	F	Stab 47/Kab 51//StabBC 42	3.9	1.9	5.8	.	2.3	2.9	19.66	.	22.06	.	46	41	.
F5120_3	F	Stab 47/Kab 51//StabBC 42	3.1	1.7	4.0	.	2.6	4.1	20.13	16.39	19.43	.	.	23	.
F5121_1	F	Stab 47/Kab 51//StabBC 42	4.1	1.6	6.5	.	2.2	5.8	20.34	.	20.88	.	36	20	.
F5121_2	F	Stab 47/Kab 51//StabBC	3.3	2.5	4.4	3.1	4.1	3.0	20.54	16.78	21.34	18.34	.	23	28
F5121_3	F	Stab 47/Kab 51//StabBC 42	2.8	3.1	5.1	.	1.5	4.3	20.07	16.82	21.70	.	44	23	.
F5121_4	F	Stab 47/Kab 51//StabBC	3.8	1.7	5.2	3.1	2	2.8	20.43	16.93	21.25	18.61	.	18	26
F5121_5	F	Stab 47/Kab 51//StabBC 42	4.1	2.6	5.3	.	2.5	5.6	20.36	.	21.79	.	37	25	.
F5124_1	F	Stab 47/Kab 51//J1	4.0	1.6	4.1	2.8	4.7	4.0	20.18	16.25	22.11	18.80	.	28	28
F5131_1	F	Stab 47/Kab 51//StabBC 42	4.2	1.1	4.4	.	2.3	1.7	20.25	.	18.80	.	.	21	.
F5132_1	F	StabBC 42//Bu 37/Maja	4.3	2.6	5.4	.	8	8.0	20.66	16.00	20.52	.	.	31	.
F5134_3	F	J2///Kab 51/Excel//Kab 51	3.2	2.0	4.5	2.0	2.9	2.3	20.61	16.80	19.70	16.71	42	32	26
F522_3	F	StabBC 42//Bu 37/Maja	3.8	2.4	5.4	2.9	2.5	2.5	20.61	17.46	21.61	18.84	.	30	25
F557_2	F	Stab 47/Kab 51//StabBC 42	4.0	1.3	6.9	3.0	2.1	1.7	20.04	16.03	20.84	18.61	34	36	28
F559_1	F	Stab 47/Kab 51//StabBC	3.4	1.8	5.3	.	2.5	3.8	20.36	16.84	20.34	.	40	37	.
F559_2	F	Stab 47/Kab 51//StabBC 42	3.9	2.1	4.3	2.8	5.2	2.9	20.11	16.57	19.16	20.84	.	22	26
F576_4	F	Stab 47/Kab 51//StabBC 42	3.8	1.8	5.8	2.2	2.4	2.9	21.63	18.25	22.20	17.71	.	22	22
F590_5	F	StabBC 182///K47/Excel//Stab 47/Excel	3.7	2.8	4.4	3.1	1.6	1.8	19.30	16.25	20.84	18.84	37	30	26
F591_2	F	StabBC ///Kab 47/Excel//Stab 47/Excel	3.8	2.6	5.0	2.1	2.1	1.8	19.95	16.53	20.38	18.75	46	33	26
F595_1	F	J1///Stab 47/Excel//StabBC 42	3.8	3.2	4.3	3.3	1.4	4.6	20.70	16.91	19.48	.	29	31	.

F596_2	F	J2///Stab 47/Excel//Stab 47	4.3	1.5	2.3	.	1.8	1.1	20.82	15.94	21.16	18.89	.	28	.
F596_4	F	J1///Stab 47/Excel//StabBC 42	4.1	2.9	5.2	2.6	2.5	1.3	20.66	17.07	19.66	19.20	41	28	.
Short11	F	Bu 27/Stab 47//Maja/Stab 47	3.5	3.5	4.3	.	2.3	8.9	20.27	16.84	19.34	.	.	17	.
Short12	F	Bu 27/Stab 47//Maja/Stab 47	3.5	2.7	5.4	.	1.5	5.4	20.13	16.21	20.79	.	25	20	.
Short13	F	Bu 27/Stab 47/3/Maja/Stab 47	2.6	2.7	4.1	.	3.1	4.4	20.59	17.39	21.93	18.61	.	42	10
Short16	F	Bu 27/Stab 47/3/Maja/Stab 47	3.6	2.1	6.6	.	2.5	5.8	20.75	16.96	22.52	.	47	46	.
Short8	F	Bu 27/Stab 47/3/Maja/Stab 47	3.0	2.2	6.5	0.8	3.2	3.2	20.84	16.03	21.57	18.11	.	53	.
Maja	F	Strider/88Ab536	3.7	3.0	.	2.0	0.5	2.1	21.12	16.68	.	18.57	41	.	23
MW76_1	F	TAMBAR 501 / FEG188-02 (MW08-03)	3.6	1.1	5.5	2.3	2.2	3.8	20.77	16.28	22.06	19.70	.	37	23
MW76_2	F	TAMBAR 501 / FEG188-02 (MW08-04)	3.3	1.0	.	.	.	.	20.52	16.03	.	.	.	.	.
MW80_1	F	88ab536 / Rasmusson (MW08-10)	3.2	2.3	4.1	.	3.4	7.4	21.36	18.68	21.29	.	.	38	.
MW116_3	F	TAMBAR 501 / *2 M115	3.4	3.5	3.8	3.2	4.4	3.8	21.04	18.59	19.20	20.43	45	38	31
MW116_4	F	TAMBAR 501 / *2 M115	3.3	3.9	4.7	.	1.3	5.2	19.79	18.11	22.70	.	51	38	.
MW118_1	F	NB99845 / *2 M115	3.2	3.1	3.7	.	1.1	3.3	20.91	17.59	21.57	.	.	36	.
MW118_3	F	NB99845 / *2 M115	3.5	3.0	5.3	.	0.8	7	21.61	19.52	21.25	.	.	36	.
MW118_4	F	NB99845 / *2 M115	2.6	4.3	5.6	.	1.1	4.2	21.34	18.09	22.52	.	.	32	.
MW120_8	F	88ab536 / *2 Rasmusson	3.2	3.0	6.6	.	1.3	7.3	21.27	18.21	22.16	.	37	38	.
MW122_1	F	88ab536 / *2 M115	3.7	3.7	4.7	1.6	1.9	4.4	20.29	17.91	22.43	19.11	.	36	30
MW122_5	F	88ab536 / *2 M115	3.0	3.5	4.8	.	1.4	2.5	21.32	18.30	19.93	.	37	36	.
OBA11_13	F	NB3437f/OR76	3.3	3.0	3.7	.	1.3	7.1	20.32	17.80	21.43	.	28	36	.
OBA11_2	F	NB3437f/OR71	3.6	2.8	5.5	.	1.2	6.9	21.47	18.25	20.20	.	40	34	.
OBA11_29	F	NB3437f/OR71	3.2	2.8	5.3	3.4	3	7.9	21.43	16.34	20.02	.	43	32	25
OBA11_31	F	NB3437f/OR71	3.7	2.3	.	2.2	.	3.5	20.63	16.91	.	.	29	.	23
OR101	F	StabBC 42///Kab 51/Legacy//Kab 51	4.2	2.7	4.4	2.3	4.3	4.5	20.45	16.12	18.93	.	.	15	15
OR103	F	StabBC 42/3/Kab51/Legacy//Kab51	4.3	2.8	5.3	3.8	2.1	2.6	20.93	16.55	18.70	.	31	7	8
OR104	F	StabBC 50/Maja	4.1	1.0	4.7	.	2.2	2.9	20.32	16.48	20.61	.	.	26	23
OR106	F	StabBC 50/Maja	2.5	3.0	4.7	.	1.6	8.4	20.52	15.87	21.11	.	.	27	21
OR108	F	J2/Maja	2.8	1.4	5.8	2.8	2.4	2.5	21.86	16.00	20.84	19.66	34	32	22
OR818	F	J2/Maja	3.0	2.9	4.3	.	1.7	5.5	20.84	16.57	22.52	.	32	42	.
OR91	F	Bu27/Stab 47/3/Maja/Stab 47	2.7	1.9	5.0	2.7	2.7	3.2	20.34	16.07	20.43	19.84	.	35	30
OR910	F	Bu27/Stab 47/3/Maja/Stab 47	3.8	2.0	5.7	.	1.2	5.6	20.18	16.75	20.34	.	47	56	.
PO71_104	F	P713/OR71	3.2	1.9	4.8	.	2.4	4.3	20.45	.	20.20	.	31	41	.
PY211_6	F	Maja/Legacy//Maja/3/Kab 47	3.1	2.4	4.2	.	2.1	2.5	22.54	17.77	21.70	.	.	22	.
F5105_3	W	Stab 47/Kab 51//StabBC 42	3.6	2.1	5.4	2.1	2.4	2.2	20.4	16.4	22.3	21.4	45	27	21
F5106_1	W	Stab 47/Kab 51//StabBC 42	3.8	2.2	5.4	.	2.1	1.8	19.7	16.5	21.4	.	.	30	.
F5109_1	W	Stab 47/Kab 51//StabBC 42	3.0	2.5	5.1	.	1.8	6.1	20.8	17.0	21.2	.	.	29	.
F5109_3	W	Stab 47/Kab 51//StabBC 42	3.4	2.9	5.7	2.0	2.8	5.9	20.0	.	22.7	19.2	.	37	26
F5126_1	W	StabBC 182//Stab 47/Kab 51	3.2	2.4	5.3	.	2.5	4.4	20.3	16.5	21.6	.	.	20	.
F5126_2	W	StabBC 182//Stab 47/Kab 51	3.4	1.2	4.9	2.1	3.7	1.6	20.4	17.1	21.6	17.7	.	28	24
F5129_1	W	StabBC 182///K47/Excel//Stab 47/Excel	4.5	2.1	4.4	.	1.6	3.5	20.1	16.5	20.8	.	.	26	.
F5135_4	W	J1///Stab 47/Excel//StabBC 42	1.8	1.9	5.7	.	1.5	5.9	19.3	.	19.9	.	.	26	.
F5136_1	W	UTWB940119/J1	4.4	2.6	4.5	.	1.3	4.6	20.1	15.9	20.5	.	.	24	.
F523_1	W	StabBC 42//Bu 37/Maja	3.9	3.3	6.4	.	1.9	7.8	21.0	17.8	22.2	.	.	35	.
F527_1	W	StabBC 42//Bu 37/Maja	4.1	3.7	4.9	3.7	3.2	3.9	20.6	17.3	20.3	20.7	.	41	29
F532_1	W	StabBC 50//Bu 37/Maja	3.4	1.6	8.0	2.8	2.7	2.8	22.4	16.9	22.2	21.2	42	25	30
F535_2	W	UTWB940119/StabBC 50	3.6	2.8	7.0	3.8	2.6	5.8	20.3	16.3	22.6	21.2	.	58	34
F536_2	W	UTWB940119/J1	4.7	1.9	6.0	.	2.5	1.4	21.7	18.0	21.8	.	33	28	.
F537_1	W	UTWB940119/J1	4.2	1.8	6.7	.	2	0.9	20.3	17.7	21.5	.	.	26	.
F537_3	W	UTWB940119/J1	3.6	2.3	7.6	2.4	2.1	2.2	21.0	18.2	22.7	20.8	38	33	21
F54_2	W	StabBC 42//Bu 37/Maja	3.3	2.4	5.7	.	3.2	1.7	21.7	17.0	20.3	.	.	20	.
F547_1	W	StabBC 42//Bu 37/Maja	3.7	3.0	5.8	.	1.3	3.7	21.2	18.2	21.7	.	34	32	.
F547_3	W	StabBC 42//Bu 37/Maja	3.1	2.9	4.2	.	1.2	8.0	20.6	17.4	18.8	.	34	33	.
F548_1	W	StabBC 42/Bu 37//Maja	3.4	3.2	4.3	.	1.2	4.9	20.0	17.7	19.2	.	40	30	.
F55_1	W	StabBC 42//Bu 37/Maja	4.2	2.1	6.2	3.5	2.6	2.9	21.1	17.4	21.3	20.0	38	23	24
F550_1	W	StabBC 42/Bu 37//Maja	3.6	3.5	6.2	.	1.5	2.2	20.7	16.7	22.6	.	.	31	.
F552_2	W	StabBC 50/Maja	3.8	1.8	6.2	.	1.5	2.6	21.3	18.0	22.6	.	.	27	.
F555_1	W	UTWB940119/J1	4.2	1.8	7.3	2.2	1.5	2.5	21.8	17.7	20.4	18.6	38	35	24
F556_1	W	Stab 47/Kab 51//StabBC 42	.	1.8	.	.	1.2	2.4	.	16.6	.	.	.	.	.
F556_3	W	Stab 47/Kab 51//StabBC 42	4.1	1.4	7.9	2.6	4.2	1.5	19.6	17.4	21.6	20.7	41	35	28

F560_2	W	StabBC 182//Stab 47/Kab 51	3.7	2.4	5.8	2.2	2.4	4.4	20.1	16.8	20.4	17.2	.	25	22
F564_1	W	StabBC 42//Bu 37/Maja	3.8	1.8	6.3	.	2.2	2.8	19.2	17.1	20.9	.	.	28	.
F566_3	W	Kab 51/Excel//Maja/3/Stab 7/Maja	3.6	2.2	4.2	2.6	2.9	2.8	20.4	16.2	17.7	18.2	.	31	28
F572_3	W	UTWB940119/StabBC 50	3.8	3.0	5.2	0.8	2.7	4.2	20.6	17.3	19.3	17.7	.	24	.
F576_1	W	Stab 47/Kab 51//StabBC 42	3.8	2.2	5.5	.	1.4	3.2	20.1	17.2	21.1	.	40	38	.
F583_1	W	StabBC 42//Stab 47/Kab 51	3.5	2.3	5.6	.	2.2	6.4	20.5	16.5	21.3	.	44	23	.
F588_3	W	StabBC 182//Stab 47/Kab 51	3.3	2.1	5.9	.	1.6	3.2	19.6	16.1	22.4	.	.	23	.
F59_2	W	StabBC 50//Bu 37/Maja	3.7	1.9	5.6	3.6	2.1	1.1	20.4	16.7	20.2	20.4	.	23	21
F591_1	W	StabBC 182///K47/Excel//Stab 47/Excel	3.4	2.5	4.9	3.0	2.5	3.6	21.5	17.6	23.2	21.6	33	38	22
Alba	W	Strider/Orca	3.4	2.3	6.4	1.1	2.8	5.7	20.0	16.7	21.7	17.9	47	36.5	21
OK216	W	Post 90*4 / R036	3.5	2.1	.	2.4	2.6	2.2	20.9	17.5	.	18.3	.	.	25
OK249	W	Post 90*4 / R019	3.5	2.0	.	.	.	.	20.7	17.6	.	.	44	.	.
OK248	W	Post 90*4 / R019	4.2	0.9	5.0	0.9	.	.	21.9	16.7	21.3	18.2	.	11	.
OK242	W	Post 90*4 / R012	3.5	1.5	4.5	0.8	.	.	23.0	19.0	18.8	19.6	.	11	23
OK452	W	Post 90*4 / R011	2.0	1.9	6.3	1.2	.	.	21.8	19.2	20.4	19.1	.	9	24
OK474	W	Post 90*4 / R001	4.0	1.6	4.9	1.3	.	.	21.3	18.9	19.2	17.2	.	14	21
OR76	W	STAB 47/KAB 51	3.1	1.7	5.5	.	1.9	1.4	19.9	.	22.0	.	.	35	.
OR813	W	Stab 47/Kab51	3.7	2.7	4.7	2.6	2.5	3.6	21.3	16.7	21.4	20.8	.	24	23
OR815	W	CC99B	2.9	3.0	5.1	2.3	2.7	4.7	20.4	.	23.1	19.7	.	42	24
PO71_87	W	P713/OR71	3.1	1.3	.	2.1	2.8	4.3	21.6	16.0	.	16.6	.	.	.
06AB_24	S2	93AB859/BZ594-19	.	2.5	.	1.6	1.7	2.5	.	20.3	.	19.7	43	.	.
06AB_44	S2	96AB8309/Steffi	.	2.6	.	2.6	2.5	2.0	.	20.4	.	20.8	29	.	.
06BA_81	S2	Scarlett/Z037C005G//Z051B038C/Z006C018G	.	1.7	.	2.0	2.6	4.9	.	20.7	.	20.3	37	.	.
06MT_26	S2	GS1750/MT050051	.	2.6	.	2.4	2.4	4.0	.	20.9	.	20.1	49	.	.
06MT_59	S2	MT970110/MTLB5	.	2.5	.	4.6	2.7	2.8	.	21.1	.	22.4	43	.	43
06MT_67	S2	Haxby/Craft	.	2.6	.	4.4	2.0	3.7	.	21.0	.	21.3	55	.	61
06MT_82	S2	MTLB5/MT960222	.	3.2	.	3.4	2.0	3.9	.	21.9	.	22.4	56	.	56
06N2_06	S2	ND19088//ND17291/ND19098	.	2.1	.	3.5	2.2	3.9	.	20.8	.	21.4	42	.	42
06N2_17	S2	Logan/ND19119-5	.	2.2	.	3.7	1.2	2.5	.	20.8	.	21.6	50	.	50
06N2_37	S2	ND19872/ND19854	.	2.6	.	.	1.7	8.2	.	21.3	.	.	.	.	.
06N2_39	S2	ND20794//Lacey/ND19922	.	2.0	.	3.3	2.4	2.0	.	20.1	.	20.8	55	.	.
06N2_70	S2	Shenmai 3/ND19119-1//ND21117	.	2.6	.	4.0	2.0	5.4	.	20.3	.	21.7	45	.	42
06WA_38	S2	Farmington/Jersey	.	1.9	.	2.1	2.1	2.9	.	20.5	.	20.2	54	.	54
06WA_77	S2	Bob/Xena	.	2.8	.	2.0	2.2	5.6	.	20.5	.	19.0	37	.	37
07AB_53	S2	97Ab7804/Garnet	.	2.2	.	4.0	1.6	1.4	.	20.1	.	20.0	57	.	.
07AB_77	S2	91Ab2303/96Ab8289	.	2.7	.	3.1	3.3	8.5	.	21.2	.	22.1	55	.	55
07BA_80	S2	2B99-2657/2B99-2123	.	1.7	.	3.0	1.1	3.6	.	20.6	.	20.1	.	.	.
07MT_40	S2	MT010178/MT970116	.	3.2	.	2.6	1.6	5.0	.	20.3	.	21.4	51	.	51
07MT_67	S2	MT990173/Bearpaw	.	2.1	.	1.5	2.0	3.6	.	20.8	.	21.2	.	.	.
07MT_94	S2	LK644///Craft F5	.	1.6	.	3.3	1.2	4.2	.	21.2	.	19.9	56	.	62
07N2_02	S2	ND229966//Mildew 25/Rawson	.	2.3	.	2.8	1.2	2.8	.	20.9	.	20.4	54	.	58
07N2_13	S2	ND21957-2/ND23024	.	1.8	.	4.5	1.3	4.3	.	20.2	.	20.8	54	.	51
07N2_31	S2	ND22089-2/Rawson	.	1.9	.	3.4	1.2	3.6	.	19.3	.	20.3	61	.	59
07N2_38	S2	C2-00-303-18/ND21089-3	.	3.0	.	.	.	5.2	.	21.2	.	22.1	55	.	55
07N2_61	S2	ND22974/ND22947	.	2.5	.	0.7	1.3	3.4	.	18.9	.	19.7	46	.	46
07N2_73	S2	ND23013/ND21865-6	.	1.5	.	3.0	1.2	3.5	.	21.3	.	20.3	49	.	49
07WA_03	S2	Bob/Merit//CDC Select	.	2.9	.	1.9	1.1	4.2	.	20.5	.	18.3	49	.	.
07WA_13	S2	Radiant/2B98-5416	.	1.7	.	2.2	1.1	6.0	.	20.8	.	18.3	48	.	.
08AB_17	S2	93Ab835/01Ab10072	.	2.3	.	1.2	1.0	3.1	.	20.9	.	20.0	48	.	48
08AB_24	S2	94GH86-5/Acuario	.	2.2	.	2.1	1.1	4.5	.	20.7	.	20.1	49	.	.
08AB_45	S2	B1202/98Ab12210	.	1.7	.	1.7	1.1	3.3	.	20.0	.	18.8	41	.	53
08BA_02	S2	Z010C020E/Z011L088L	.	2.2	.	1.5	1.1	6.9	.	20.8	.	15.9	47	.	46
08BA_11	S2	Z005J004J/Cork//B1215/Z078H050i	.	1.3	.	1.1	1.1	2.8	.	19.7	.	17.8	50	.	52
08BA_25	S2	Z017L114L/Z020C014E	.	2.1	.	1.6	1.1	2.1	.	19.7	.	.	.	.	.
08BA_30	S2	Z180i017M//B1215/Z001C011F	.	0.5	.	.	.	5.8	.	19.8	.	.	.	.	.
08BA_76	S2	2B01-1961/2B01-1703	.	2.2	.	2.3	1.2	5.4	.	20.4	.	21.5	41	.	.
08MT_04	S2	Amulet/MT960101	.	2.0	.	2.6	1.0	5.0	.	20.7	.	20.0	57	.	.
08MT_41	S2	MT10105/Eslick	.	.	.	.	1.0	7.1	.	.	.	.	45	.	.
08MT_63	S2	MT96010/MT981210	.	2.5	.	2.0	1.2	1.7	.	21.1	.	19.0	29	.	.

08MT_68	S2	MT970026/Eslick	.	2.3	.	.	1.0	5.2	.	21.0	.	.	42	.	.
08N2_12	S2	ND24289/ND229966//Conlon	.	2.9	.	.	.	4.5	.	20.6	.	.	60	.	60
08N2_37	S2	ND22895/ND24490//ND24365	.	1.8	.	.	.	4.2	.	20.9	.	.	51	.	.
08N2_62	S2	ND24519/ND24260	.	2.5	.	4.1	2.4	1.7	.	20.4	.	20.2	60	.	.
08N2_66	S2	ND24519/Conlon	.	2.3	.	.	2.5	4.4	.	20.8	.	.	53	.	53
08N2_73	S2	ND24383/ND24260	.	2.3	.	3.6	1.8	3.2	.	20.5	.	20.6	60	.	60
08N2_80	S2	ND24365/ND24519	.	2.9	.	.	.	5.5	.	21.0	.	.	59	.	62
08WA_11	S2	WA10701-99/WA10429-00	.	1.8	.	1.3	1.5	2.0	.	19.8	.	16.9	47	.	47
08WA_27	S2	Bob/Baronesse//85Ab2323/3/NZDK00-131	.	2.0	.	1.6	2.1	5.7	.	21.0	.	19.3	45	.	.
08WA_40	S2	Bob/Baronesse//Xena/3/WA10497-97	.	2.9	.	1.8	2.9	4.3	.	21.5	.	19.9	44	.	.
08WA_64	S2	WA8601-97/CDC Select/90M5194/Baronesse*2	.	1.7	.	1.4	2.2	5.6	.	20.3	.	15.9	59	.	.
09AB_10	S2	.	.	2.1	.	1.1	2.0	0.9	.	20.8	.	17.8	39	.	.
09AB_15	S2	.	.	.	.	.	1.6	2.7	.	.	.	20.5	51	.	.
09AB_43	S2	.	.	1.3	.	1.7	1.3	2.4	.	21.8	.	20.7	46	.	44
09AB_48	S2	.	.	1.7	.	2.3	1.8	1.5	.	20.7	.	20.8	58	.	58
09AB_82	S2	.	.	2.9	.	2.2	2.4	2.9	.	21.1	.	20.3	47	.	.
09BA_03	S2	B1215/Z077G026i//B1215/Z167i004M	.	2.3	.	3.7	1.8	4.8	.	19.3	.	18.8	38	.	38
09BA_10	S2	Z020L037L/Metcalfe	.	1.9	.	2.2	2.1	3.4	.	20.3	.	.	40	.	39
09BA_68	S2	2B01-1707/2B99-2316	.	2.7	.	2.5	1.5	3.3	.	20.9	.	18.5	.	.	.
09BA_89	S2	2B99-2763//2B00-0719/2B00-0794	.	1.0	.	1.8	2.4	3.5	.	19.0	.	16.6	52	.	56
09BA_94	S2	Merit/98NZ-015	.	0.5	.	.	2.0	5.6	.	19.7	.	.	.	.	.
09MT_16	S2	LK6-44/Conlon (75-35)	.	2.4	.	1.9	2.9	5.0	.	20.8	.	19.1	45	.	.
09MT_78	S2	MT910189/MT910189/Lk644/Eslick BC3F3 7-I	.	2.6	.	2.6	2.3	3.6	.	21.1	.	20.1	49	.	49
09MT_94	S2	MT910189/MT910189/Lk644/Eslick BC3F3 3-G	.	2.3	.	1.5	1.8	4.1	.	19.8	.	17.9	48	.	45
09N2_04	S2	ND24519/ND24383	.	1.9	.	2.9	3.0	6.8	.	20.4	.	20.3	.	.	.
09N2_12	S2	ND24253/ND24519	.	1.8	.	4.0	2.3	4.4	.	21.0	.	20.4	60	.	.
09N2_16	S2	ND24190/ND2895	.	1.9	.	.	1.5	5.5	.	20.7	.	.	54	.	.
09N2_21	S2	ND19922//ND19974/ND19119/3/ND23146	.	3.0	.	4.2	2.2	2.7	.	20.2	.	20.4	46	.	40
09N2_29	S2	ND23146/ND24519	.	2.6	.	2.6	3.1	4.5	.	21.1	.	20.9	52	.	52
09N2_39	S2	ND24519/ND24379	.	2.7	.	2.4	3.3	5.2	.	20.5	.	21.2	53	.	57
09N2_55	S2	2ND24253/TR05286	.	1.8	.	3.0	1.7	2.8	.	20.8	.	19.7	54	.	.
09N2_73	S2	2ND24266/TR05285	.	2.5	.	2.4	2.6	3.0	.	20.7	.	19.7	70	.	.
09WA_15	S2	WA10701-99/Baronesse	.	.	.	1.5	2.4	2.3	.	20.6	.	18.7	51	.	.
09WA_19	S2	NZDK00-146/Baronesse//Farmington/Baronesse	.	2.3	.	1.7	2.4	3.9	.	20.2	.	19.9	40	.	40
09WA_52	S2	Farmington/CDC Select//Baronesse/Samish 23/3/YU 597-432	.	2.6	.	2.4	1.6	2.6	.	20.3	.	21.2	49	.	52
09WA_64	S2	Radiant/Baronesse	.	2.3	.	1.3	2.0	5.5	.	21.2	.	20.3	45	.	.
AC_Met	S2	TR226/Manley	.	2.0	.	1.8	1.3	4.0	.	20.8	.	18.7	51	.	50
CDC	S2	WM861-5/TR118	.	1.8	.	2.0	1.4	3.2	.	20.5	.	18.7	27	.	.
CON	S2	Bowman*2/DWS1008//ND10232	.	1.8	.	2.4	1.4	4.3	.	20.7	.	20.7	50	.	.
S_622B	S2	B1201*4/R034	.	45.7	.	2.1	.	.	.	19.2	.	13.2	1.4	.	.
SIDNEY	S2	Otis*4/STARS 9301B	.	45.4	.	0.8	33	.	.	20.3	.	12.7	1.0	.	.
STONE	S2	Otis*4/STARS 9577B	.	39.8	.	0.5	33	.	.	17.7	.	.	1.0	.	.
F_Pint2	S2	Strider/Harrington	.	3.4	.	44.7	37.3	0.6	.	21.6	.	3.2	4.0	.	2
06AB_55	S6	92Ab5189/M83//Foster	.	1.5	.	3.5	1.8	6.1	.	18.4	.	18.5	52	.	27
06AB_62	S6	92Ab5697/95Ab15156//92Ab5180	.	2.1	.	2.6	1.9	4.4	.	19.5	.	20.2	49	.	58
06AB_84	S6	86Ab599/B2912	.	2.2	.	3.9	2.4	5.1	.	19.2	.	19.6	51	.	39
06BA_06	S6	6B94-7378//B22027/M84	.	1.9	.	3.1	2.2	6.2	.	19.7	.	20.0	56	.	43
06BA_30	S6	Tradition//6B94-8253/Drummond	.	1.5	.	3.4	2.3	4.9	.	20.3	.	20.1	.	.	46
06MN_10	S6	ND20407/M118 FHB (F3:4)	.	2.0	.	2.9	2.2	4.0	.	19.1	.	20.3	.	.	42
06MN_18	S6	MN99-52/FEG66-08	.	1.5	.	3.5	2.2	3.5	.	19.1	.	19.8	53	.	43
06MN_51	S6	FEG67-32/M117	.	1.8	.	2.9	1.5	5.6	.	19.4	.	21.3	.	.	36
06MN_62	S6	M115/M119	.	1.2	.	2.6	1.9	4.6	.	18.8	.	17.7	54	.	23
06N6_66	S6	Drummond/ND19651	.	1.7	.	3.8	2.6	3.9	.	18.9	.	20.6	.	.	39
06N6_71	S6	Drummond/ND17643	.	2.0	.	3.4	1.8	5.0	.	19.8	.	21.7	58	.	46
06N6_88	S6	ND18546/ND19655	.	1.9	.	1.8	1.9	4.1	.	19.1	.	20.0	53	.	42
07AB_10	S6	93Ab355/3/92Ab5187//88Y394/M75	.	1.9	.	2.8	2.7	4.8	.	17.8	.	17.7	.	.	36
07AB_16	S6	Colter/98Ab12399	.	1.9	.	1.9	1.8	7.1	.	18.1	.	18.9	44	.	29
07BA_09	S6	Tradition/3/6B97-2063//6B94-8253/6B97-2245	.	2.1	.	3.4	2.5	3.1	.	19.3	.	20.1	61	.	45
07BA_18	S6	6B97-2063//6B94-8253/6B97-2245/3/Tradition	.	2.1	.	2.5	2.5	4.7	.	20.2	.	19.3	.	.	33

07BA_24	S6	6B98-9555/Lacey	.	1.7	.	3.2	2.2	7.3	.	19.3	.	20.2	.	.	58
07BA_28	S6	6B98-9920/6B98-9058	.	2.0	.	2.9	2.7	4.8	.	18.5	.	19.7	62	.	54
07MN_42	S6	M00-51/M123 MAS	.	1.5	.	2.5	1.9	3.2	.	19.6	.	20.9	54	.	55
07MN_52	S6	Quest/M123	.	1.2	.	2.9	1.6	5.6	.	19.2	.	20.7	.	.	53
07MN_85	S6	M01-65/M121 NB	.	1.3	.	3.5	1.5	5.2	.	19.0	.	20.3	54	.	53
07MN_90	S6	Sep2-01/M116 Se	.	1.8	.	3.3	2.3	5.4	.	20.3	.	19.1	59	.	54
07MN_94	S6	Sep2-01/M99-106 Se NB	.	1.6	.	1.7	1.5	2.5	.	18.8	.	18.9	.	.	41
07N6_51	S6	Stellar-ND/ND20481	.	1.7	.	3.1	2.7	3.4	.	18.8	.	19.6	.	.	26
07N6_80	S6	ND19474/ND20477	.	1.9	.	4.2	1.9	2.1	.	18.3	.	20.6	48	.	29
07UT_18	S6	UT95B1216-4087/Baronesse	.	1.9	.	1.2	2.2	2.6	.	19.5	.	17.1	.	.	27
07UT_36	S6	UT5344/Baronesse	.	1.6	.	2.1	2.7	3.6	.	19.7	.	18.8	39	.	39
07UT_71	S6	SDB1-1009/M72-395/3/Short2//ID633019/Woodvale/4/Steptoe/M27//Gusto/5/WA11825-95/6//Baronesse	.	1.8	.	0.4	1.8	4.2	.	19.5	.	17.8	48	.	.
07UT_83	S6	SDB1-1009/M72-395/3/Short2//ID633019/Woodvale/4/Steptoe/M27//Gusto/5/WA11825-95/6//Harrington	.	2.0	.	2.0	2.5	8.1	.	19.7	.	20.7	.	.	20
07UT_88	S6	Harrington/UT4392	.	1.4	.	1.9	2.5	2.7	.	19.5	.	19.2	.	.	24
07UT_93	S6	Harrington/UT95B1216-4087	.	1.8	.	1.9	1.9	5.6	.	20.4	.	20.6	.	.	21
07UT_96	S6	PB 17090/6/SDB1-1009/M72-395/3/Short2//ID633019/Woodvale/4/Steptoe/M27//Gusto/5/WA11825-95	.	2.1	.	2.0	2.2	4.0	.	20.2	.	21.6	53	.	47
08AB_54	S6	92Ab5180/Lacey	.	1.9	.	2.0	2.5	3.1	.	19.0	.	19.1	58	.	28
08AB_80	S6	98Ab12399/94-Ab13449	.	1.4	.	2.7	2.0	4.4	.	19.2	.	19.4	.	.	38
08BA_41	S6	6B00-0906/6B99-6557	.	2.4	.	2.5	2.9	2.9	.	20.1	.	18.4	.	.	35
08BA_44	S6	6B98-9339/C01-6761	.	1.9	.	3.6	3.2	7.3	.	18.8	.	19.7	53	.	44
08BA_54	S6	6B00-0906/6B98-9558	.	2.2	.	2.1	2.6	4.8	.	20.4	.	19.7	.	.	38
08BA_60	S6	6B01-2600/Tradition	.	2.1	.	3.2	3.3	6.9	.	19.5	.	20.0	.	.	37
08BA_64	S6	FEG26-93/6B98-9022	.	0.8	.	2.1	2.7	4.3	.	19.1	.	18.9	58	.	17
08MN_34	S6	FEG109-44/FEG100-41	.	1.6	.	1.8	2.2	3.0	.	18.8	.	19.1	56	.	38
08MN_49	S6	FEG116-05/FEG99-10	.	1.7	.	1.4	2.3	1.0	.	18.8	.	20.1	57	.	21
08MN_56	S6	FEG148-56/Rasmusson	.	1.7	.	2.7	2.2	3.5	.	19.2	.	20.0	.	.	35
08MN_67	S6	FEG150-49/M122	.	1.8	.	2.8	1.9	2.2	.	19.0	.	20.7	.	.	33
08MN_78	S6	M118/MN01-05	.	1.7	.	2.8	2.3	4.7	.	20.0	.	20.2	62	.	42
08N6_09	S6	ND19557/ND19491	.	2.1	.	3.5	3.0	5.1	.	18.9	.	20.0	.	.	46
08N6_21	S6	ND19474/ND20614	.	1.8	.	3.1	1.9	2.0	.	19.4	.	19.9	50	.	26
08N6_35	S6	ND19655/ND20542	.	1.8	.	2.5	3.5	6.2	.	18.8	.	18.4	51	.	21
08N6_52	S6	ND20364/ND20477	.	2.6	.	3.7	2.8	5.8	.	19.2	.	20.2	54	.	38
08N6_77	S6	ND20508/ND20666	.	2.5	.	2.2	1.9	6.6	.	19.4	.	19.6	62	.	35
08N6_91	S6	ND19552/ND19655	.	2.1	.	4.0	1.0	3.7	.	19.4	.	20.2	.	.	48
08N6_94	S6	ND19620/ND20281	.	2.6	.	4.1	1.8	3.6	.	20.0	.	20.4	.	.	49
08N6_96	S6	ND19655/ND20314	.	2.1	.	3.4	3.4	6.3	.	19.3	.	17.7	49	.	26
08UT_10	S6	Morex*Goldeneye	.	1.6	.	1.8	1.4	3.6	.	19.0	.	18.2	39	.	31
08UT_80	S6	AB11469*Aquila	.	1.9	.	.	2.2	5.7	.	18.6	.	.	.	.	.
09BA_37	S6	6B00-1166/ND18578	.	1.9	.	3.7	3.7	7.2	.	19.2	.	20.1	46	.	44
09BA_50	S6	6B98-9558/M99-2	.	1.8	.	3.0	2.3	6.3	.	18.3	.	20.2	55	.	44
09MN_04	S6	MN02-04/ND23657	.	2.5	.	3.2	2.8	5.3	.	19.5	.	20.4	57	.	33
09MN_30	S6	ND23657/M132	.	1.5	.	1.9	1.6	2.3	.	18.2	.	20.2	54	.	35
09MN_50	S6	M137/FEG148-26	.	1.9	.	3.7	1.8	3.9	.	19.7	.	22.2	.	.	44
09MN_70	S6	MN03-12/FEG168-19	.	1.6	.	2.2	1.7	5.7	.	20.1	.	19.2	52	.	29
09N6_36	S6	ND21376/ND21609	.	1.8	.	3.0	1.7	3.6	.	18.3	.	19.4	63	.	36
09N6_59	S6	Stellar-ND/ND23672	.	1.7	.	1.8	2.1	6.1	.	19.0	.	20.7	66	.	34
09N6_63	S6	M122/ND23497	.	1.9	.	2.2	1.7	2.5	.	19.7	.	20.3	54	.	39
09N6_69	S6	Tradition/ND20448	.	1.5	.	2.9	2.4	.	.	19.7	.	20.9	59	.	44
09UT_13	S6	Stander/Aquila	.	1.7	.	1.8	1.5	4.3	.	18.6	.	17.8	.	.	34
AC_Met	S6	TR226/Manley	.	1.8	.	1.8	1.3	2.9	.	20.1	.	19.2	62	.	30
CDC	S6	WM861-5/TR118	.	1.6	.	2.1	1.2	3.4	.	19.9	.	19.1	.	.	27
CON	S6	Bowman*2/DWS1008//ND10232	.	1.8	.	2.0	1.8	3.6	.	20.7	.	20.9	51	.	43
S_610B	S6	Morex*4/R019	.	1.4	.	2.3	.	.	.	19.4	.	18.6	.	.	26

A-4: TCAP Barley lines and commercial check malt quality and environmental evaluations (F= facultative, W= winter, S2= spring two-row, S6= spring six-row).

		Malt Quality			Lodging (%)						Bird Damage (0-5 scale)			Leaf Rust (0-5 scale)		Aphid (0-5 scale)	
		2016	2015		2016		2015		2014		2016		2014	2014		2014	
Line/Variety	Type	MCG	DIM	MCG	MCG	CAS	DIM	MCG	MCG	CAS	MCG	CAS	CAS	CAS	MCG	CAS	MCG
P919	F	.	21	17	53	.	30	.	.	.	0	.	.	.	.	.	.
06OR_10	F	.	26	.	65	95	50	.	.	.	1	3	.	0	.	0	0
06OR_37	F	36	26	.	30	95	70	.	.	.	1	5	.	0	.	0	0
06OR_41	F	34	38	23	33	13	90	10	.	.	1	5	.	5	.	0	0
06OR_42	F	.	31	.	90	95	80	.	.	.	0	5	.	10	.	0	0
06OR_43	F	33	30	21	48	53	80	15	5	.	0	5	.	0	.	0	0
06OR_44	F	.	32	.	33	100	60	.	5	.	4	5	.	0	.	0	0
06OR_45	F	.	30	21	40	100	90	15	.	.	0	5	.	10	.	0	0
06OR_52	F	.	32	.	8	95	90	.	.	.	0	5	.	30	.	0	0
06OR_59	F	34	38	.	50	18	50	.	.	.	0	5	.	5	.	0	20
06OR_62	F	.	26	26	85	48	0	80	.	.	.	.	.	40	.	0	20
06OR_75	F	.	38	.	.	100	50	.	10	.	0	.	.	20	.	0	0
06OR_78	F	.	38	.	.	90	10	.	10	.	.	5	.	10	.	0	0
06OR_9	F	.	.	.	35	100	.	.	.	80	.	.	.	0	.	9	0
06OR_91	F	24	35	.	23	60	30	.	10	.	.	.	.	20	.	0	5
07OR_21	F	.	32	26	85	65	60	10	.	.	0	3	.	0	.	0	10
07OR_3	F	45	47	.	53	48	60	.	.	.	0	5	.	5	.	7	0
07OR_4	F	.	63	24	45	80	10	80	.	.	0	5	.	5	.	0	10
07OR_59	F	38	42	.	48	80	0	.	.	.	0	5	.	0	.	7	0
07OR_6	F	31	59	21	48	100	40	.	.	.	0	5	.	5	.	0	0
07OR_63	F	30	36	.	20	33	5	.	5	.	1	5	.	0	.	0	10
07OR_8	F	.	53	19	90	100	20	15	.	.	1	5	.	0	.	0	0
08OR_30	F	40	35	18	45	100	0	60	.	.	1	0	.	0	.	0	0
08OR_44	F	.	31	.	75	100	40	.	.	.	1	.	.	0	.	0	5
08OR_48	F	.	27	.	90	75	30	.	.	.	0	5	.	30	.	0	10
08OR_53	F	.	19	.	45	100	40	.	.	.	0	5	.	50	.	0	10
08OR_73	F	.	39	.	35	80	20	.	.	.	2	5	.	5	.	0	5
08OR_81	F	.	33	.	5	100	10	70	.	.	0	5	.	5	.	0	40
F5105_1	F	.	.	.	20	65	40	5	.	.	0	4	.	0	.	0	0
F5108_1	F	.	35	21	40	100	0	.	5	.	0	.	.	0	.	0	0
F5112_1	F	40	19	.	23	100	5	.	5	.	0	5	.	0	.	0	0
F5112_3	F	36	31	24	85	95	60	.	5	.	0	5	.	0	.	0	5
F5113_2	F	28	28	.	48	100	70	.	5	.	1	5	.	5	.	0	3
F5119_1	F	46	41	.	5	70	20	.	5	.	0	4	.	5	.	7	10
F5120_3	F	.	23	.	48	95	50	.	.	.	0	5	.	0	.	0	5
F5121_1	F	36	20	.	23	100	40	40	.	.	0	3	.	0	.	0	10
F5121_2	F	.	23	28	43	100	30	.	.	.	0	5	.	0	.	0	5
F5121_3	F	44	23	.	43	100	10	10	.	.	0	5	.	0	.	0	0
F5121_4	F	.	18	26	65	100	30	.	5	.	0	.	.	0	.	0	5
F5121_5	F	37	25	.	20	5	40	50	.	.	3	5	.	20	.	0	5
F5124_1	F	.	28	28	50	93	30	.	.	.	1	5	.	10	.	0	0
F5131_1	F	.	21	.	55	90	60	.	.	.	0	5	.	10	.	0	0
F5132_1	F	.	31	.	5	90	50	90	.	.	0	5	.	0	.	0	3
F5134_3	F	42	32	26	48	100	20	.	.	.	1	5	.	0	.	0	0
F522_3	F	.	30	25	3	95	30	.	.	.	1	5	.	0	.	0	0
F557_2	F	34	36	28	48	5	50	.	.	30	0	5	.	20	.	0	0
F559_1	F	40	37	.	20	95	30	5	.	.	2	5	.	10	.	9	0
F559_2	F	.	22	26	5	80	30	.	.	40	0	.	.	0	.	0	0
F576_4	F	.	22	22	3	100	40	.	.	.	0	5	.	0	.	0	0
F590_5	F	37	30	26	33	100	10	60	.	.	0	.	.	10	.	0	3
F591_2	F	46	33	26	10	100	90	40	.	100	1	5	.	0	.	0	0
F595_1	F	29	31	.	75	100	90	10	.	.	1	5	.	20	.	0	0
F596_2	F	.	28	.	50	45	90	.	.	.	0	5	.	5	.	0	0

F596_4	F	41	28	.	28	95	90	.	.	.	0	5	.	5	.	0	0
Short11	F	.	17	.	48	60	5	.	.	.	0	5	.	5	.	0	0
Short12	F	25	20	.	30	55	0	.	.	.	0	5	.	5	.	0	0
Short13	F	.	42	10	90	75	0	50	.	.	0	5	.	70	.	0	0
Short16	F	47	46	.	75	20	0	.	.	10	0	3	.	5	.	0	0
Short8	F	.	53	.	90	100	0	10	.	.	0	3	.	10	.	0	50
Maja	F	41	.	23	65	100	.	19	.	.	0	5	.	0	.	0	0
MW76_1	F	.	37	23	5	5	80	.	.	.	1	5	.	5	.	0	0
MW76_2	F	.	.	.	75	70	5	5	.	.	0	5	.	40	.	0	0
MW80_1	F	.	38	.	48	100	5	.	.	40	.	5	.	30	.	0	30
MW116_3	F	45	38	31	30	10	5	.	.	10	2	5	.	5	.	0	0
MW116_4	F	51	38	.	60	53	15	.	.	.	1	5	.	5	.	0	0
MW118_1	F	.	36	.	48	18	0	.	.	.	0	.	.	0	.	0	40
MW118_3	F	.	36	.	10	40	0	.	.	.	1	5	.	20	.	0	40
MW118_4	F	.	32	.	48	95	0	10	.	.	0	5	.	40	.	0	40
MW120_8	F	37	38	.	60	5	60	.	.	.	0	5	.	10	.	0	40
MW122_1	F	.	36	30	50	53	10	.	.	.	0	5	.	10	.	0	20
MW122_5	F	37	36	.	48	3	10	.	.	.	1	5	.	10	.	0	40
OBA11_13	F	28	36	.	90	100	10	60	.	.	0	4	.	5	.	0	20
OBA11_2	F	40	34	.	48	100	.	40	.	.	1	5	.	10	.	0	0
OBA11_29	F	43	32	25	5	88	40	30	.	.	0	5	.	5	.	7	0
OBA11_31	F	29	.	23	35	100	60	50	.	.	0	5	.	0	.	7	0
OR101	F	.	15	15	60	90	70	.	.	40	0	5	.	30	.	0	0
OR103	F	31	7	8	90	33	70	.	.	.	0	.	.	20	.	0	0
OR104	F	.	26	23	65	.	50	70	.	.	0	.	.	60	.	0	0
OR106	F	.	27	21	50	100	40	.	.	50	0	5	.	30	.	7	0
OR108	F	34	32	22	3	98	30	40	.	10	0	5	.	10	.	7	0
OR818	F	32	42	.	85	100	40	.	.	.	0	5	.	5	.	7	25
OR91	F	.	35	30	85	100	40	40	.	.	.	5	.	0	.	0	0
OR910	F	47	56	.	43	90	.	.	.	.	0	5	.	20	.	0	0
PO71_104	F	31	41	.	45	90	40	.	.	.	0	.	.	5	.	0	0
PY211_6	F	.	22	.	.	55	20	.	.	.	0	5	.	0	.	0	0
F5105_3	W	45	27	21	45	100	10	.	.	.	0	5	.	0	.	0	3
F5106_1	W	.	30	.	53	53	15	5	.	.	0	5	.	0	.	0	3
F5109_1	W	.	29	.	.	.	20	5	.	.	0	.	.	0	.	0	0
F5109_3	W	.	37	26	45	90	10	.	.	.	0	.	.	0	.	0	0
F5126_1	W	.	20	.	20	100	5	50	.	20	0	.	.	0	.	0	0
F5126_2	W	.	28	24	48	100	40	.	.	.	0	.	.	0	.	0	3
F5129_1	W	.	26	.	48	100	80	.	.	.	0	5	.	0	.	0	0
F5135_4	W	.	26	.	95	95	10	.	.	.	0	4	.	0	.	0	0
F5136_1	W	.	24	.	3	90	10	40	.	.	0	5	.	0	.	0	0
F523_1	W	.	35	.	80	100	30	70	.	.	0	5	.	0	.	0	0
F527_1	W	.	41	29	5	90	40	50	.	.	0	.	.	5	.	0	0
F532_1	W	42	25	30	85	95	60	20	.	.	0	5	.	0	.	0	0
F535_2	W	.	58	34	3	100	5	.	.	40	0	5	.	0	.	0	0
F536_2	W	33	28	.	5	50	5	.	.	.	0	2	.	5	.	0	0
F537_1	W	.	26	.	3	100	5	.	.	.	0	5	.	0	.	0	0
F537_3	W	38	33	21	48	100	5	.	.	.	0	5	.	0	.	0	0
F54_2	W	.	20	.	30	43	5	.	.	.	1	3	.	0	.	0	25
F547_1	W	34	32	.	48	95	5	.	.	.	0	5	.	0	.	0	40
F547_3	W	34	33	.	80	95	5	.	.	.	1	5	.	5	.	7	0
F548_1	W	40	30	.	80	95	5	90	.	.	0	1	.	0	.	0	0
F55_1	W	38	23	24	85	100	30	.	.	.	0	3	.	0	.	0	0
F550_1	W	.	31	.	48	90	40	.	.	.	0	5	.	5	.	7	0
F552_2	W	.	27	.	80	100	5	10	.	30	0	5	.	0	.	0	0
F555_1	W	38	35	24	70	100	20	.	.	.	2	5	.	60	.	0	0
F556_1	W	.	.	.	90	100	0	.	.	30	0	5	.	20	.	0	0
F556_3	W	41	35	28	5	5	0	.	5	.	0	.	.	5	.	0	0
F560_2	W	.	25	22	5	95	15	5	.	.	0	5	.	0	.	7	0

F564_1	W	.	28	.	8	100	90	5	.	.	0	5	.	0	.	0	0
F566_3	W	.	31	28	3	65	10	.	.	.	1	5	.	0	.	0	0
F572_3	W	.	24	.	0	100	10	.	.	.	0	5	.	20	.	0	5
F576_1	W	40	38	.	45	95	40	.	.	.	1	5	.	0	.	0	0
F583_1	W	44	23	.	43	90	50	.	.	20	0	5	.	0	.	7	0
F588_3	W	.	23	.	53	95	10	70	.	.	1	5	.	30	.	0	0
F59_2	W	.	23	21	65	100	10	90	.	.	0	4	.	0	.	0	3
F591_1	W	33	38	22	48	53	90	.	.	.	1	5	.	0	.	7	3
Alba	W	47	36.5	21	51.3	55	.	21	.	.	0.5	5	.	0	.	0	0
OK216	W	.	.	25	30	100	50	70	.	.	1	.	.	.	.	.	.
OK249	W	44	.	.	48	100	15	100	.	.	0	.	.	.	.	.	.
OK248	W	.	11	.	15	100	15	90	.	.	0	3	.	.	.	.	.
OK242	W	.	11	23	75	10	10	100	.	.	0	5	.	.	.	.	.
OK452	W	.	9	24	75	80	10	100	.	.	1	4	.	.	.	.	.
OK474	W	.	14	21	55	95	60	100	.	.	0	2	.	.	.	.	.
OR76	W	.	35	.	.	.	50	.	.	.	0	.	.	0	.	0	0
OR813	W	.	24	23	48	65	40	.	.	.	0	5	.	0	.	0	0
OR815	W	.	42	24	48	90	30	20	.	.	0	5	.	0	.	0	50
PO71_87	W	.	.	.	48	98	70	80	50	20	0	5	.	0	.	0	0
06AB_24	S2	43	.	.	10	100		95	.	.	0	5	0	10	.	.	.
06AB_44	S2	29	.	.	5	100		95	.	.	0	4	2	5	.	.	.
06BA_81	S2	37	.	.	28	100		81	.	.	0	4	1	0	.	.	.
06MT_26	S2	49	.	.	3	100		100	.	.	0	5	1	5	.	.	.
06MT_59	S2	43	.	43	5	100		80	.	.	0	4	3	5	.	.	.
06MT_67	S2	55	.	61	13	100		90	.	.	0	5	2	10	.	.	.
06MT_82	S2	56	.	56	0	100		90	.	.	0	5	2	0	.	.	.
06N2_06	S2	42	.	42	3	52.5		0	.	.	0	3	1	5	.	.	.
06N2_17	S2	50	.	50	3	55		10	.	10	0	5	4	5	.	.	.
06N2_37	S2	.	.	.	3	50		.	.	.	0	4	1	5	.	.	.
06N2_39	S2	55	.	.	10	50		60	.	.	0	2	1	5	.	.	.
06N2_70	S2	45	.	42	3	20		5	.	.	0	3	3	10	.	.	.
06WA_38	S2	54	.	54	15	100		40	.	.	0	5	1	10	.	.	.
06WA_77	S2	37	.	37	20	100		60	.	.	0	5	0	0	.	.	.
07AB_53	S2	57	.	.	5	5		10	.	.	0	5	1	0	.	.	.
07AB_77	S2	55	.	55	20	95		15	.	.	0	1	0	5	.	.	.
07BA_80	S2	.	.	.	3	7.5		20	.	.	0	5	1	0	.	.	.
07MT_40	S2	51	.	51	23	100		60	.	.	0	5	3	0	.	.	.
07MT_67	S2	.	.	.	50	100		85	.	.	0	3	5	5	.	.	.
07MT_94	S2	56	.	62	20	100		80	.	.	0	3	1	5	.	.	.
07N2_02	S2	54	.	58	0	7.5		20	.	.	0	5	1	0	.	.	.
07N2_13	S2	54	.	51	3	70		10	.	.	0	3	1	10	.	.	.
07N2_31	S2	61	.	59	33	35		5	.	.	0	5	1	5	.	.	.
07N2_38	S2	55	.	55	3	52.5		.	.	.	0	5	1	5	.	.	.
07N2_61	S2	46	.	46	5	32.5		.	.	.	0	5	2	0	.	.	.
07N2_73	S2	49	.	49	10	2.5		5	.	.	0	5	3	10	.	.	.
07WA_03	S2	49	.	.	8	55		90	60	.	0	3	1	0	.	.	.
07WA_13	S2	48	.	.	0	65		90	.	.	0	3	0	0	.	.	.
08AB_17	S2	48	.	48	13	70		95	.	.	0	4	0	20	.	.	.
08AB_24	S2	49	.	.	3	57.5		90	.	.	0	4	1	10	.	.	.
08AB_45	S2	41	.	53	45	85		90	.	.	0	5	0	5	.	.	.
08BA_02	S2	47	.	46	10	100		90	.	.	0	5	1	10	.	.	.
08BA_11	S2	50	.	52	45	100		80	.	.	0	5	0	10	.	.	.
08BA_25	S2	.	.	.	3	65		90	.	40	0	4	0	5	.	.	.
08BA_30	S2	.	.	.	3	22.5		.	.	.	0	5	3	5	.	.	.
08BA_76	S2	41	.	.	5	55		70	.	.	0	5	1	10	.	.	.
08MT_04	S2	57	.	.	23	80		90	.	.	0	3	2	0	.	.	.
08MT_41	S2	45	.	.	3	100		.	.	.	0	5	0	0	.	.	.
08MT_63	S2	29	.	.	33	50		60	.	40	0	3	0	0	.	.	.
08MT_68	S2	42	.	.	5	47.5		.	.	.	0	5	0	0	.	.	.

08N2_12	S2	60	.	60	30	95	.	.	.	0	5	1	30	.	.	.
08N2_37	S2	51	.	.	5	55	.	.	.	0	5	2	10	.	.	.
08N2_62	S2	60	.	.	45	17.5	30	.	.	0	5	1	10	.	.	.
08N2_66	S2	53	.	53	5	100	.	.	.	0	5	3	30	.	.	.
08N2_73	S2	60	.	60	0	75	40	.	.	0	5	3	20	.	.	.
08N2_80	S2	59	.	62	3	7.5	.	.	.	0	5	1	10	.	.	.
08WA_11	S2	47	.	47	0	100	50	.	.	0	3	0	5	.	.	.
08WA_27	S2	45	.	.	0	100	90	.	.	0	5	1	5	.	.	.
08WA_40	S2	44	.	.	25	100	100	.	.	0	5	0	0	.	.	.
08WA_64	S2	59	.	.	13	7.5	100	.	.	0	4	0	0	.	.	.
09AB_10	S2	39	.	.	18	55	100	.	.	0	5	4	0	.	.	.
09AB_15	S2	51	.	.	8	32.5	.	.	.	0	3	1	10	.	.	.
09AB_43	S2	46	.	44	85	60	90	.	.	0	5	2	5	.	.	.
09AB_48	S2	58	.	58	8	22.5	90	.	.	0	1	5	20	.	.	.
09AB_82	S2	47	.	.	5	100	80	.	.	0	5	0	0	.	.	.
09BA_03	S2	38	.	38	3	55	60	.	.	0	3	1	0	.	.	.
09BA_10	S2	40	.	39	40	85	90	.	.	0	5	2	5	.	.	.
09BA_68	S2	.	.	.	5	100	70	.	.	0	5	0	0	.	.	.
09BA_89	S2	52	.	56	20	95	80	.	.	0	5	0	0	.	.	.
09BA_94	S2	.	.	.	0	50	.	.	.	0	5	1	0	.	.	.
09MT_16	S2	45	.	.	0	100	90	.	.	0	5	2	5	.	.	.
09MT_78	S2	49	.	49	0	50	70	.	.	0	5	2	0	.	.	.
09MT_94	S2	48	.	45	3	95	60	.	.	0	5	0	0	.	.	.
09N2_04	S2	.	.	.	0	85	70	.	.	0	5	0	0	.	.	.
09N2_12	S2	60	.	.	0	32.5	50	.	.	0	5	3	5	.	.	.
09N2_16	S2	54	.	.	0	5	.	.	.	0	5	1	5	.	.	.
09N2_21	S2	46	.	40	5	32.5	70	.	30	0	3	1	0	.	.	.
09N2_29	S2	52	.	52	5	55	70	.	.	0	5	2	0	.	.	.
09N2_39	S2	53	.	57	8	50	80	.	.	0	5	1	0	.	.	.
09N2_55	S2	54	.	.	3	100	30	.	.	0	5	1	0	.	.	.
09N2_73	S2	70	.	.	5	100	50	5	.	0	5	1	0	.	.	.
09WA_15	S2	51	.	.	45	95	95	.	10	0	3	2	0	.	.	.
09WA_19	S2	40	.	40	20	100	95	.	.	0	3	0	0	.	.	.
09WA_52	S2	49	.	52	28	100	95	.	.	0	5	0	0	.	.	.
09WA_64	S2	45	.	.	40	100	95	.	.	0	4	0	0	.	.	.
AC_Met	S2	51	.	50	5	80	65	.	.	0	5	0	0	.	.	.
CDC	S2	27	.	.	5	100	70	.	.	0	5	0	0	.	.	.
CON	S2	50	.	.	48	75	70	.	.	0	3	0	0	.	.	.
S_622B	S2	1.4	.	.	3.5	.	100	70	.	50	.	.	.	.	.	.
SIDNEY	S2	1.0	.	.	5	.	93	5	.	47.5	.	.	.	.	.	.
STONE	S2	1.0	.	.	4.5	.	100	5	.	47.5	.	.	.	.	.	.
F_Pint2	S2	4.0	.	2	.	.	.	0	40	.	.	.	23	.	.	.
06AB_55	S6	52	.	27	43	93	50	.	.	0	3	0	20	0	.	.
06AB_62	S6	49	.	58	5	100	.	.	.	0	3	0	0	0	.	.
06AB_84	S6	51	.	39	0	85	50	.	.	0	5	0	0	0	.	.
06BA_06	S6	56	.	43	5	100	5	.	.	0	0	0	0	0	.	.
06BA_30	S6	.	.	46	35	98	10	.	.	0	1	1	0	0	.	.
06MN_10	S6	.	.	42	3	100	5	.	.	0	5	0	5	0	.	.
06MN_18	S6	53	.	43	45	55	10	10	.	0	5	1	0	0	.	.
06MN_51	S6	.	.	36	30	95	5	.	.	0	5	1	0	0	.	.
06MN_62	S6	54	.	23	43	95	5	.	.	0	4.5	0	5	0	.	.
06N6_66	S6	.	.	39	45	80	5	.	.	0	5	0	0	0	.	.
06N6_71	S6	58	.	46	0	50	50	.	.	0	3	.	0	0	.	.
06N6_88	S6	53	.	42	3	45	50	.	.	0	5	4	0	0	.	.
07AB_10	S6	.	.	36	0	95	.	.	.	0	3	0	0	40	.	.
07AB_16	S6	44	.	29	8	95	90	.	.	0	3	2	0	40	.	.
07BA_09	S6	61	.	45	5	80	70	.	.	0	4	0	5	40	.	.
07BA_18	S6	.	.	33	35	100	40	20	.	0	3	2	0	30	.	.
07BA_24	S6	.	.	58	15	100	50	.	.	0	5	0	0	20	.	.

07BA_28	S6	62	.	54	0	90	90	.	.	0	5	0	10	50	.	.
07MN_42	S6	54	.	55	5	33	.	20	.	0	3	1	10	20	.	.
07MN_52	S6	.	.	53	48	53	5	20	.	0	5	0	5	10	.	.
07MN_85	S6	54	.	53	30	90	5	.	.	0	5	0	0	30	.	.
07MN_90	S6	59	.	54	20	48	.	5	.	0	5	0	4	10	.	.
07MN_94	S6	.	.	41	0	100	5	.	.	0	3	8	6	20	.	.
07N6_51	S6	.	.	26	40	100	.	.	.	0	5	0	7	20	.	.
07N6_80	S6	48	.	29	10	95	90	.	.	0	5	0	3	20	.	.
07UT_18	S6	.	.	27	3	30	90	.	20	0	3.5	0	8	0	.	.
07UT_36	S6	39	.	39	90	50	90	.	.	0	2.5	0	3	0	.	.
07UT_71	S6	48	.	.	23	100	15	40	.	0	5	0	8	0	.	.
07UT_83	S6	.	.	20	30	95	5	.	.	0	3	0	4	0	.	.
07UT_88	S6	.	.	24	5	98	30	.	.	0	2.5	4	4	0	.	.
07UT_93	S6	.	.	21	45	53	80	.	.	0	3.5	0	6	20	.	.
07UT_96	S6	53	.	47	5	95	5	.	.	0	2.5	0	5	10	.	.
08AB_54	S6	58	.	28	0	53	90	.	.	0	2.5	0	4	0	.	.
08AB_80	S6	.	.	38	3	48	.	.	.	0	5	0	3	0	.	.
08BA_41	S6	.	.	35	3	65	90	.	.	0	3	0	3	0	.	.
08BA_44	S6	53	.	44	3	93	10	.	.	0	5	0	5	0	.	.
08BA_54	S6	.	.	38	75	75	60	.	.	0	5	0	4	0	.	.
08BA_60	S6	.	.	37	30	100	70	5	.	0	2.5	0	6	0	.	.
08BA_64	S6	58	.	17	0	90	95	.	.	0	3	0	4	0	.	.
08MN_34	S6	56	.	38	20	95	30	.	50	0	4	0	7	0	.	.
08MN_49	S6	57	.	21	48	100	40	5	.	0	5	0	5	0	.	.
08MN_56	S6	.	.	35	3	60	90	.	.	0	2.5	0	8	0	.	.
08MN_67	S6	.	.	33	3	100	5	.	80	0	5	3	8	0	.	.
08MN_78	S6	62	.	42	0	80	5	.	.	0	5	0	7	0	.	.
08N6_09	S6	.	.	46	0	5	.	.	.	0	3.5	0	3	0	.	.
08N6_21	S6	50	.	26	75	48	.	.	.	0	5	0	5	10	.	.
08N6_35	S6	51	.	21	5	100	90	.	.	0	5	0	4	0	.	.
08N6_52	S6	54	.	38	0	8	90	.	.	0	5	0	7	0	.	.
08N6_77	S6	62	.	35	3	100	50	.	.	0	2.5	0	3	0	.	.
08N6_91	S6	.	.	48	5	90	30	.	.	0	3.5	0	3	10	.	.
08N6_94	S6	.	.	49	0	55	80	.	.	0	5	7	4	0	.	.
08N6_96	S6	49	.	26	25	80	80	.	.	0	5	0	8	10	.	.
08UT_10	S6	39	.	31	3	5	5	.	.	0	2	0	7	10	.	.
08UT_80	S6	.	.	.	5	45	.	.	40	0	3	0	5	0	.	.
09BA_37	S6	46	.	44	25	95	5	.	.	0	3	0	3	0	.	.
09BA_50	S6	55	.	44	3	60	90	.	.	0	5	0	4	10	.	.
09MN_04	S6	57	.	33	3	53	.	.	.	0	5	3	3	0	.	.
09MN_30	S6	54	.	35	5	80	60	.	100	0	5	0	7	0	.	.
09MN_50	S6	.	.	44	0	75	60	.	.	0	5	1	8	0	.	.
09MN_70	S6	52	.	29	48	35	5	.	.	0	5	0	8	0	.	.
09N6_36	S6	63	.	36	3	5	.	.	.	0	5	0	5	0	.	.
09N6_59	S6	66	.	34	3	50	.	.	20	0	1	0	6	10	.	.
09N6_63	S6	54	.	39	45	70	.	.	.	0	3.5	0	7	0	.	.
09N6_69	S6	59	.	44	0	100	60	.	.	0	5	0	7	0	.	.
09UT_13	S6	.	.	34	45	100	30	.	.	0	5	0	7	0	.	.
AC_Met	S6	62	.	30	36	83	40	.	.	0	3	2	0	0	.	.
CDC	S6	.	.	27	30	55	45	.	.	0	2.8	.	.	.	.	.
CON	S6	51	.	43	30	50	34	.	.	0	2.5	1	1	0	.	.
S_610B	S6	.	.	26	43	93	70	.	.	0	3.5	.	.	.	.	.

A-5: TCAP winter/facultative barley lines and commercial check malt quality evaluations (Bold indicate lines that met criteria).

Year	LOC	Type	SAS_Name	Yield	Kernel Weight (mg)	Plump 6/64" (%)	Barley Color (Agtron)	Malt Extract (%)	Wort Color	Wort Clarity	Barley Protein (%)	Wort Protein (%)	S/T (%)	DP (°ASBC)	Alpha-amylase (20°DU)	Beta-glucan (ppm)	FAN (ppm)	Quality Score	Overall Rank
2015	DIM	W	06OR_10	3.68	28	56.4	34.0	75.5	2.9	1	15.3	5.0	34.6	**184.7**	**61.2**	379.0	209.7	26	97
2015	DIM	W	06OR_37	2.83	29	70.3	28.0	74.1	2.8	1	15.8	5.0	31.9	**182.8**	**59.9**	703.4	**215.9**	26	97
2015	DIM	W	06OR_41	4.17	32	**82.3**	32.0	76.7	3.0	1	15.0	**5.7**	39.7	**185.4**	**65.3**	369.8	**244.5**	38	21
2015	DIM	W	06OR_42	2.90	30	75.6	31.0	76.5	3.7	1	15.4	6.0	40.2	**176.5**	**70.4**	182.6	**274.3**	31	65
2015	DIM	W	06OR_43	3.72	29	63.5	39.0	74.3	3.1	1	16.9	**5.2**	32.1	**162.5**	**58.4**	434.3	**221.8**	30	72
2015	DIM	W	06OR_44	2.53	31	72.2	35.0	74.2	3.6	1	15.8	**5.4**	34.5	**183.6**	**65.0**	415.6	**228.9**	32	57
2015	DIM	W	06OR_45	3.26	29	68.5	33.0	76.1	3.5	1	14.2	**5.3**	38.4	**165.0**	**70.1**	293.4	**243.8**	30	72
2015	DIM	W	06OR_52	3.55	32	70.8	33.0	74.6	3.0	1	15.7	**5.5**	37.2	**186.3**	**64.0**	391.3	**245.1**	32	57
2015	DIM	W	06OR_59	3.52	34	**85.5**	34.0	75.1	3.2	1	16.0	**5.4**	35.5	**150.7**	**54.0**	346.3	**217.5**	38	21
2015	DIM	W	06OR_62	3.17	29	70.5	34.0	75.2	3.7	1	16.6	**5.7**	36.1	**221.5**	**74.3**	207.3	**254.8**	26	97
2015	DIM	W	06OR_75	3.26	33	**81.5**	29.0	75.6	2.6	1	14.0	**5.6**	41.4	**214.8**	**72.4**	448.5	**246.8**	38	21
2015	DIM	W	06OR_78	2.42	33	80.0	33.0	74.7	2.8	1	15.5	**5.6**	36.2	**192.0**	**66.1**	383.2	**244.9**	38	21
2015	DIM	W	06OR_91	5.65	31	76.2	31.0	75.4	2.6	1	14.9	**5.5**	39.0	**203.3**	**60.6**	451.9	**239.5**	35	41
2015	DIM	W	07OR_21	4.95	31	72.8	34.0	76.7	3.0	1	14.5	**5.4**	39.4	**177.6**	**65.7**	407.5	**254.2**	32	57
2015	DIM	W	07OR_3	7.40	30	**85.5**	20.0	76.1	3.2	1	13.4	**5.3**	40.9	**166.3**	**75.7**	260.8	**246.0**	47	10
2015	DIM	W	07OR_4	6.86	32	**86.2**	20.0	80.4	3.0	1	**12.3**	**5.4**	**44.9**	**159.7**	**96.0**	276.3	**258.7**	63	1
2015	DIM	W	07OR_59	6.43	31	79.6	30.0	78.7	3.1	1	**12.1**	4.5	38.6	133.2	**58.6**	272.4	**227.0**	42	12
2015	DIM	W	07OR_6	4.86	31	**85.7**	26.0	78.8	3.4	1	**12.7**	**5.5**	**45.9**	**173.6**	**98.0**	311.0	**323.2**	59	2
2015	DIM	W	07OR_63	5.67	32	**80.4**	40.0	76.7	3.6	1	13.9	4.8	36.2	147.1	**63.1**	289.5	**226.6**	36	34
2015	DIM	W	07OR_8	5.92	29	**81.9**	25.0	78.8	3.8	1	**12.3**	**5.2**	**44.3**	144.4	**86.1**	341.1	**304.7**	53	5
2015	DIM	W	08OR_30	4.07	31	79.7	27.0	75.1	3.4	1	**12.9**	4.6	36.6	123.1	**60.5**	485.1	**219.7**	35	41
2015	DIM	W	08OR_44	5.38	33	**82.7**	30.0	77.6	3.4	1	14.1	5.0	36.8	137.7	**59.9**	759.8	**241.7**	31	65
2015	DIM	W	08OR_48	5.85	30	68.9	30.0	75.1	3.8	2	15.7	5.0	33.5	**161.0**	**61.0**	405.3	**262.8**	27	90
2015	DIM	W	08OR_53	5.11	29	71.4	32.0	75.9	4.4	2	15.6	4.8	32.7	133.3	**51.9**	343.6	**262.6**	19	130
2015	DIM	W	08OR_73	5.75	29	73.7	30.0	76.9	4.1	1	13.4	**5.2**	39.2	146.7	**79.1**	379.3	**261.1**	39	20
2015	DIM	W	08OR_81	4.60	26	65.9	32.0	76.5	3.9	1	13.8	**5.4**	41.1	**156.0**	**70.1**	390.1	**325.7**	33	52
2015	DIM	W	F5105_1	5.40	31	**81.0**	37.0	76.3	3.1	1	13.5	4.5	35.2	123.4	**54.0**	379.8	188.9	27	90
2015	DIM	W	F5105_3	5.38	28	61.5	40.0	75.0	2.9	1	13.4	4.4	33.6	129.7	**54.6**	316.2	201.7	30	72
2015	DIM	W	F5106_1	6.51	34	**86.9**	33.0	76.4	3.0	1	13.1	4.3	34.3	121.9	48.1	549.6	206.5	35	41
2015	DIM	W	F5108_1	5.08	33	77.8	36.0	74.9	3.0	1	14.3	4.6	32.3	141.6	**52.0**	652.0	**223.1**	29	79
2015	DIM	W	F5109_1	5.67	33	**80.1**	38.0	77.4	2.8	2	**12.5**	4.1	33.2	120.2	**50.9**	613.9	202.8	37	31
2015	DIM	W	F5109_3	5.27	32	**81.4**	40.0	74.7	3.2	1	15.0	4.6	31.8	126.8	50.0	586.5	184.2	19	130
2015	DIM	W	F5112_1	4.06	31	77.4	40.0	74.0	3.4	1	15.7	5.1	33.9	**157.7**	**59.9**	630.5	**218.4**	31	65
2015	DIM	W	F5112_3	4.62	31	76.4	37.0	73.3	3.1	1	14.6	4.8	32.8	**157.2**	**56.7**	601.0	203.6	28	82
2015	DIM	W	F5113_2	5.84	31	77.5	42.0	77.3	2.8	1	13.4	4.9	37.4	**159.1**	**65.3**	207.0	**210.3**	41	16
2015	DIM	W	F5119_1	4.04	34	80.0	41.0	75.1	3.1	1	14.0	4.6	34.3	127.1	**52.1**	576.7	186.0	23	110
2015	DIM	W	F5120_3	6.46	33	**82.1**	37.0	74.9	3.1	1	14.8	4.4	31.9	128.6	47.5	666.6	179.9	20	123
2015	DIM	W	F5121_1	4.38	33	**81.9**	37.0	74.2	3.1	1	14.5	4.6	31.8	140.1	49.4	610.4	187.1	23	110
2015	DIM	W	F5121_2	5.06	32	**80.3**	35.0	74.7	2.7	1	14.7	4.2	29.0	142.5	48.6	678.8	163.8	23	110
2015	DIM	W	F5121_3	5.23	33	79.4	33.0	75.1	2.8	1	14.4	4.5	31.5	136.9	47.8	643.2	180.7	18	133
2015	DIM	W	F5124_1	5.25	33	**81.9**	36.0	74.9	3.3	1	13.8	4.7	34.7	132.6	48.1	518.8	187.4	25	104
2015	DIM	W	F5124_1	.	33	**84.6**	41.0	75.4	3.4	1	14.0	4.4	32.2	126.0	46.7	642.0	173.8	20	123
2015	DIM	W	F5126_1	4.44	31	75.8	35.0	75.3	3.2	1	14.7	4.9	34.6	**153.6**	**57.0**	590.9	202.4	28	82
2015	DIM	W	F5126_2	.	33	**83.5**	38.0	75.5	3.0	1	14.6	4.7	33.0	144.7	**57.5**	701.4	188.2	26	97
2015	DIM	W	F5129_1	4.40	29	79.5	33.0	75.2	2.8	1	15.0	6.1	41.4	**193.6**	**58.0**	608.1	189.5	21	120
2015	DIM	W	F5131_1	5.36	34	68.2	43.0	76.1	**2.3**	1	13.4	4.9	36.8	130.2	**55.2**	687.0	189.9	31	65
2015	DIM	W	F5134_3	5.70	32	75.0	35.0	73.6	2.6	1	16.4	**5.1**	32.6	143.3	**51.4**	748.1	181.5	26	97
2015	DIM	W	F5135_4	4.53	29	74.2	36.0	72.8	2.9	1	15.4	5.0	33.3	146.4	**54.6**	569.3	181.4	24	107
2015	DIM	W	F5136_1	5.36	34	74.0	24.0	74.2	2.9	2	14.9	**5.2**	37.1	**179.5**	**58.1**	584.0	172.4	30	72

2015	DIM	W	F522_3	6.45	31	**82.7**	33.0	76.6	**2.3**	1	13.4	4.9	38.3	135.6	**58.8**	714.4	187.3	35	41
2015	DIM	W	F523_1	4.90	31	**91.7**	31.0	77.2	3.0	1	13.9	**5.7**	**43.5**	**155.6**	**68.7**	402.7	196.7	41	16
2015	DIM	W	F527_1	8.01	31	73.1	32.0	75.7	**2.0**	1	13.7	4.5	34.5	**151.9**	49.8	1014.0	169.9	25	104
2015	DIM	W	F532_1	6.98	34	**88.4**	30.0	78.8	2.7	1	**11.8**	4.9	**42.4**	148.7	**72.0**	**97.0**	186.8	58	3
2015	DIM	W	F535_2	5.95	30	**86.7**	33.0	75.7	.	3	13.6	4.9	37.2	138.7	**53.1**	650.8	165.3	28	82
2015	DIM	W	F536_2	6.72	33	66.6	23.0	74.8	.	3	13.4	4.5	36.4	144.1	48.0	856.6	131.8	26	97
2015	DIM	W	F537_1	7.59	32	**86.3**	27.0	75.3	3.1	2	13.9	5.0	38.0	149.2	**57.4**	1010.2	142.1	33	52
2015	DIM	W	F537_3	5.69	29	75.0	32.0	73.8	2.9	2	14.4	4.7	34.8	**176.0**	**58.3**	674.4	161.7	20	123
2015	DIM	W	F54_2	5.83	32	71.8	35.0	76.4	2.9	1	14.5	**5.2**	36.8	**177.3**	**59.9**	433.8	**230.6**	32	57
2015	DIM	W	F547_1	4.24	30	**87.9**	35.0	75.3	3.0	1	14.0	4.9	35.0	**174.3**	**57.9**	559.3	167.2	33	52
2015	DIM	W	F547_3	4.31	31	**80.9**	32.0	74.8	3.0	1	13.6	4.8	36.2	**157.8**	**53.2**	636.9	161.9	30	72
2015	DIM	W	F548_1	6.20	32	61.0	31.0	75.4	2.6	1	14.0	4.7	33.6	138.5	**56.1**	829.2	200.4	23	110
2015	DIM	W	F55_1	6.18	32	**86.7**	30.0	75.9	**2.4**	1	13.8	4.5	34.6	145.6	**55.4**	520.9	179.4	31	65
2015	DIM	W	F550_1	6.16	32	**85.1**	32.0	76.4	**2.2**	1	14.0	4.4	32.6	140.0	46.2	651.4	174.1	27	90
2015	DIM	W	F552_2	7.31	31	**80.2**	33.0	76.5	2.6	1	13.8	4.6	33.8	145.7	**55.1**	550.0	203.1	35	41
2015	DIM	W	F555_1	7.88	32	**88.9**	20.0	75.7	3.6	2	**12.0**	4.0	36.5	**163.1**	**51.7**	1007.3	169.2	35	41
2015	DIM	W	F556_1	6.87	33	80.0	38.0	76.0	**2.5**	1	13.5	4.7	36.8	136.0	**58.3**	609.0	192.6	36	34
2015	DIM	W	F556_3	5.25	33	**81.6**	39.0	77.9	**2.1**	1	**12.6**	4.3	37.2	134.1	**56.4**	598.0	170.2	37	31
2015	DIM	W	F557_2	4.3	32	**80.5**	31.0	75.2	**2.2**	1	15.2	4.7	31.4	135.7	**58.8**	640.2	184.8	22	117
2015	DIM	W	F559_1	5.77	32	**81.5**	36.0	75.7	**2.3**	1	14.8	4.4	31.8	146.3	**53.4**	811.8	169.3	25	104
2015	DIM	W	F559_2	6.33	32	76.8	39.0	76.0	**2.2**	1	13.7	4.5	33.3	148.5	**53.4**	850.5	177.6	28	82
2015	DIM	W	F560_2	4.21	32	78.2	34.0	75.2	**2.4**	1	14.9	5.0	34.9	150.0	**63.5**	715.2	204.2	31	65
2015	DIM	W	F564_1	5.18	33	74.8	40.0	74.9	**2.2**	1	14.7	4.6	31.5	**184.3**	**59.0**	608.9	188.8	24	107
2015	DIM	W	F566_3	5.53	34	**81.5**	31.0	76.3	**2.3**	1	14.9	**5.3**	36.1	**170.1**	**63.2**	676.3	**226.6**	38	21
2015	DIM	W	F572_3	5.77	33	**91.2**	20.0	75.0	3.5	2	14.3	4.2	31.2	140.1	45.4	1040.8	153.2	22	117
2015	DIM	W	F576_1	5.58	31	74.1	32.0	73.3	**2.2**	1	15.2	4.6	30.1	153.3	**55.0**	838.8	171.1	23	110
2015	DIM	W	F576_4	5.89	32	**80.5**	28.0	75.9	**2.1**	1	14.5	4.4	31.2	128.5	**50.4**	926.2	168.5	23	110
2015	DIM	W	F583_1	5.55	32	**84.4**	26.0	75.7	**2.3**	1	14.1	4.5	32.8	127.3	**52.5**	920.1	173.9	23	110
2015	DIM	W	F588_3	4.41	33	74.4	38.0	76.0	**2.5**	1	15.1	5.1	35.6	151.5	**60.8**	634.6	197.5	30	72
2015	DIM	W	F59_2	4.86	31	**85.7**	26.0	78.3	**2.3**	1	**13.0**	4.8	37.9	111.7	**58.4**	476.4	197.2	38	21
2015	DIM	W	F590_5	5.01	29	73.6	31.0	76.5	**2.4**	1	14.1	**5.4**	39.9	141.6	**65.0**	625.5	**224.2**	33	52
2015	DIM	W	F591_1	4.29	28	55.5	34.0	77.8	3.4	2	14.2	**5.2**	37.8	171.5	**52.4**	658.5	191.7	31	65
2015	DIM	W	F591_2	2.33	27	53.4	37.0	74.9	**2.4**	1	16.7	**5.6**	34.6	**203.7**	**57.9**	678.5	206.9	28	82
2015	DIM	W	F595_1	5.20	25	31.5	32.0	73.9	**2.5**	1	15.2	**5.2**	35.0	144.5	**64.7**	599.6	**210.4**	28	82
2015	DIM	W	F596_2	4.3	31	68.4	30.0	74.7	**2.2**	1	15.9	4.5	30.3	149.7	50.0	800.3	177.2	17	134
2015	DIM	W	F596_4	5.44	32	77.5	37.0	74.0	**2.2**	1	15.6	4.5	29.2	**163.8**	48.0	867.6	169.5	20	123
2015	DIM	W	MAJA	4.78	28	66.8	32.0	76.9	3.2	1	14.1	5.0	37.3	**221.2**	**69.8**	157.0	**244.7**	27	90
2015	DIM	W	MAJA	6.74	31	**87.2**	35.0	79.5	3.5	2	**10.9**	4.2	40.8	145.7	**63.0**	**118.3**	196.4	49	9
2015	DIM	W	MAJA	4.91	29	70.7	31.0	77.3	3.4	1	15.0	**5.5**	38.9	**216.6**	**73.5**	181.0	**285.5**	30	72
2015	DIM	W	MAJA	6.79	27	77.7	34.0	77.6	2.7	1	13.2	**5.1**	41.6	190.5	**67.2**	150.3	**233.0**	40	19
2015	DIM	W	MAJA	5.30	28	79.3	24.0	77.0	2.9	1	14.7	5.1	37.0	**197.4**	**64.8**	172.0	**218.0**	29	79
2015	DIM	W	MAJA	5.45	30	**80.6**	37.0	78.7	**2.3**	1	**12.8**	5.0	39.9	179.2	**66.0**	289.2	**239.3**	50	8
2015	DIM	W	MAJA	4.63	29	77.7	32.0	78.0	2.6	1	14.2	**5.4**	38.9	**192.9**	**69.7**	312.8	**247.8**	37	31
2015	DIM	W	MAJA	5.34	29	75.6	39.0	77.6	2.7	1	13.8	5.1	39.3	**195.0**	**64.9**	263.0	**238.8**	34	49
2015	DIM	W	MW116_3	3.70	34	**85.0**	34.0	77.6	3.0	1	14.9	**5.3**	36.0	**186.0**	**66.7**	565.0	192.1	36	34
2015	DIM	W	MW116_4	5.34	34	77.8	32.0	76.6	2.6	1	14.9	**5.5**	37.4	142.0	**75.8**	479.8	**221.5**	36	34
2015	DIM	W	MW118_1	5.63	**37**	**90.4**	33.0	77.1	**2.2**	1	14.4	4.9	35.0	**193.4**	**59.2**	704.2	198.1	32	57
2015	DIM	W	MW118_3	6.62	35	**84.3**	30.0	77.1	**2.4**	1	14.2	**5.4**	39.5	**198.0**	**64.6**	532.7	**228.3**	38	21
2015	DIM	W	MW118_4	4.69	33	78.0	32.0	76.5	**2.4**	1	15.2	**5.3**	36.7	**194.3**	**63.9**	707.5	**228.1**	36	34
2015	DIM	W	MW120_8	4.83	33	**85.7**	30.0	76.1	2.7	1	15.1	6.2	**44.3**	**233.1**	**77.1**	503.1	**288.5**	36	34
2015	DIM	W	MW122_1	3.75	34	**80.4**	35.0	77.1	2.9	1	15.6	6.7	**44.4**	**214.5**	**81.8**	382.1	**314.5**	36	34
2015	DIM	W	MW122_5	5.50	33	**86.7**	32.0	76.9	**2.4**	1	15.4	5.8	39.9	**226.2**	**65.7**	463.7	**234.7**	34	49
2015	DIM	W	MW76_1	4.13	32	**88.4**	21.0	74.9	**2.3**	1	14.7	**5.5**	40.0	**197.4**	**70.6**	867.9	**241.5**	38	21
2015	DIM	W	MW76_2	3.76	32	**85.2**	10.0	75.2	2.9	1	14.7	**5.6**	40.7	**182.1**	**64.0**	600.8	**244.6**	38	21

2015	DIM	W	MW80_1	4.72	33	**83.6**	23.0	77.5	**2.1**	1	14.9	**5.6**	39.0	**237.3**	**73.4**	352.0	**252.0**	38	21
2015	DIM	W	OBA11_13	5.31	32	73.0	33.0	74.6	2.8	1	16.3	**5.2**	33.6	**162.4**	44.8	646.8	205.3	32	57
2015	DIM	W	OBA11_29	4.38	29	68.1	32.0	74.2	3.1	1	15.0	4.8	32.4	**154.1**	43.1	781.0	178.4	15	137
2015	DIM	W	OBA11_31	5.33	28	78.0	24.0	74.8	4.2	2	14.6	4.9	33.5	111.4	39.0	509.4	182.8	7	147
2015	DIM	W	OK216	5.02	27	78.8	15.0	69.8	.	3	14.1	4.1	29.9	132.2	44.4	1147.5	154.0	11	141
2015	DIM	W	OK242	4.88	27	77.3	11.0	70.9	.	3	15.6	4.6	31.2	**238.0**	41.4	826.3	173.7	14	138
2015	DIM	W	OK246	.	23	56.8	16.0	71.1	.	3	16.4	4.5	28.7	**203.5**	48.9	935.4	154.2	11	141
2015	DIM	W	OK248	6.30	26	**81.4**	12.0	71.0	.	3	14.0	3.7	27.6	120.9	35.0	1475.0	119.5	9	146
2015	DIM	W	OK452	4.50	29	78.4	14.0	68.9	.	3	14.6	3.9	28.1	**184.8**	41.0	1092.5	112.8	16	136
2015	DIM	W	OK474	6.00	25	62.0	16.0	76.5	.	3	16.3	4.4	28.5	**161.1**	36.7	1103.6	140.9	7	147
2015	DIM	W	OR101	3.98	29	65.7	33.0	77.0	3.4	1	15.8	6.0	38.1	**220.8**	**65.5**	336.8	**251.1**	26	97
2015	DIM	W	OR103	4.70	32	76.4	36.0	76.6	2.8	1	15.6	**5.2**	35.6	**165.4**	**61.3**	745.8	174.2	27	90
2015	DIM	W	OR104	4.65	30	**81.7**	26.0	77.9	3.0	1	14.2	5.1	36.2	**164.6**	**64.6**	480.4	181.7	32	57
2015	DIM	W	OR106	5.78	32	**81.0**	36.0	77.2	3.0	2	13.1	4.6	35.5	**158.8**	**56.8**	672.5	163.7	35	41
2015	DIM	W	OR108	5.54	33	77.4	39.0	76.1	**2.5**	1	14.1	4.5	33.0	140.5	**54.2**	799.7	159.2	24	107
2015	DIM	W	OR76	4.71	34	**85.5**	38.0	78.1	2.7	1	14.3	**5.3**	38.6	142.7	**67.4**	408.7	**227.9**	42	12
2015	DIM	W	OR813	5.06	35	**88.4**	42.0	78.1	2.7	1	14.4	**5.5**	41.0	145.8	**77.5**	342.8	**216.7**	42	12
2015	DIM	W	OR815	4.30	32	74.0	41.0	76.2	2.6	1	15.5	**5.4**	37.5	**164.8**	**67.0**	492.8	**218.0**	35	41
2015	DIM	W	OR818	4.97	30	**85.9**	24.0	79.1	3.0	1	13.3	5.9	**45.7**	**166.6**	**93.3**	459.5	**264.4**	56	4
2015	DIM	W	OR91	5.68	28	73.9	22.0	79.1	3.6	1	13.9	6.4	49.5	**172.5**	**96.9**	402.4	**309.1**	41	16
2015	DIM	W	P919	4.79	28	42.4	10.0	73.8	3.4	1	15.0	5.3	36.0	138.2	**61.4**	329.6	**229.8**	27	90
2015	DIM	W	P919	3.34	30	63.7	14.0	75.8	4.2	2	**12.7**	4.7	37.2	99.1	**57.5**	364.6	200.2	27	90
2015	DIM	W	P919	4.69	31	63.7	14.0	75.2	3.8	1	14.1	5.0	36.5	102.6	**52.6**	339.2	**230.4**	21	120
2015	DIM	W	P919	4.59	30	**93.0**	13.0	76.2	3.8	2	13.1	**5.3**	41.2	105.3	**54.7**	394.4	169.9	34	49
2015	DIM	W	P919	4.05	29	**84.9**	6.0	74.5	3.2	1	15.3	5.9	40.3	123.0	**54.9**	324.1	**214.5**	28	82
2015	DIM	W	P919	4.54	29	55.4	8.0	74.8	3.0	1	14.4	5.0	36.2	99.3	**50.9**	426.2	206.8	19	130
2015	DIM	W	P919	4.73	29	60.6	15.0	75.4	.	3	14.5	5.1	37.6	109.9	**52.8**	546.2	**214.4**	17	134
2015	DIM	W	P919	4.62	30	62.5	15.0	75.9	3.0	1	14.4	**5.5**	38.6	123.4	**59.9**	443.4	**245.7**	29	79
2015	DIM	W	PO71_104	4.16	29	80.0	27.0	75.6	3.5	2	14.9	5.0	36.3	139.9	**60.1**	429.1	169.2	22	117
2015	DIM	W	PO71_87	4.08	34	**87.4**	21.0	77.1	.	3	14.4	4.5	32.5	128.3	**59.0**	563.0	169.7	21	120
2015	DIM	W	PY211_6	5.54	29	76.3	28.0	76.0	2.9	1	14.3	**5.4**	39.2	**160.0**	**77.0**	290.9	**239.3**	33	52
2015	DIM	W	Short_11	4.11	31	**81.3**	30.0	77.7	2.7	1	13.9	**5.2**	38.6	**184.3**	**77.4**	250.0	**220.2**	42	12
2015	DIM	W	Short_12	6.64	34	**86.2**	30.0	78.3	3.0	1	14.1	5.8	**42.7**	**194.8**	**85.4**	271.3	**268.7**	46	11
2015	DIM	W	Short_13	6.49	34	**82.2**	34.0	71.5	3.1	1	**13.0**	**5.5**	**45.6**	**197.9**	**84.7**	226.3	**243.6**	53	5
2015	DIM	W	Short_16	6.83	33	**85.7**	33.0	74.1	2.8	1	**13.0**	**5.3**	**43.0**	**188.2**	**76.2**	403.0	**239.6**	53	5
2015	DIM	W	Short_8	5.99	31	72.7	35.0	70.9	**2.5**	1	15.0	4.7	32.1	**159.3**	**56.3**	926.4	163.1	20	123
2015	DIM	W	TBAR501	5.11	34	**82.2**	6.0	70.7	.	3	15.2	4.0	28.2	80.4	38.3	941.0	138.8	10	143
2015	DIM	W	TBAR501	3.21	**36**	**92.3**	14.0	73.3	.	3	**12.4**	3.6	29.6	60.7	36.8	1260.3	124.8	20	123
2015	DIM	W	TBAR501	4.58	35	**85.4**	14.0	72.3	.	3	14.0	4.0	29.2	78.0	42.4	1197.0	150.7	14	138
2015	DIM	W	TBAR501	5.25	**36**	64.6	10.0	72.6	.	3	13.8	3.9	29.8	72.8	38.8	1240.0	128.2	10	143
2015	DIM	W	TBAR501	5.59	34	**84.5**	4.0	71.9	.	3	14.4	3.8	28.2	76.2	39.8	1139.4	137.0	10	143
2015	DIM	W	TBAR501	5.15	35	**88.1**	5.0	73.0	4.3	2	13.9	4.1	31.3	75.7	40.5	1225.3	148.0	20	123
2015	DIM	W	TBAR501	6.02	33	74.1	15.0	71.1	.	3	14.6	4.4	30.6	107.4	49.8	985.8	158.3	12	140
2015	MCG	W	06OR_41	1.8	29	57.9	32.0	73.3	2.8	1	17.6	6.5	38.0	**197.4**	**65.9**	1004.9	**257.1**	23	63
2015	MCG	W	06OR_43	2	27	50.2	30.0	72.0	2.9	1	16.9	6.4	39.9	**176.7**	**86.1**	574.2	**267.0**	21	74
2015	MCG	W	07OR_59	1.1	33	**88.8**	20.0	71.5	.	3	14.1	3.9	28.7	64.4	33.9	1631.0	140.0	10	104
2015	MCG	W	07OR_6	1.7	26	72.1	23.0	75.8	5.2	1	15.1	8.1	54.6	**174.0**	**70.9**	424.4	**323.3**	21	74
2015	MCG	W	08OR_30	2.9	26	71.1	29.0	75.5	2.6	1	14.0	4.8	35.2	135.4	**72.8**	676.3	164.6	18	100
2015	MCG	W	Alba	.	27	58.7	29.4	73.1	4.1	1	15.5	**5.7**	38.3	**161.3**	**80.9**	753.9	**238.3**	25	47
2015	MCG	W	F_Pint	.	29	65.0	23.0	73.7	3.4	1	15.8	5.8	38.0	**164.3**	**62.3**	821.3	**233.5**	24	53
2015	MCG	W	F5105_1	2.1	25	56.3	18.0	70.7	4.2	1	17.2	6.6	39.1	**197.6**	**88.0**	643.9	**268.7**	21	74
2015	MCG	W	F5112_1	2.5	27	63.7	35.0	73.4	3.5	1	14.4	5.8	41.9	**153.2**	**87.7**	693.9	**236.9**	24	49
2015	MCG	W	F5121_1	2.5	27	65.9	40.0	73.9	3.4	1	14.3	**5.3**	37.9	144.3	**85.1**	596.8	**215.6**	28	21
2015	MCG	W	F5121_5	1.6	27	65.2	38.0	73.2	3.2	1	14.4	**5.4**	39.6	142.9	**82.0**	623.5	**213.3**	28	21

2015	MCG	W	F5132_1	2	25	48.5	36.0	71.2	4.6	1	16.1	7.1	**44.0**	**186.1**	**95.1**	649.8	**279.7**	26	33
2015	MCG	W	F523_1	3.7	29	77.0	35.0	77.1	3.4	1	14.6	5.0	35.3	**168.0**	**78.2**	466.6	**267.4**	29	14
2015	MCG	W	F527_1	1.6	28	**82.9**	34.0	75.0	3.4	2	16.8	5.8	34.4	**204.2**	**61.0**	828.8	**349.4**	30	9
2015	MCG	W	F537_1	2.3	27	61.8	20.0	72.3	.	3	18.0	**5.5**	30.8	**198.8**	**54.4**	1154.9	158.9	21	74
2015	MCG	W	F537_3	2.4	27	46.7	7.0	75.0	3.3	1	13.9	4.9	36.8	123.6	**65.3**	487.8	175.0	21	74
2015	MCG	W	F548_1	2.1	29	75.2	32.0	74.7	3.5	1	15.4	5.1	34.4	**153.1**	**72.5**	757.0	158.8	24	49
2015	MCG	W	F552_2	1.8	29	**84.5**	27.0	75.2	6.9	2	16.5	6.7	41.3	**176.3**	49.1	394.8	**305.8**	24	49
2015	MCG	W	F555_1	1.4	29	65.9	18.0	74.0	.	3	15.5	**5.6**	38.1	**210.7**	**67.8**	770.8	**242.5**	28	21
2015	MCG	W	F556_1	1.3	26	63.5	31.0	73.1	4.1	1	14.6	**5.3**	36.6	**159.9**	**86.6**	495.0	**220.0**	28	21
2015	MCG	W	F559_1	2.4	24	39.4	26.0	68.5	4.9	2	17.2	**5.5**	32.0	**165.2**	**76.4**	835.2	174.6	22	70
2015	MCG	W	F588_3	2.8	26	53.0	31.0	73.7	3.9	1	14.8	6.4	**45.8**	**211.7**	**97.1**	371.5	**268.4**	26	33
2015	MCG	W	F59_2	2.5	26	68.6	32.0	75.9	2.8	1	14.8	**5.2**	35.6	146.3	**68.3**	541.6	191.8	22	70
2015	MCG	W	F590_5	2.6	25	54.6	27.0	73.0	4.0	1	16.6	7.0	**43.1**	**219.8**	**96.8**	626.2	**312.2**	26	33
2015	MCG	W	F595_1	2.9	25	46.6	25.0	72.3	3.4	1	16.4	6.0	36.9	**185.3**	**82.7**	756.5	**240.4**	21	74
2015	MCG	W	Maja	.	27	64.1	28.4	74.4	3.3	1	16.1	6.0	38.4	**250.6**	**80.5**	472.5	**267.9**	23	56
2015	MCG	W	MW118_4	3.7	33	**80.5**	20.0	75.0	4.7	2	18.3	7.2	40.8	**320.4**	**62.8**	391.0	**306.3**	30	9
2015	MCG	W	MW76_2	3.5	30	77.2	28.0	73.4	2.9	1	14.2	**5.2**	37.6	**237.2**	**65.6**	1016.7	**216.2**	31	5
2015	MCG	W	OBA11_13	2.8	31	72.3	34.0	75.3	2.9	1	14.9	4.6	32.1	**166.8**	**58.3**	689.8	201.1	25	46
2015	MCG	W	OBA11_2	2.3	26	71.9	31.0	74.8	3.3	1	13.5	4.6	34.1	126.0	**72.0**	530.4	204.3	23	63
2015	MCG	W	OBA11_31	2.8	23	64.9	27.0	73.4	3.9	2	14.0	4.4	32.8	111.6	45.7	480.6	196.7	8	108
2015	MCG	W	OK242	1.6	27	62.8	19.0	73.0	4.0	1	18.1	6.0	34.3	**276.1**	**55.3**	966.6	**210.2**	21	74
2015	MCG	W	OK248	1.9	23	60.7	13.0	70.4	5.1	1	15.4	4.9	32.4	**197.3**	**55.1**	1242.6	208.8	24	49
2015	MCG	W	OK249	1.5	23	56.7	19.0	69.7	4.9	1	15.8	**5.5**	35.3	**212.8**	**60.3**	1106.0	173.5	23	63
2015	MCG	W	OK452	1.3	27	66.8	24.0	71.7	.	3	18.2	6.8	37.8	**295.8**	**61.0**	826.5	**292.6**	19	93
2015	MCG	W	OK474	2	25	70.9	15.0	70.9	4.1	1	15.2	**5.2**	34.7	**190.4**	**50.9**	982.0	181.1	23	63
2015	MCG	W	OR104	1.4	26	62.7	26.0	74.2	3.8	1	16.0	4.9	32.2	**216.7**	**71.9**	536.9	193.8	22	70
2015	MCG	W	OR108	2.7	30	64.0	37.0	75.4	3.1	1	13.9	4.6	35.2	**168.8**	**74.8**	609.6	182.4	23	63
2015	MCG	W	PO71_87	2.4	28	75.7	26.0	76.5	4.4	2	14.2	4.8	35.5	127.0	**64.9**	521.4	173.3	17	101
2015	MCG	W	Short_11	.	33	**87.0**	20.0	70.6	.	3	14.2	3.9	29.0	74.5	39.5	1614.3	132.6	10	104
2016	DIM	W	06OR_10	3.3	34	78.5	60.0	79.0	**2.5**	2	13.5	4.1	32	127	**61**	409.4	188.8	32	56
2016	DIM	W	06OR_37	3.2	35	**82.6**	53.0	77.6	**2.1**	1	14.6	4.2	28	**176**	**57**	596.8	166.1	26	88
2016	DIM	W	06OR_41	2.6	33	67.0	67.0	78.2	**2.3**	2	14.0	4.6	34	**172**	**68**	398.4	**220.4**	29	67
2016	DIM	W	06OR_42	2.7	34	79.8	60.0	78.6	2.8	2	13.6	4.5	34	136	**68**	334.3	**211.4**	37	38
2016	DIM	W	06OR_43	3.8	33	**80.1**	62.0	78.1	**1.9**	1	**13.0**	4.2	33	104	**58**	452.1	181.1	33	50
2016	DIM	W	06OR_44	3.7	33	72.5	50.0	77.7	**2.1**	1	14.8	4.3	30	139	**61**	348.7	200.9	27	83
2016	DIM	W	06OR_45	2.6	32	71.0	62.0	78.1	.	3	**13.0**	4.7	37	137	**67**	402.6	**252.3**	35	40
2016	DIM	W	06OR_52	3.3	32	64.4	66.0	76.7	**2.0**	1	14.3	4.7	33	**160**	**66**	402.6	**233.0**	26	88
2016	DIM	W	06OR_59	3.3	34	**88.1**	45.5	77.3	**2.2**	2	15.6	4.7	31	140	**60**	337.3	**222.6**	29	71
2016	DIM	W	06OR_62	3.2	32	**80.3**	60.0	77.9	.	3	13.8	4.7	35	**170**	**68**	307.2	**223.9**	38	32
2016	DIM	W	06OR_75	3.3	31	63.7	67.0	77.2	**2.2**	1	13.7	5.1	38	**181**	**75**	372.8	**290.8**	33	50
2016	DIM	W	06OR_78	2.8	33	64.5	63.0	76.6	**2.1**	1	14.9	**5.2**	36	**193**	**75**	250.0	**263.4**	29	67
2016	DIM	W	06OR_91	3.4	29	40.5	52.0	75.7	**2.2**	1	14.4	4.5	33	**219**	**69**	213.4	**220.4**	23	102
2016	DIM	W	07OR_21	3.6	34	62.5	58.0	78.1	**2.4**	2	13.7	4.6	34	**164**	**64**	405.1	**221.6**	34	44
2016	DIM	W	07OR_3	4.4	32	**83.2**	52.0	77.6	3.0	1	13.9	5.0	36	148	**90**	190.1	**265.9**	38	32
2016	DIM	W	07OR_4	3.4	34	**89.8**	42.0	80.7	3.1	1	14.1	**5.4**	41	**179**	**98**	269.8	**303.4**	48	10
2016	DIM	W	07OR_59	3.5	33	**80.3**	52.0	80.8	**2.1**	1	13.7	4.3	33	117	**65**	331.2	188.9	34	44
2016	DIM	W	07OR_6	3.7	32	**80.2**	51.0	79.4	2.9	1	**13.4**	5.1	40	**160**	**99**	259.8	**294.7**	54	2
2016	DIM	W	07OR_63	2.9	**36**	**84.8**	52.0	80.2	**2.3**	1	14.6	4.6	33	126	**66**	235.7	**230.2**	38	32
2016	DIM	W	07OR_8	3.0	34	**89.4**	51.0	79.8	**2.5**	1	**12.9**	**5.4**	**45**	**154**	**89**	238.2	**258.1**	63	1
2016	DIM	W	08OR_30	2.9	33	78.6	59.0	77.4	**2.2**	1	**12.9**	4.0	32	145	**62**	329.3	151.3	34	44
2016	DIM	W	08OR_44	2.9	**37**	**87.7**	53.0	79.8	.	3	14.1	4.2	31	110	**59**	596.4	196.3	30	62
2016	DIM	W	08OR_48	4.0	35	**86.4**	52.0	78.0	2.6	2	13.6	4.4	33	136	**59**	421.0	186.9	35	49
2016	DIM	W	08OR_53	4.2	34	**85.0**	43.0	78.4	2.9	2	14.8	4.3	30	136	**57**	332.3	187.1	29	67
2016	DIM	W	08OR_73	3.9	35	**89.0**	52.0	79.7	**2.1**	1	14.4	4.9	35	**182**	**82**	404.7	**272.2**	44	16

2016	DIM	W	08OR_81	3.1	30	49.0	74.0	77.4	**2.2**	1	14.7	4.4	32	**178**	**62**	453.3	207.6	23	102
2016	DIM	W	08OR_9	.	32	**82.5**	38.0	74.8	.	3	13.7	4.1	31	**215**	44	485.6	126.0	25	97
2016	DIM	W	ALBA	3.5	**37**	**85.6**	58.0	78.5	**1.9**	1	14.7	4.0	28	121	**51**	626.6	161.8	25	92.5
2016	DIM	W	F_Pint	3.7	33	78.6	49.0	75.9	**2.3**	1	14.3	4.3	31	140	**56**	507.3	179.8	25	91
2016	DIM	W	F106_1	3.6	35	**85.4**	55.0	78.6	**2.1**	1	13.6	3.9	29	132	49	627.5	176.3	32	56
2016	DIM	W	F5105_1	3.6	32	77.2	62.0	76.1	**1.8**	1	14.2	4.4	31	134	**61**	286.7	150.5	21	115
2016	DIM	W	F5105_3	3.8	35	80.0	61.0	78.6	**1.9**	1	14.5	4.0	29	119	**52**	346.7	175.7	26	88
2016	DIM	W	F5108_1	3.0	**36**	77.6	55.0	75.4	2.6	1	14.8	4.0	26	128	47	613.7	153.8	18	135
2016	DIM	W	F5109_1	3.4	**36**	**83.9**	53.0	77.6	**2.0**	1	14.8	3.7	27	110	49	532.5	153.0	16	143
2016	DIM	W	F5109_3	3.9	**36**	**80.8**	62.0	77.0	**2.1**	1	14.7	4.1	28	124	49	556.9	165.6	19	126.5
2016	DIM	W	F5112_1	3.7	34	79.3	65.0	75.3	**1.7**	1	14.9	4.4	30	121	50	575.8	175.4	21	115
2016	DIM	W	F5112_3	4.4	35	**82.1**	51.0	77.1	**2.2**	1	15.5	4.2	28	129	48	584.4	166.8	20	125
2016	DIM	W	F5113_2	3.9	34	75.6	56.0	76.6	**2.2**	1	15.1	4.4	29	132	**63**	275.2	180.8	21	115
2016	DIM	W	F5119_1	3.1	35	**80.1**	59.0	76.2	**2.0**	1	14.4	4.0	28	120	47	492.5	167.8	20	125
2016	DIM	W	F5120_3	4.1	35	76.9	41.0	76.1	**2.1**	1	16.0	3.9	26	130	46	542.6	152.9	18	135
2016	DIM	W	F5121_1	3.3	34	69.6	65.0	75.8	**1.7**	1	14.7	4.3	30	117	**53**	527.0	136.3	14	146
2016	DIM	W	F5121_2	2.8	34	**82.3**	57.0	76.1	**2.3**	1	16.3	4.2	28	145	**52**	558.1	167.8	26	88
2016	DIM	W	F5121_3	3.8	33	76.3	57.0	76.3	**2.1**	1	14.8	3.9	27	126	48	553.9	144.5	18	135
2016	DIM	W	F5121_4	4.1	34	**81.8**	57.0	76.1	**1.9**	1	15.2	4.0	27	125	47	558.6	140.7	20	125
2016	DIM	W	F5121_5	4.0	34	76.4	70.0	77.0	**2.2**	2	**13.2**	3.8	29	114	49	463.0	169.5	23	102
2016	DIM	W	F5124_1	3.2	35	**80.9**	61.0	77.0	**2.1**	2	14.8	4.0	28	129	47	518.2	145.5	22	108.5
2016	DIM	W	F5126_1	3.4	35	**85.0**	54.0	77.7	**2.0**	1	14.6	4.2	29	118	**54**	587.4	156.5	19	131
2016	DIM	W	F5126_2	4.5	33	**85.8**	53.0	77.6	**1.9**	1	14.8	4.1	29	115	**55**	456.1	184.0	19	131
2016	DIM	W	F5129_1	4.2	34	71.4	62.0	79.3	**2.5**	2	**13.2**	4.3	34	145	**51**	527.8	156.7	40	26
2016	DIM	W	F5131_1	4.3	35	76.8	73.0	78.1	**1.7**	1	14.1	4.2	31	123	**56**	478.9	191.2	28	78
2016	DIM	W	F5132_1	3.2	35	**84.2**	69.0	77.4	**1.7**	1	**13.4**	4.2	32	127	**57**	547.4	168.5	34.5	46.5
2016	DIM	W	F5134_3	1.8	**36**	**83.9**	55.0	76.9	**2.0**	1	14.3	4.4	32	116	49	553.2	168.2	18	134
2016	DIM	W	F5135_4	4.4	35	**81.7**	66.0	76.3	**1.9**	1	14.0	4.2	31	134	**54**	516.8	181.7	25	93
2016	DIM	W	F5136_1	3.8	35	65.0	63.0	75.9	**2.5**	2	13.9	4.5	33	132	**59**	478.4	163.2	22	110
2016	DIM	W	F522_3	3.9	34	78.7	54.0	77.0	**2.2**	1	15.2	4.3	30	133	**58**	578.7	181.9	21	115
2016	DIM	W	F523_1	4.1	35	78.8	55.0	77.6	**2.2**	1	15.6	4.4	30	**173**	**64**	504.6	186.8	24	98
2016	DIM	W	F527_1	3.4	34	**85.2**	60.0	78.6	**1.8**	1	14.0	4.0	30	135	48	625.3	167.2	27	83
2016	DIM	W	F532_1	3.6	34	**82.7**	62.0	76.8	**1.9**	1	**12.9**	4.2	33	150	**67**	**119.0**	167.7	43	19
2016	DIM	W	F535_2	4.7	33	77.0	60.5	76.9	**2.4**	3	**13.2**	4.0	31	115	48	643.6	137.5	24	99
2016	DIM	W	F536_2	4.2	33	77.0	56.0	75.8	.	3	**12.7**	4.4	36	138	**53**	526.2	152.0	29	67
2016	DIM	W	F537_1	3.6	32	79.6	64.0	76.9	.	3	**12.4**	4.3	35	132	**56**	553.0	190.9	32	56
2016	DIM	W	F537_3	3.3	34	78.8	61.0	76.8	.	3	**12.2**	4.3	36	131	**55**	566.2	171.9	29	67
2016	DIM	W	F54_2	3.7	34	**86.7**	63.0	77.2	**1.9**	1	14.9	4.6	32	**151**	**60**	435.5	188.3	27.5	77.5
2016	DIM	W	F547_1	3.1	34	79.0	55.0	79.0	**2.5**	2	14.1	4.4	33	150	**59**	606.0	188.7	33	50
2016	DIM	W	F547_3	3.4	35	**82.6**	42.0	78.7	**2.5**	1	14.6	4.3	30	**151**	**54**	641.4	168.5	33	50
2016	DIM	W	F548_1	4.2	35	79.3	50.0	75.6	**2.0**	1	15.9	4.4	29	147	**58**	576.0	174.3	24	98
2016	DIM	W	F55_1	3.6	34	**82.6**	65.0	78.4	**1.8**	1	13.8	3.9	30	**151**	**55**	448.5	163.5	38	32
2016	DIM	W	F550_1	3.8	35	**88.4**	53.0	77.7	**2.5**	2	14.2	4.1	31	126	45	649.7	160.8	19	131
2016	DIM	W	F550_2	.	35	**89.9**	51.0	78.2	**1.9**	1	14.4	4.2	30	143	**57**	543.9	208.9	35	40
2016	DIM	W	F555_1	4.1	33	66.2	46.0	75.4	2.8	2	14.9	4.4	30	**163**	**56**	536.2	173.6	20	125
2016	DIM	W	F556_1	4.0	35	**82.8**	53.0	76.8	**2.0**	1	15.8	4.4	29	128	**52**	431.8	161.2	23	102
2016	DIM	W	F556_3	3.4	35	**85.7**	62.0	78.2	**2.1**	2	**13.0**	4.0	31	119	**58**	419.0	172.0	35	40
2016	DIM	W	F557_2	3.9	35	**83.1**	59.0	78.7	**1.8**	1	14.7	4.0	28	128	**57**	460.7	165.1	30	62
2016	DIM	W	F559_1	3.7	34	79.0	61.0	77.3	**2.2**	2	14.2	4.0	29	123	48	601.6	159.8	17	141
2016	DIM	W	F559_2	3.8	35	75.0	59.0	76.6	**2.4**	1	15.4	4.0	27	138	47	633.9	162.2	18	135
2016	DIM	W	F560_2	3.6	35	**85.7**	67.0	77.3	**1.6**	1	14.3	4.3	31	122	**57**	519.2	137.2	23	102
2016	DIM	W	F564_1	3.8	**37**	**80.6**	55.0	76.3	**2.0**	1	14.1	4.3	31	**151**	**60**	373.4	205.7	31	59
2016	DIM	W	F566_3	3.8	34	67.0	54.0	77.5	**1.8**	1	13.5	4.8	37	**153**	**64**	396.9	188.2	29	76.5
2016	DIM	W	F572_3	3.8	34	**80.1**	50.0	76.3	**2.5**	2	14.1	4.0	30	126	48	549.7	139.3	19	131

2016	DIM	W	F576_1	3.5	**36**	**84.0**	56.0	76.7	**2.1**	1	**13.2**	4.1	31	114	**52**	566.3	176.9	29	67
2016	DIM	W	F576_4	3.3	35	**82.3**	65.0	77.8	**2.1**	1	14.0	3.9	29	115	**54**	516.8	174.0	23	102
2016	DIM	W	F583_1	3.7	35	**83.8**	61.0	78.4	**1.9**	2	13.5	4.2	33	115	**55**	538.7	137.6	30	62
2016	DIM	W	F588_3	3.7	35	78.3	70.0	80.2	**1.9**	1	**12.9**	3.8	31	129	**59**	364.3	176.6	41	24
2016	DIM	W	F59_2	3.4	31	**80.5**	52.0	78.5	**2.0**	1	**12.5**	4.0	33	115	**59**	377.3	175.3	35	40
2016	DIM	W	F590_5	3.8	34	**81.2**	58.0	77.4	**2.2**	1	15.2	4.3	30	**156**	**62**	503.3	192.6	29	67
2016	DIM	W	F591_1	3.8	33	68.7	50.0	78.8	.	3	**13.4**	4.5	35	**165**	50	500.3	170.7	33	50
2016	DIM	W	F591_2	4.3	34	74.6	59.0	78.0	**2.1**	1	14.6	4.3	31	**159**	**52**	591.5	177.2	28	78
2016	DIM	W	F595_1	4.1	34	74.5	54.0	78.4	**2.3**	1	14.0	4.1	31	116	49	524.6	166.6	26	88
2016	DIM	W	F596_2	3.5	33	68.6	56.0	77.6	**2.0**	1	14.6	3.8	27	129	50	529.6	154.9	18	135
2016	DIM	W	F596_4	3.5	35	73.8	62.0	77.6	**1.9**	1	13.8	4.4	33	120	**51**	567.3	145.7	26	88
2016	DIM	W	MAJA	3.5	33	**83.5**	50.0	79.2	**2.4**	2	**13.1**	4.7	37	**178**	**69**	243.2	**219.2**	47	14
2016	DIM	W	MW116_3	3.2	**36**	**87.6**	55.0	80.4	.	3	13.7	4.4	34	129	**65**	422.4	197.7	39	31
2016	DIM	W	MW116_4	3.5	**36**	**87.8**	52.0	78.6	**2.5**	2	**13.4**	4.5	35	117	**69**	306.1	198.1	38	32
2016	DIM	W	MW118_1	2.6	**37**	**87.1**	48.0	77.3	**1.8**	1	14.9	5.0	35	**173**	**62**	446.0	188.0	29	67
2016	DIM	W	MW118_3	3.2	34	**81.3**	56.0	78.3	**2.2**	1	**12.8**	4.9	40	**202**	**72**	269.6	**252.2**	51	6
2016	DIM	W	MW118_4	3.7	35	**82.4**	64.0	78.5	**2.0**	2	13.9	4.3	33	**165**	**59**	384.1	203.4	42	20
2016	DIM	W	MW120_8	3.0	33	**86.7**	57.0	79.0	**2.0**	1	14.6	**5.2**	38	**197**	**70**	417.2	**267.2**	44	16
2016	DIM	W	MW122_1	3.3	33	76.4	45.0	77.9	**2.3**	1	15.2	**5.5**	37	**183**	**77**	223.7	**270.2**	40	26
2016	DIM	W	MW122_5	3.6	35	75.0	47.0	78.5	**1.6**	1	14.8	**5.3**	38	**211**	**70**	339.8	196.6	41	24
2016	DIM	W	MW80_1	3.3	32	76.9	56.0	78.5	**1.8**	1	13.7	4.9	37	**215**	**73**	200.5	197.6	42	20
2016	DIM	W	OBA11_13	3.2	**36**	76.8	59.0	76.7	**2.1**	2	13.7	4.5	33	144	49	393.9	160.3	25	94
2016	DIM	W	OBA11_2	3.7	**36**	90.8	57.0	77.6	2.7	2	13.6	4.1	30	104	44	585.6	160.8	20	125
2016	DIM	W	OBA11_29	4.2	33	76.9	66.0	76.0	**2.2**	1	14.2	4.2	31	126	44	527.5	160.2	21	116.5
2016	DIM	W	OBA11_31	4.3	32	**85.8**	54.0	75.7	.	3	14.9	3.9	26	99	37	444.1	118.1	9	147
2016	DIM	W	OK242	4.2	33	**82.8**	33.0	75.1	.	3	14.6	4.1	29	**225**	42	451.9	126.2	21	115
2016	DIM	W	OK248	3.5	30	78.0	41.0	74.3	.	3	**13.0**	3.8	29	145	42	582.4	125.4	28	78
2016	DIM	W	OK249	2.0	30	74.9	32.0	73.8	2.7	2	**13.0**	3.8	29	**180**	45	624.1	113.9	27	83
2016	DIM	W	OK452	4.0	32	**82.6**	46.0	74.7	.	3	**12.2**	3.8	31	147	41	519.0	150.0	31	59
2016	DIM	W	OK474	3.7	32	**86.5**	43.0	75.0	2.8	2	14.1	4.0	29	**175**	42	615.1	163.6	21	115
2016	DIM	W	OR101	3.4	34	**85.2**	58.0	79.7	.	3	**13.2**	4.5	37	**160**	**65**	275.7	206.7	49	8
2016	DIM	W	OR103	2.5	**37**	**89.2**	57.0	81.0	2.7	2	**13.3**	4.1	31	125	**61**	578.4	203.6	47	13
2016	DIM	W	OR104	2.8	35	**85.8**	44.0	79.3	3.2	2	**13.3**	4.4	35	146	**59**	424.2	179.0	45	15
2016	DIM	W	OR106	3.1	34	**87.0**	47.0	76.7	2.6	2	13.7	4.6	35	**174**	**64**	293.3	186.2	30	62
2016	DIM	W	OR108	3.7	**36**	78.2	68.0	78.5	**1.7**	1	**12.6**	4.2	35	126	**58**	469.1	160.5	38	32
2016	DIM	W	OR76	2.9	34	**80.7**	68.0	79.3	2.9	1	14.3	4.6	34	110	**73**	257.8	**234.1**	34	44
2016	DIM	W	OR813	3.0	34	**85.0**	75.0	79.9	2.6	1	**12.6**	5.0	40	120	**78**	286.6	**242.1**	47	13
2016	DIM	W	OR815	2.7	**36**	**86.3**	56.0	79.6	**2.3**	1	14.2	4.5	32	114	**62**	383.0	203.5	34	44
2016	DIM	W	OR818	3.8	34	**82.5**	43.0	79.4	3.0	1	14.1	**5.4**	40	**167**	**93**	274.3	**280.4**	48	10
2016	DIM	W	OR91	3.2	34	**85.4**	50.0	80.1	3.0	1	**13.4**	5.0	39	146	**85**	340.3	**280.9**	54	2
2016	DIM	W	OR910	3.1	34	**87.2**	51.0	79.6	3.0	1	13.6	5.0	39	**157**	**90**	253.7	**263.2**	49	8
2016	DIM	W	PO71_104	3.1	**36**	**85.4**	54.0	76.6	3.3	2	14.5	4.6	33	121	**53**	289.7	187.4	22	110
2016	DIM	W	PO71_87	3.3	**36**	90.2	47.0	78.8	.	3	13.6	4.3	32	125	**56**	470.4	173.1	33	50
2016	DIM	W	PY211_6	4.0	32	**82.0**	60.0	79.2	2.6	1	**12.2**	4.7	42	155	**71**	218.1	**230.3**	50	7
2016	DIM	W	Short_11	2.6	32	78.4	51.0	80.3	**2.2**	1	13.9	4.5	34	**171**	**80**	283.0	**219.4**	44	16
2016	DIM	W	Short_12	3.6	33	76.2	54.0	79.5	**2.2**	1	14.2	4.9	35	**177**	**85**	230.8	**252.4**	42	20
2016	DIM	W	Short_13	3.0	33	76.8	56.0	80.4	2.6	1	**13.5**	5.0	40	**168**	**83**	202.6	**288.2**	52	5
2016	DIM	W	Short_16	3.0	33	77.7	54.0	77.8	**2.3**	1	14.3	**5.3**	38	141	**67**	429.5	**255.1**	40	26
2016	DIM	W	Short_8	3.8	34	75.2	53.0	76.2	**1.7**	1	14.4	4.2	30	125	50	547.9	147.9	21	115
2016	MCG	W	06OR_10	2.2	27	54.3	27.0	77.4	3.4	1	**13.0**	**5.3**	**44.0**	**162.5**	**90.6**	168.6	**282.3**	46	10
2016	MCG	W	06OR_37	1.9	28	75.8	32.0	76.3	3.5	1	**12.2**	4.7	41.1	**196.4**	**70.6**	411.0	**257.7**	36	40
2016	MCG	W	06OR_41	1.8	27	61.7	34.0	76.5	3.4	1	**11.9**	4.8	41.1	**169.1**	**77.5**	267.3	**265.0**	34	46
2016	MCG	W	06OR_43	2.0	28	57.9	37.0	75.7	2.9	1	**11.7**	4.6	41.0	**159.2**	**78.3**	253.4	**217.4**	33	49
2016	MCG	W	06OR_44	2.6	28	66.3	32.0	76.9	3.9	1	**12.2**	**5.2**	**44.6**	**159.3**	**91.1**	211.0	**253.6**	43	15

2016	MCG	W	06OR_59	3.1	31	**88.7**	28.0	77.6	3.0	2	**11.8**	4.5	40.1	118.7	**69.7**	295.4	**212.7**	34	43
2016	MCG	W	06OR_91	1.7	25	33.8	28.0	73.7	3.9	1	15.6	5.8	38.1	**220.6**	**103.4**	213.3	**305.5**	24	69
2016	MCG	W	07OR_3	2.6	26	79.5	20.5	75.6	5.5	1	12.3	5.9	**45.7**	135.4	**92.6**	**76.5**	**302.9**	45	22
2016	MCG	W	07OR_59	1.1	27	66.8	30.0	77.9	4.4	1	**12.3**	5.1	40.6	**159.7**	**90.0**	178.9	**280.8**	38	31
2016	MCG	W	07OR_6	1.7	23	50.8	23.0	76.6	7.3	1	**12.1**	6.9	60.2	115.2	**107.3**	**53.0**	**342.7**	31	52
2016	MCG	W	07OR_63	2.3	29	72.7	41.0	77.5	3.9	1	14.6	**5.7**	40.6	**189.5**	**71.2**	359.0	**237.9**	30	56
2016	MCG	W	08BA_54	.	33	**88.2**	43.0	80.1	3.1	2	14.0	**5.5**	**42.3**	147.7	**85.5**	**47.0**	**280.2**	64	1
2016	MCG	W	08OR_30	2.9	28	70.5	26.0	75.6	4.0	1	**12.8**	**5.3**	41.3	**163.8**	**86.4**	261.6	**265.3**	40	27
2016	MCG	W	Alba	.	33	77.7	22.0	78.3	4.0	1	13.1	**5.5**	**44.1**	128.9	**89.4**	203.6	**258.0**	42	17.5
2016	MCG	W	F_Pint	3	28	65.3	24.0	75.6	3.9	1	**13.0**	**5.2**	40.8	152.6	**76.0**	263.9	**230.1**	39	27
2016	MCG	W	F5105_1	2.1	29	69.8	37.0	77.3	3.4	1	**12.1**	**5.2**	**45.7**	**173.4**	**76.3**	171.1	**250.0**	45	13
2016	MCG	W	F5105_3	2.2	27	57.9	31.0	76.6	5.1	1	**12.8**	**5.4**	**43.7**	**157.0**	**105.7**	141.3	**265.2**	46	10
2016	MCG	W	F5108_1	2.5	32	**81.0**	26.0	77.9	4.2	1	**12.5**	5.1	**42.3**	145.2	**86.6**	452.5	**240.8**	53	4
2016	MCG	W	F5109_3	2.6	30	65.0	24.0	75.8	4.0	1	**12.7**	**5.3**	**43.7**	121.1	**71.2**	328.3	**227.2**	41	23.5
2016	MCG	W	F5112_1	2.5	28	65.3	30.0	76.2	4.4	1	**11.9**	5.1	**45.0**	135.8	**86.9**	300.2	**238.4**	37	31.5
2016	MCG	W	F5112_3	2	27	62.0	30.0	74.9	4.8	1	13.8	**5.4**	39.8	**167.6**	**93.9**	260.9	**283.6**	36.5	35.5
2016	MCG	W	F5113_2	1.9	26	51.7	33.0	75.5	5.5	1	**13.0**	5.9	**46.6**	**150.9**	**107.1**	**77.7**	**297.5**	42	17
2016	MCG	W	F5120_3	1.6	28	56.8	36.0	74.4	5.8	1	13.4	**5.7**	**45.3**	135.0	**79.8**	228.4	**242.6**	36	40
2016	MCG	W	F5121_1	2.5	31	68.3	28.0	76.5	4.1	1	**12.0**	4.9	**42.5**	137.4	**76.0**	377.5	**222.0**	40	19
2016	MCG	W	F5121_2	3.1	31	**84.8**	26.0	78.0	3.0	1	**11.6**	4.3	39.7	147.5	**74.8**	410.8	**217.9**	44	16
2016	MCG	W	F5121_4	2.6	27	63.1	36.0	74.8	4.9	1	**12.3**	5.9	49.3	**150.3**	**88.4**	142.8	**251.9**	37	38
2016	MCG	W	F5121_5	1.6	29	69.7	35.0	76.1	3.5	1	**11.5**	4.9	**43.0**	124.0	**79.9**	326.0	**233.8**	38	23
2016	MCG	W	F5124_1	2.4	29	66.2	36.0	76.5	3.7	1	**12.2**	4.9	41.0	117.9	**83.3**	266.0	**225.8**	29	37
2016	MCG	W	F5126_2	2.1	29	75.5	31.0	77.4	3.7	1	**11.7**	5.0	**43.3**	143.5	**85.3**	338.3	**238.2**	43	15
2016	MCG	W	F5132_1	2	30	72.7	34.0	76.2	5.2	1	**12.4**	**5.5**	**44.6**	132.7	**90.6**	365.3	**240.8**	42	22
2016	MCG	W	F5135_4	2.6	28	59.5	15.0	76.3	3.2	1	**11.6**	4.9	**44.8**	107.2	**72.9**	132.5	**241.3**	37	27
2016	MCG	W	F522_3	3.3	31	**83.6**	34.0	78.6	3.0	1	**12.0**	4.9	**43.1**	132.5	**82.0**	270.4	**239.3**	52	5
2016	MCG	W	F523_1	3.7	27	64.8	31.0	76.9	3.2	1	**12.6**	5.0	40.3	149.4	**90.1**	226.0	**232.1**	34	31
2016	MCG	W	F527_1	1.6	27	73.8	28.0	76.6	4.1	1	**12.1**	5.0	44.4	**153.3**	**61.5**	407.7	**236.7**	42	22
2016	MCG	W	F535_2	1.9	29	69.6	19.0	77.0	4.2	1	**12.2**	4.6	40.0	**157.9**	**74.6**	458.2	**247.9**	33	49
2016	MCG	W	F536_2	1.8	32	**80.5**	17.0	76.0	3.7	1	**12.0**	5.0	**43.8**	**179.4**	**75.1**	431.6	**208.5**	48	8
2016	MCG	W	F537_1	2.3	30	75.3	17.0	76.4	3.9	1	**12.3**	4.7	39.6	**167.2**	**75.8**	502.1	**252.3**	38	31
2016	MCG	W	F537_3	2.4	30	71.4	18.5	76.6	4.2	1	**12.8**	**5.2**	**43.0**	**170.3**	**81.8**	393.6	**245.1**	42.5	17.5
2016	MCG	W	F54_2	3	30	78.9	15.5	77.3	4.9	1	14.3	**5.5**	38.7	**191.5**	**98.6**	333.8	**304.0**	34	43.5
2016	MCG	W	F547_1	2.9	30	79.2	15.0	76.2	2.8	2	14.0	5.0	35.9	**160.1**	**66.7**	309.1	**254.2**	34	43
2016	MCG	W	F547_3	3.2	30	77.6	31.5	76.3	3.4	1	**12.8**	4.7	37.7	**167.8**	**62.9**	436.6	202.3	40	26.5
2016	MCG	W	F548_1	2.1	31	75.3	25.0	77.5	4.3	1	**12.0**	4.5	40.9	**153.3**	**85.0**	319.9	**244.6**	38	31
2016	MCG	W	F55_1	3.5	30	**83.1**	40.0	78.4	2.9	1	**11.0**	4.7	**45.8**	139.7	**75.8**	330.0	**235.7**	44	14
2016	MCG	W	F552_2	1.8	29	74.4	20.5	76.7	3.6	1	13.8	**5.2**	40.0	**184.6**	**65.7**	360.4	**249.2**	34.5	32.5
2016	MCG	W	F555_1	1.4	29	66.3	16.0	75.4	4.0	1	**12.1**	5.0	**42.0**	**169.9**	**78.7**	340.7	**259.3**	41	25
2016	MCG	W	F556_1	1.3	26	55.7	35.0	76.3	3.7	1	13.1	5.0	39.8	**191.9**	**78.6**	298.1	**294.6**	34	46
2016	MCG	W	F559_1	2.4	32	74.8	27.0	77.6	4.7	1	**11.9**	**5.2**	**45.4**	139.5	**88.0**	328.9	**222.8**	43	15
2016	MCG	W	F566_3	2.2	30	72.4	32.5	77.5	4.6	1	**12.1**	**5.7**	47.2	**152.9**	**82.3**	393.7	**298.6**	40	28
2016	MCG	W	F576_1	2.3	30	75.0	36.0	76.4	4.3	1	**11.7**	5.1	**43.4**	146.4	**83.8**	331.3	**230.3**	44	16
2016	MCG	W	F588_3	2.8	29	67.8	36.0	76.5	5.1	1	**11.9**	5.6	48.4	139.6	**77.9**	236.9	**236.2**	37	38
2016	MCG	W	F59_2	2.5	29	73.0	33.5	76.6	3.5	2	**11.8**	4.6	39.9	135.7	**70.0**	349.5	**232.6**	32.5	47.5
2016	MCG	W	F590_5	2.6	27	75.1	28.0	76.2	4.7	1	**12.8**	**5.7**	**45.2**	**158.6**	**87.3**	330.3	**316.4**	46	11
2016	MCG	W	F591_1	3.2	27	61.7	31.5	78.6	3.6	2	**10.8**	4.0	38.6	137.6	**67.2**	355.4	**211.4**	29.5	46.5
2016	MCG	W	F595_1	2.9	29	74.9	35.0	77.6	4.1	1	**11.5**	5.0	**43.8**	129.9	**74.0**	308.9	**220.4**	41	25
2016	MCG	W	F596_4	2.7	28	63.1	33.0	77.2	3.3	1	**10.4**	3.6	36.2	134.2	**60.9**	362.7	201.6	25	67
2016	MCG	W	MW118_3	3	31	**82.9**	23.0	76.6	2.9	1	**12.7**	5.1	**42.2**	**173.1**	**80.1**	222.0	**243.5**	39.33	27
2016	MCG	W	MW118_4	3.7	34	**91.8**	22.0	79.1	3.0	1	**12.8**	**5.4**	**43.0**	**216.5**	**86.9**	225.9	**261.8**	63	2
2016	MCG	W	MW120_8	3.5	27	75.6	13.0	74.0	2.9	1	16.2	**5.6**	36.7	**236.5**	**89.6**	390.7	**263.4**	31	52
2016	MCG	W	MW122_1	3	30	**81.0**	16.0	77.1	3.2	1	14.8	6.0	40.1	**211.3**	**102.5**	306.1	**336.9**	28	59

2016	MCG	W	MW122_5	3.5	30	**83.1**	20.0	76.7	2.7	1	14.3	**5.3**	38.5	**208.2**	**82.3**	308.8	**260.3**	39.5	30.5	
2016	MCG	W	MW76_1	2.3	32	91.2	16.0	76.5	3.2	1	**12.9**	**5.6**	**44.0**	**188.8**	**95.3**	305.2	**319.2**	43.5	16.5	
2016	MCG	W	MW76_2	3.5	30	75.2	20.0	74.0	3.2	1	13.3	**5.2**	39.6	**244.2**	**67.7**	353.0	**260.5**	45	13	
2016	MCG	W	MW80_1	3.9	31	**89.1**	21.0	77.9	3.2	1	**11.8**	**5.5**	**48.1**	**169.8**	**78.2**	191.3	**251.3**	51	2	
2016	MCG	W	OBA11_13	2.8	29	68.1	34.5	76.0	3.2	1	**12.7**	**5.2**	41.5	**182.4**	**76.2**	240.5	**249.9**	42	18.5	
2016	MCG	W	OBA11_2	2.3	26	60.0	24.0	72.5	5.8	1	15.8	6.8	**43.7**	**168.0**	**92.4**	159.9	**341.5**	29	57	
2016	MCG	W	OBA11_31	2.8	26	77.0	24.0	74.7	3.8	1	13.1	4.7	36.6	135.6	**59.6**	235.9	**215.6**	31	52	
2016	MCG	W	OR104	1.4	26	64.3	21.0	77.3	4.4	1	**12.1**	**5.7**	49.8	**171.1**	**88.1**	174.3	**265.7**	34	46	
2016	MCG	W	OR106	1.7	25	51.6	29.0	75.5	3.6	1	13.1	**5.2**	41.6	**204.4**	**79.1**	264.9	**268.6**	38	23	
2016	MCG	W	OR108	2.7	29	55.3	31.0	77.0	3.5	1	**12.3**	4.9	40.8	147.0	**83.0**	311.3	**225.7**	34.5	29.5	
2016	MCG	W	OR813	2.9	27	70.4	36.0	77.0	3.3	2	**11.5**	4.7	**43.7**	131.3	**79.7**	157.2	**229.8**	31.5	49	
2016	MCG	W	OR818	2	23	57.4	21.0	75.6	6.2	1	**12.1**	**5.4**	**45.7**	122.9	**89.5**	103.3	**317.7**	47	4	
2016	MCG	W	OR91	1.9	24	61.3	28.0	77.2	6.4	1	**11.5**	6.7	56.1	117.5	**98.0**	**85.9**	**318.0**	31	52	
2016	MCG	W	PO71_87	2.4	27	66.9	20.0	77.6	4.2	1	**12.6**	5.1	**42.8**	**161.3**	**89.7**	185.4	**235.0**	39	21	
2016	MCG	W	Short_11	2.7	29	78.2	24.0	78.8	3.7	1	**11.7**	5.1	**46.1**	**156.1**	**91.8**	141.7	**251.8**	54	3	
2016	MCG	W	Short_12	2.1	30	**83.3**	28.0	78.5	3.9	1	**11.0**	4.8	**44.3**	139.6	**92.8**	139.8	**306.2**	47	4	
2016	MCG	W	Short_13	2.2	28	70.6	23.0	75.6	5.4	1	17.7	7.1	**42.6**	**201.7**	**105.3**	141.2	**395.0**	31	34	
2016	MCG	W	Short_16	2.8	29	76.9	31.0	78.1	3.7	1	**11.9**	4.9	**42.6**	140.5	**85.5**	231.5	**277.4**	44.5	10.5	
			Min	1.1	23.1	50.8	13.0	72.5	2.7	1.0	10.4	3.6	35.9	107.2	59.6	47.0	201.6	25.0	1.0	
			Max	3.9	34.1	91.8	43.0	80.1	7.3	2.0	17.7	7.1	60.2	244.2	107.3	502.1	395.0	64.0	67.0	
			Avg	2.5	28.9	71.3	27.2	76.7	4.0	1.1	12.6	5.2	42.9	157.6	82.6	275.0	257.7	39.6	27.6	
			Std. Dev	0.6	2.2	9.7	7.3	1.3	0.9	0.3	1.2	0.6	4.0	28.5	11.0	105.2	37.6	7.5	16.3	
			Std. Error	0.1	0.3	1.2	0.9	0.2	0.1	0.0	0.1	0.1	0.5	3.4	1.3	12.7	4.5	0.9	2.0	
			Ideal Range	.	36-45	> 80%	.	.	1.8-2.5	.	≤ 13.0%	5.2-5.7%	42-47%	> 150	> 50	< 120	> 210	.	.	
			# Lines met criteria	.		158	.	.	105	.	88	79	53	194	327	9	191	.		.

A-6: TCAP spring two- and six-row barley lines and commercial check malt quality evaluations (Bold indicate lines that met criteria).

Year	Loc	Type	SAS_Name	Yield	Kernel Weight (mg)	Plump 6/64" (%)	Barley Color (Agtron)	Malt Extract (%)	Wort Color	Wort Clarity	Barley Protein (%)	Wort Protein (%)	S/T (%)	DP (°ASBC)	Alpha-amylase (20°DU)	Beta-glucan (ppm)	FAN (ppm)	Quality Score	Overall Rank
2015	MCG	S2	06AB_24	1.6	26.7	84.7	12.0	78.0	4.7	1	13.2	6.0	46.8	**117.3**	95.9	536.2	281.0	35	69
2015	MCG	S2	06BA_81	2	29.3	84.9	18.0	79.3	.	3	13.4	6.1	47.0	87.1	**60.4**	202.7	201.5	21	141
2015	MCG	S2	06MT_26	2.4	31.9	73.0	11.0	78.0	3.7	1	13.4	**5.1**	**38.9**	95.0	**55.4**	713.0	**182.3**	28	115
2015	MCG	S2	06MT_59	4.6	28.2	67.7	15.0	78.2	4.4	1	13.3	5.3	**41.4**	**114.5**	**50.0**	858.6	212.8	36	63
2015	MCG	S2	06MT_67	4.4	34.6	88.6	17.0	79.7	4.5	2	13.6	6.0	47.1	**114.8**	79.1	185.2	220.7	30	99
2015	MCG	S2	06MT_82	3.4	31.6	88.6	14.0	78.5	.	3	13.1	**5.0**	**38.9**	**122.5**	**62.0**	704.4	211.8	38	53
2015	MCG	S2	06N2_06	3.5	**36.8**	**90.7**	16.0	78.4	.	3	12.8	**5.1**	**42.1**	**127.0**	**59.7**	821.7	198.3	50	9
2015	MCG	S2	06N2_17	3.7	**41.4**	**95.2**	8.0	80.9	.	3	12.3	5.4	48.1	101.5	**56.7**	548.3	**187.4**	47	16
2015	MCG	S2	06N2_39	3.3	34.2	**92.5**	9.0	80.0	.	3	13.4	5.7	**42.9**	**114.1**	39.5	593.4	**171.9**	29	104
2015	MCG	S2	06N2_70	4	35.3	**90.4**	23.0	81.4	.	3	12.8	5.4	**43.7**	84.0	**52.8**	471.3	240.5	49	11
2015	MCG	S2	06WA_38	2.1	29.3	63.8	11.0	76.5	5.9	1	15.6	6.6	**43.1**	157.7	**67.2**	546.5	254.1	26	120
2015	MCG	S2	06WA_77	2	29.5	74.5	7.0	78.9	5.7	2	13.3	6.7	51.8	153.6	78.2	228.2	291.5	29	104
2015	MCG	S2	07AB_53	4	29.7	**90.3**	23.0	77.0	4.6	2	13.3	5.6	**43.4**	102.0	**69.9**	473.0	200.3	35	69
2015	MCG	S2	07AB_77	3.1	33.0	78.1	17.0	78.0	3.9	1	14.4	**5.2**	37.5	156.3	**64.2**	622.5	218.8	32	89
2015	MCG	S2	07MT_40	2.6	35.0	82.3	16.0	79.8	4.6	1	12.5	5.3	**44.7**	**130.3**	81.1	471.1	216.6	50	9
2015	MCG	S2	07MT_94	3.5	33.7	90.0	15.0	79.4	.	3	12.9	5.6	46.8	100.9	**56.9**	222.2	210.2	46	18
2015	MCG	S2	07N2_02	2.8	35.8	**92.7**	20.0	78.3	.	3	13.5	5.8	45.6	**118.9**	**61.4**	470.3	223.2	33	83
2015	MCG	S2	07N2_13	4.5	33.9	**92.9**	22.0	79.0	.	3	12.9	5.8	48.0	109.0	**56.7**	230.9	233.7	38	53
2015	MCG	S2	07N2_31	3.4	**37.4**	**93.3**	27.0	79.8	.	3	13.6	6.0	46.5	**124.8**	**66.7**	365.5	263.8	36	63
2015	MCG	S2	07N2_73	3	32.9	**91.1**	22.0	75.6	.	3	14.8	6.8	46.4	95.8	**48.2**	498.9	235.6	19	148
2015	MCG	S2	07WA_03	1.9	33.9	**94.0**	11.0	78.2	5.7	2	13.1	**5.2**	**41.8**	**114.4**	**61.5**	350.6	191.1	43	31
2015	MCG	S2	07WA_13	2.2	32.2	87.5	12.0	75.4	14.0	2	13.8	8.3	60.5	89.9	**54.0**	**32.9**	358.7	23	135
2015	MCG	S2	08AB_17	1.2	27.8	63.1	10.0	77.0	8.0	2	14.0	6.7	47.7	103.9	**58.7**	146.8	279.9	20	146
2015	MCG	S2	08AB_24	2.1	29.5	73.4	7.0	77.0	.	3	13.9	8.6	60.7	84.9	**48.8**	**44.7**	338.3	16	154
2015	MCG	S2	08AB_45	1.7	31.6	73.3	11.0	77.0	.	3	15.7	6.5	**42.4**	**125.0**	76.1	525.9	252.0	24	130
2015	MCG	S2	08BA_02	1.5	30.4	81.4	10.0	76.4	.	3	14.3	8.4	56.1	86.5	**60.3**	**61.9**	368.5	19	148
2015	MCG	S2	08BA_11	1.1	31.7	86.8	11.0	75.0	.	3	14.1	10.2	62.2	96.4	**58.1**	**27.9**	419.0	22	138
2015	MCG	S2	08BA_76	2.3	**36.7**	**90.7**	12.0	79.2	4.3	1	13.9	5.7	**43.5**	108.7	**54.9**	357.7	225.1	35	69
2015	MCG	S2	08MT_04	2.6	30.6	83.3	15.0	76.9	4.5	2	14.6	5.6	**40.6**	**141.4**	**67.1**	845.3	212.8	32	89
2015	MCG	S2	08N2_73	3.6	**37.4**	**91.7**	18.0	78.7	.	3	12.3	**5.1**	**43.7**	74.7	**54.2**	384.4	198.7	43	31
2015	MCG	S2	08WA_11	1.3	27.6	82.5	14.0	74.8	.	3	13.7	8.5	54.3	92.1	**59.8**	**21.7**	426.0	19	148
2015	MCG	S2	08WA_27	1.6	31.2	76.4	10.0	77.1	4.8	2	13.3	5.9	45.1	100.2	**59.6**	384.4	275.6	30	99
2015	MCG	S2	08WA_40	1.8	29.6	68.1	9.0	77.7	3.8	2	12.6	**5.0**	**41.0**	93.5	**57.5**	355.2	192.0	35	69
2015	MCG	S2	08WA_64	1.4	24.4	80.8	1.0	71.2	.	3	13.9	9.3	55.7	97.5	**48.3**	**19.9**	434.5	16	154
2015	MCG	S2	09AB_10	1.1	26.4	78.2	10.0	76.3	5.8	1	14.7	6.7	**44.4**	89.6	**57.6**	1064.5	302.6	19	148
2015	MCG	S2	09AB_43	1.7	31.5	62.3	10.0	77.4	.	3	14.9	6.1	**41.3**	52.3	31.9	1329.0	205.6	10	158
2015	MCG	S2	09AB_48	2.3	**36.1**	**95.1**	24.0	78.1	2.7	1	13.9	**5.1**	36.7	161.6	**62.7**	523.4	191.2	37	59
2015	MCG	S2	09AB_82	2.2	33.2	**90.2**	12.0	78.3	5.3	1	12.9	5.8	45.6	82.2	**61.5**	390.2	204.4	41	45
2015	MCG	S2	09BA_03	3.7	30.6	**91.9**	25.0	79.1	2.9	1	12.5	5.9	50.6	173.2	71.0	586.2	286.1	43	31
2015	MCG	S2	09BA_10	2.2	28.6	**91.3**	8.0	74.5	10.1	2	14.8	8.7	56.7	**137.6**	**48.0**	**51.1**	342.2	29	104
2015	MCG	S2	09BA_89	1.8	27.7	68.6	17.0	76.9	.	3	14.8	9.1	56.7	**130.5**	**44.7**	**22.6**	385.9	23	135
2015	MCG	S2	09MT_16	1.9	28.8	70.3	12.0	78.0	4.4	1	12.6	5.6	45.7	**134.5**	97.8	383.0	273.9	43	31
2015	MCG	S2	09MT_78	2.6	32.1	89.8	16.0	79.7	3.8	2	12.5	5.6	46.5	174.5	76.9	383.8	202.3	48	13
2015	MCG	S2	09MT_94	1.5	27.5	62.3	9.0	78.5	.	3	12.3	7.4	61.5	**117.4**	96.0	**52.6**	323.2	37	59
2015	MCG	S2	09N2_12	4	32.4	81.4	19.0	78.4	4.0	2	12.8	5.4	45.6	178.6	74.1	358.3	219.0	46	18
2015	MCG	S2	09N2_21	4.2	32.8	88.1	20.0	79.0	3.9	1	13.0	5.5	**44.7**	**127.9**	83.3	218.5	242.2	45	24
2015	MCG	S2	09N2_29	2.6	31.9	81.3	21.0	79.1	.	3	12.2	4.9	**40.8**	**117.3**	64.0	653.4	203.4	42	40
2015	MCG	S2	09N2_39	2.4	32.9	75.5	21.0	78.1	4.0	2	12.2	**5.1**	**43.0**	**131.8**	74.0	503.0	210.4	46	18
2015	MCG	S2	09N2_55	3	33.1	87.3	22.0	79.6	.	3	**11.9**	6.3	53.8	**140.5**	**65.2**	113.5	259.9	42	40

2015	MCG	S2	09WA_15	1.5	27.9	79.1	5.0	76.7	.	3	13.0	7.3	55.1	99.6	**58.4**	**78.5**	277.0	24	130
2015	MCG	S2	09WA_19	1.7	29.4	79.0	9.0	75.9	3.8	1	14.1	5.8	**43.9**	**121.8**	**67.5**	243.8	208.7	29	104
2015	MCG	S2	09WA_52	2.4	29.5	80.1	16.0	78.7	8.0	3	13.3	6.6	52.6	**173.3**	74.9	111.0	257.1	31	95
2015	MCG	S2	09WA_64	1.3	30.5	79.3	10.0	75.9	2.9	1	13.3	**5.1**	**39.7**	**135.6**	75.3	350.6	187.3	31	95
2015	MCG	S2	AC_MET	1.8	30.3	85.2	18.4	76.2	.	3	14.6	7.8	52.0	**133.0**	**56.7**	**52.6**	349.3	29	104
2015	MCG	S2	CDC	2	31.1	87.4	19.8	76.3	.	3	13.2	7.5	53.2	94.8	**40.3**	**31.8**	299.8	27	113
2015	MCG	S2	CON	2.4	32.3	84.5	14.8	78.4	4.5	1	13.7	5.8	43.6	**133.3**	80.0	383.6	257.1	33	84
2015	MCG	S6	06AB_55	3.5	27.7	66.4	15	76.6	2.8	1	**11.9**	4.8	**43.8**	103.4	**55.0**	848.1	194.9	27	118
2015	MCG	S6	06AB_62	2.6	29.0	74.1	18	79.1	2.8	1	**12.3**	**5.4**	**44.8**	148.9	**65.2**	431.2	**221.7**	58	1
2015	MCG	S6	06AB_84	3.9	26.0	68.9	23	76.2	**2.5**	1	**11.8**	5.0	**43.5**	**154.5**	**56.8**	684.1	**212.0**	39	49
2015	MCG	S6	06BA_06	3.1	29.1	**83.1**	25	79.3	2.9	1	13.6	6.1	49.8	**213.8**	**79.9**	295.9	**262.2**	43	31
2015	MCG	S6	06BA_30	3.4	28.5	**87.9**	21	79.2	.	3	**12.7**	6.3	50.2	**182.9**	**66.2**	170.3	**277.4**	46	18
2015	MCG	S6	06MN_10	2.9	29.9	**90.1**	25	77.9	3.2	1	13.2	6.1	49.3	**205.1**	**72.1**	528.3	**256.6**	42	40
2015	MCG	S6	06MN_18	3.5	32.1	**88.6**	20	78.4	6.3	2	**12.8**	6.8	56.0	113.2	**53.7**	128.8	316.1	43	31
2015	MCG	S6	06MN_51	2.9	29.8	**82.1**	25	76.9	2.9	1	14.1	5.9	**43.9**	**183.4**	**55.7**	557.5	**256.4**	36	63
2015	MCG	S6	06MN_62	2.6	29.7	**83.8**	15	74.6	.	3	14.3	7.4	51.7	116.1	44.8	**30.4**	**336.0**	23	135
2015	MCG	S6	06N6_66	3.8	28.5	**83.8**	21	78.4	4.2	2	13.5	6.1	47.2	**164.4**	**57.5**	370.0	**288.2**	39	49
2015	MCG	S6	06N6_71	3.4	29.7	**88.3**	23	79.0	**2.5**	1	13.6	5.1	40.5	**161.7**	**60.6**	479.1	**220.7**	46	18
2015	MCG	S6	06N6_88	1.8	30.9	**84.4**	13	76.1	3.4	2	13.8	5.8	**43.7**	**152.4**	**64.7**	681.8	**260.8**	42	40
2015	MCG	S6	07AB_16	1.9	27.6	64.3	21	77.8	3.1	1	**11.3**	4.7	**42.6**	119.8	**70.2**	127.3	193.5	29	104
2015	MCG	S6	07BA_09	3.4	27.3	**81.3**	25	78.3	5.0	2	**12.8**	6.6	54.2	**153.2**	**82.4**	122.2	**279.7**	45	24
2015	MCG	S6	07BA_24	3.2	28.0	75.7	29	79.4	**2.4**	1	**12.1**	**5.4**	46.0	**151.9**	**66.5**	310.1	**234.4**	58	1
2015	MCG	S6	07BA_28	2.9	31.3	**88.3**	27	78.6	2.7	1	**12.9**	**5.7**	47.2	**217.7**	**59.5**	677.5	**261.2**	54	4
2015	MCG	S6	07MN_42	2.5	31.4	**84.7**	28	78.8	2.8	1	13.4	5.9	**45.2**	**199.7**	**61.8**	625.3	**248.1**	55	3
2015	MCG	S6	07MN_52	2.9	32.0	**87.4**	22	79.0	**2.5**	1	13.8	5.9	**45.9**	**206.4**	**68.0**	916.3	**221.0**	53	6
2015	MCG	S6	07MN_85	3.5	31.4	**87.6**	19	79.3	2.7	1	13.9	5.8	**42.9**	**196.9**	**58.6**	881.0	**232.2**	53	6
2015	MCG	S6	07MN_90	3.3	29.1	**83.1**	22	78.1	2.8	1	13.4	**5.6**	**44.9**	**183.0**	**73.2**	672.5	**233.6**	54	4
2015	MCG	S6	07MN_94	1.7	30.3	**87.5**	24	77.7	2.9	1	14.9	**5.6**	38.3	**220.8**	**75.0**	557.9	**218.3**	41	45
2015	MCG	S6	07N6_51	3.1	29.0	**88.0**	24	77.3	.	3	14.8	7.1	51.5	**165.2**	**64.2**	170.3	**273.7**	26	120
2015	MCG	S6	07N6_80	4.2	27.0	76.3	21	77.3	3.6	1	13.6	6.3	49.6	**162.3**	**70.4**	533.7	**262.6**	29	104
2015	MCG	S6	07UT_18	1.2	27.8	**80.6**	16	76.2	4.3	2	15.4	6.2	**42.4**	127.6	**68.5**	601.8	**254.6**	27	118
2015	MCG	S6	07UT_36	2.1	34.5	**81.8**	1	72.7	3.4	1	**12.5**	4.9	41.6	**183.2**	**66.7**	1033.2	175.9	39	49
2015	MCG	S6	07UT_83	2.0	29.5	**80.6**	11	74.0	**2.2**	1	14.6	4.7	34.1	**150.8**	49.0	1246.4	163.2	20	146
2015	MCG	S6	07UT_88	1.9	32.4	**87.0**	15	75.8	.	3	14.2	6.2	**43.9**	77.3	41.1	701.8	**214.8**	24	130
2015	MCG	S6	07UT_93	1.9	29.3	68.7	9	75.6	**2.3**	1	15.5	**5.2**	35.1	123.9	**52.4**	1054.7	191.3	21	141
2015	MCG	S6	07UT_96	2.0	30.2	78.2	8	77.3	2.7	1	13.3	**5.5**	**42.9**	138.9	**59.3**	1044.4	208.5	47	16
2015	MCG	S6	08AB_54	2.0	29.9	**83.2**	16	76.3	3.2	1	16.0	6.2	39.6	**219.8**	**68.1**	576.7	**237.7**	28	115
2015	MCG	S6	08AB_80	2.7	31.4	**90.4**	18	77.9	3.8	2	14.9	6.0	**43.4**	**198.8**	**54.8**	1050.6	**239.0**	38	53
2015	MCG	S6	08BA_44	3.6	28.4	78.3	23	77.4	2.8	1	13.4	5.8	**44.7**	**190.5**	**57.9**	731.5	**211.3**	44	26
2015	MCG	S6	08BA_54	2.1	27.0	70.4	24	78.6	3.6	1	13.6	6.0	**46.3**	**213.1**	**62.4**	605.3	**264.5**	38	53
2015	MCG	S6	08BA_60	3.2	24.0	61.3	16	78.6	4.5	2	**13.0**	6.5	53.0	**183.1**	**71.8**	622.3	**260.8**	37	59
2015	MCG	S6	08BA_64	2.1	29.7	**94.0**	18	75.2	.	3	13.6	7.5	56.2	119.3	28.1	198.5	**257.9**	17	152
2015	MCG	S6	08MN_34	1.8	27.7	67.4	20	78.3	.	3	13.5	9.7	73.9	143.3	**65.4**	**86.7**	**362.5**	38	53
2015	MCG	S6	08MN_49	1.4	27.8	67.4	25	77.5	3.7	1	14.5	6.8	49.4	**189.2**	**73.3**	374.6	**281.4**	21	141
2015	MCG	S6	08MN_67	2.8	30.6	**87.4**	25	76.9	2.7	1	14.9	5.8	41.7	**203.4**	**65.6**	621.6	**260.2**	33	83
2015	MCG	S6	08MN_78	2.8	30.6	**83.2**	20	78.4	3.0	1	13.6	6.1	48.2	**210.5**	**68.7**	587.8	**285.5**	42	40
2015	MCG	S6	08N6_09	3.5	26.9	73.0	15	78.7	3.5	1	**12.1**	5.1	**45.3**	133.2	**69.9**	672.2	**258.7**	46	18
2015	MCG	S6	08N6_21	3.1	26.2	71.1	25	78.0	4.1	2	13.9	6.4	48.6	137.6	**67.6**	713.1	**298.2**	26	120
2015	MCG	S6	08N6_35	2.5	23.8	61.0	15	74.6	4.5	1	14.3	6.8	49.6	147.6	**63.3**	601.6	**307.2**	21	141
2015	MCG	S6	08N6_52	3.7	28.5	**86.2**	21	77.9	4.6	2	13.1	6.6	52.7	138.9	**61.8**	223.0	**293.7**	38	53
2015	MCG	S6	08N6_77	2.2	28.0	**83.9**	22	76.6	3.2	1	14.2	**5.6**	40.6	**203.7**	**69.7**	620.9	**222.7**	35	69
2015	MCG	S6	08N6_91	4.0	26.5	**82.5**	14	77.8	3.8	1	**12.9**	5.8	45.7	**153.7**	**66.6**	681.8	**277.8**	48	13
2015	MCG	S6	08N6_96	3.4	25.5	66.6	20	76.5	4.3	1	13.7	6.5	49.8	**157.0**	**71.6**	469.4	**300.1**	26	120
2015	MCG	S6	08UT_10	1.8	32.3	**83.1**	13	75.8	3.2	1	15.8	**5.7**	37.9	137.6	**50.1**	814.1	**252.2**	31	95

2015	MCG	S6	09BA_37	3.7	26.6	77.3	16	79.0	3.9	1	**12.8**	6.2	51.3	**186.7**	**77.5**	404.0	**294.2**	44	26
2015	MCG	S6	09BA_50	3.0	33.1	**91.5**	16	78.3	3.6	2	14.4	**5.7**	39.9	**186.2**	**51.6**	894.3	**220.3**	44	26
2015	MCG	S6	09MN_04	3.2	27.5	**86.2**	22	77.3	2.7	1	14.3	**5.7**	41.2	**177.0**	**68.1**	459.5	**237.9**	33	83
2015	MCG	S6	09MN_30	1.9	31.1	**85.5**	26	77.2	2.9	1	14.0	6.0	**43.9**	**203.7**	**60.3**	824.8	**248.3**	35	69
2015	MCG	S6	09MN_50	3.7	31.6	**90.3**	21	78.2	3.5	2	14.2	5.9	**42.9**	**164.7**	**50.2**	757.2	**241.3**	44	26
2015	MCG	S6	09MN_70	2.2	31.3	79.0	24	77.5	.	3	14.6	8.2	57.8	**176.3**	**70.3**	168.3	**348.8**	29	104
2015	MCG	S6	09N6_36	3.0	29.4	79.2	15	77.1	3.6	1	13.6	6.0	**45.0**	**194.3**	**59.4**	682.8	**235.6**	36	63
2015	MCG	S6	09N6_59	1.8	28.0	72.9	22	79.1	3.4	2	14.0	6.2	**44.2**	**181.7**	45.6	380.5	**261.6**	34	78
2015	MCG	S6	09N6_63	2.2	30.2	**88.5**	14	77.8	3.1	1	14.6	6.3	**44.0**	**198.4**	**60.3**	584.5	**262.5**	39	49
2015	MCG	S6	09N6_69	2.9	29.1	**87.6**	20	77.8	3.5	2	13.7	5.9	**44.9**	**163.7**	**61.1**	334.8	**255.1**	44	26
2015	MCG	S6	09UT_13	1.8	29.3	78.0	18	76.5	3.3	1	14.4	6.0	**43.5**	**192.2**	**64.6**	1026.0	**249.1**	34	78
2015	MCG	S6	AC_MET	1.8	29.7	**80.0**	23	75.3	.	3	15.8	9.4	58.7	134.7	**53.6**	**82.9**	**347.3**	30	96
2015	MCG	S6	CDC	2.1	32.4	**87.8**	17.8	76.8	10.2	2.8	14.1	7.8	54.9	99.1	**39.4**	**37.7**	**313.4**	27	115
2015	MCG	S6	CON	2	31.3	**82.9**	16	78.3	3.3	1	13.9	5.8	**42.6**	110.7	**69.5**	377.1	**243.4**	43	31
2015	MCG	S6	S_610B	2.3	25.6	61.8	19	76.6	3.2	1	15.1	6.4	**44.9**	**162.4**	**75.9**	393.3	**278.6**	26	120
2015	MCG	S6	S_622B	2.1	32.8	**82.0**	14	74.5	.	3	17.9	11.2	64.4	134.8	**62.3**	145.3	**396.0**	29	104
2015	MCG	S6	SIDNEY	0.8	**37.1**	**89.6**	27	72.4	2.8	1	18.1	**5.2**	30.2	112.8	43.5	832.0	**211.1**	28	115
2016	MCG	S2	06AB_24	2.5	33.1	**93.7**	26.0	80.2	**2.4**	1	**10.9**	**4.6**	**44.0**	**124.4**	76.1	265.9	212.9	50	24
2016	MCG	S2	06BA_63	.	**37.1**	**92.3**	20.0	80.9	3.8	1	**10.4**	**5.2**	50.1	99.2	80.0	234.1	235.2	38	55
2016	MCG	S2	06BA_81	1.7	33.0	**99.0**	24.0	83.5	**2.4**	1	**9.2**	**4.9**	54.3	**115.3**	80.8	**49.5**	198.6	52	16
2016	MCG	S2	06MT_26	2.6	**39.3**	**97.8**	25.0	82.3	2.8	2	**9.6**	**4.5**	46.8	**116.7**	**60.6**	253.4	195.0	49	33
2016	MCG	S2	06MT_59	2.5	31.2	**94.4**	31.5	81.1	2.7	2	**11.0**	**4.9**	46.2	**112.6**	**48.5**	619.2	**188.4**	43	43
2016	MCG	S2	06MT_67	2.6	**39.1**	**98.6**	23.0	82.3	2.8	2	**10.2**	**4.7**	46.8	96.5	82.1	**54.1**	249.6	55	20
2016	MCG	S2	06MT_82	3.2	35.2	**98.2**	28.5	82.0	2.6	1	**11.2**	**4.9**	45.5	**145.3**	74.9	418.8	215.9	56	14
2016	MCG	S2	06N2_06	2.1	34.5	**98.9**	25.5	80.6	2.8	1	**10.7**	**4.9**	48.7	97.4	**64.3**	389.5	200.6	42	48
2016	MCG	S2	06N2_17	2.2	46.9	**99.4**	14.0	83.3	**2.4**	1	**10.6**	**5.0**	49.9	107.8	76.8	623.7	249.5	50	28
2016	MCG	S2	06N2_39	2.0	**42.3**	**99.6**	17.5	81.9	2.7	1	**10.9**	**5.2**	48.7	164.1	76.7	258.0	206.6	55	12
2016	MCG	S2	06N2_70	2.6	**40.1**	**98.5**	35.0	84.1	3.0	1	**10.8**	5.7	56.7	97.0	92.3	**95.5**	296.8	45	41
2016	MCG	S2	06WA_38	1.9	**36.2**	**93.2**	26.0	80.8	2.7	1	**11.6**	**4.7**	**43.9**	176.1	71.5	291.6	266.5	54	18
2016	MCG	S2	06WA_77	2.8	33.5	**92.9**	21.5	81.6	**2.2**	2	**9.7**	**4.2**	47.8	108.0	**62.9**	382.7	**174.1**	37	52
2016	MCG	S2	07AB_53	2.2	35.5	**99.0**	27.0	81.0	2.6	1	**11.7**	5.3	47.0	198.3	100.0	114.5	269.7	57	8
2016	MCG	S2	07AB_77	2.7	35.9	**94.2**	35.0	80.9	3.2	1	**11.1**	**5.1**	46.5	151.5	**54.0**	658.6	209.2	55	15
2016	MCG	S2	07MT_40	3.2	**40.8**	**95.0**	19.5	81.5	**2.5**	1	**10.8**	**4.4**	**43.5**	**130.8**	**69.6**	428.5	209.1	51	28
2016	MCG	S2	07MT_94	1.6	**40.3**	**97.3**	27.5	81.9	**2.5**	1	**10.6**	**4.7**	46.3	**140.6**	73.2	240.3	206.6	56	13
2016	MCG	S2	07N2_02	2.3	**40.8**	**97.8**	24.5	81.1	3.1	2	12.6	5.4	**43.7**	**125.9**	**60.1**	587.8	259.0	54	16
2016	MCG	S2	07N2_08		35.6	**97.5**	22.0	81.5	4.2	1	**10.1**	5.5	55.6	90.3	81.9	**85.8**	269.3	48	36
2016	MCG	S2	07N2_13	1.8	**42.8**	**99.4**	21.5	82.3	.	3	**10.8**	**5.1**	47.8	**125.2**	**69.5**	488.3	237.9	54	20
2016	MCG	S2	07N2_31	1.9	**43.8**	**96.7**	32.0	83.3	.	3	12.5	5.6	46.5	**137.3**	72.1	501.6	296.2	59	7
2016	MCG	S2	07N2_38	3	**38.3**	**98.1**	14.5	82.2	3.0	1	**10.8**	**4.3**	**43.2**	**132.9**	70.9	552.7	209.4	55	17
2016	MCG	S2	07N2_61	2.5	**42.4**	**98.5**	22.0	81.6	3.4	1	**11.4**	5.5	50.5	101.1	94.0	389.7	270.2	48	32
2016	MCG	S2	07N2_73	1.5	**38.8**	**97.8**	30.5	82.3	2.9	1	12.3	6.1	51.5	167.1	110.7	454.4	283.0	50	28
2016	MCG	S2	07WA_03	2.9	**40.7**	**99.2**	12.0	81.3	3.5	2	**9.9**	**4.6**	47.5	**116.0**	**57.7**	145.7	**182.0**	49	30
2016	MCG	S2	07WA_13	1.7	**39.1**	**95.5**	22.5	80.5	3.9	1	**10.8**	5.6	53.5	109.0	108.6	122.5	288.7	48	37
2016	MCG	S2	08AB_17	2.3	35.4	**99.1**	29.0	82.1	2.8	1	**10.0**	**4.5**	46.4	106.5	**67.8**	323.7	**189.2**	48	36
2016	MCG	S2	08AB_24	2.2	**39.2**	**95.6**	17.0	80.7	3.4	1	**11.4**	5.4	50.3	**143.3**	104.7	247.7	265.0	49	20
2016	MCG	S2	08AB_45	1.7	**37.1**	**97.6**	19.0	82.7	3.7	1	**11.8**	5.7	50.8	**143.8**	85.7	191.3	282.3	41	7
2016	MCG	S2	08BA_02	2.2	35.8	**94.6**	26.0	81.1	3.0	1	**10.9**	5.5	51.9	**142.3**	91.7	226.5	250.6	47	17
2016	MCG	S2	08BA_11	1.3	**38.7**	**98.0**	24.0	82.6	4.8	1	**11.8**	6.1	52.8	**119.7**	103.5	248.0	328.2	50	32
2016	MCG	S2	08BA_76	2.2	**36.4**	88.4	23.0	79.8	4.3	1	12.3	6.1	50.3	181.6	123.8	183.9	332.0	41	28
2016	MCG	S2	08MT_04	2	**39.2**	**97.9**	17.0	80.1	2.8	1	12.1	**5.1**	45.9	163.7	72.5	364.3	220.1	57	30
2016	MCG	S2	08MT_41	.	**37.3**	**97.5**	23.0	81.3	3.7	1	**10.2**	**5.2**	54.0	101.4	83.9	212.2	240.2	45	37
2016	MCG	S2	08MT_68	2.3	**37.1**	**97.4**	20.5	81.0	2.6	1	**9.9**	**4.4**	45.1	109.7	**61.0**	308.5	**172.0**	42	36
2016	MCG	S2	08N2_12	2.9	**44.4**	**99.1**	23.5	81.6	**2.1**	1	**11.4**	**4.9**	45.3	**113.1**	**64.3**	481.7	220.3	60	30
2016	MCG	S2	08N2_37	1.8	**44.1**	**98.8**	20.0	80.9	3.3	1	12.4	5.7	48.0	**120.6**	95.3	328.0	298.9	51	39

2016	MCG	S2	08N2_62	2.5	47.5	**99.5**	25.0	82.7	2.6	1	**11.0**	**4.8**	45.5	107.7	**66.9**	337.6	237.4	60	38
2016	MCG	S2	08N2_66	2.3	**43.7**	**98.7**	24.0	82.9	**2.5**	1	**10.5**	**5.2**	51.8	**124.2**	75.3	422.7	230.3	53	30
2016	MCG	S2	08N2_73	2.3	46.8	**98.8**	25.0	81.7	2.8	1	**11.4**	**4.8**	45.2	103.4	73.5	600.9	239.4	60	50
2016	MCG	S2	08N2_80	2.9	**42.6**	**99.0**	23.5	81.5	3.4	2	**11.3**	**5.2**	48.6	**144.2**	77.6	477.2	239.3	59	9
2016	MCG	S2	08WA_11	1.8	**37.0**	**95.3**	29.0	82.9	3.4	1	**10.2**	5.3	56.7	**114.9**	107.4	194.5	285.0	47	47
2016	MCG	S2	08WA_27	2	**38.9**	**96.7**	27.0	81.4	**2.5**	1	**10.2**	**4.8**	47.5	**113.7**	**68.3**	327.9	**185.0**	45	35
2016	MCG	S2	08WA_40	2.9	**36.6**	**97.2**	21.0	81.3	2.8	1	**9.3**	**4.7**	**44.5**	**116.7**	**59.6**	193.0	**170.1**	44	5
2016	MCG	S2	08WA_64	1.7	**42.8**	**99.3**	14.0	81.3	3.4	1	**10.6**	**4.6**	45.9	**130.6**	**55.3**	111.4	**186.6**	59	22
2016	MCG	S2	09AB_10	2.1	**38.5**	**96.2**	25.0	81.9	2.8	2	**11.5**	**4.6**	**41.1**	94.0	**50.8**	.	**176.6**	40	3
2016	MCG	S2	09AB_15	.	**39.0**	**98.0**	21.5	81.0	3.6	1	**11.4**	**5.1**	46.5	101.4	74.0	250.0	243.1	51	20
2016	MCG	S2	09AB_43	1.3	**38.5**	88.1	12.5	81.9	3.7	2	13.2	5.8	**43.3**	**128.5**	87.5	.	271.4	46	5
2016	MCG	S2	09AB_48	1.7	**39.7**	**96.0**	27.0	81.6	2.0	1	**11.4**	**4.5**	**41.1**	154.6	**65.6**	662.3	187.7	58	6
2016	MCG	S2	09AB_82	2.9	**38.9**	**99.3**	23.0	81.4	2.8	2	**10.2**	**4.5**	46.2	92.6	**61.0**	376.1	192.8	47	39
2016	MCG	S2	09BA_03	2.3	34.9	**98.2**	25.0	79.5	**2.5**	1	14.1	6.3	45.6	225.0	87.3	223.4	330.6	38	47
2016	MCG	S2	09BA_10	1.9	**44.3**	**99.0**	21.5	82.0	2.9	2	**10.5**	**4.8**	48.3	**119.9**	95.0	238.8	227.4	55	47
2016	MCG	S2	09BA_89	1	**36.2**	**93.4**	26.0	81.0	4.3	1	**11.3**	5.3	48.4	**138.1**	122.8	179.0	310.0	52	5
2016	MCG	S2	09MT_16	2.4	**37.6**	**98.1**	21.0	81.7	2.7	1	**9.6**	**4.5**	49.4	**118.4**	91.3	202.0	223.6	45	50
2016	MCG	S2	09MT_78	2.6	**39.6**	**99.4**	26.0	81.1	2.7	1	**10.3**	**4.4**	45.3	152.9	**67.9**	279.8	**184.9**	49	27
2016	MCG	S2	09MT_94	2.3	**36.5**	**96.6**	24.0	81.4	3.1	1	**9.8**	5.3	57.0	**114.0**	105.3	281.6	264.4	47	40
2016	MCG	S2	09N2_12	1.8	**42.1**	**96.6**	20.0	79.8	**2.3**	1	**11.9**	**5.0**	45.2	165.5	76.0	323.6	240.9	60	8
2016	MCG	S2	09N2_16	1.9	**42.0**	**98.0**	25.0	82.0	4.1	2	**11.3**	5.3	48.9	106.5	74.3	175.0	262.7	54	31
2016	MCG	S2	09N2_21	3	**40.7**	**98.9**	25.5	82.6	2.8	2	**10.4**	**4.5**	**44.8**	**116.3**	85.7	209.4	240.3	46	50
2016	MCG	S2	09N2_29	2.6	**40.3**	**97.9**	31.0	82.4	.	3	**10.5**	**4.8**	46.7	**117.1**	**64.1**	841.4	223.7	52	12
2016	MCG	S2	09N2_39	2.7	**41.4**	**96.6**	23.0	80.8	3.1	2	**11.2**	**4.9**	46.2	**137.8**	71.2	393.5	220.8	53	25
2016	MCG	S2	09N2_55	1.8	**40.4**	**96.2**	20.5	80.9	3.2	1	**10.9**	**5.2**	49.8	156.6	100.6	174.8	241.2	54	47
2016	MCG	S2	09N2_72	.	47.6	**99.5**	23.0	81.3	2.8	1	**11.7**	5.3	45.8	150.4	98.2	**70.1**	258.8	70	31
2016	MCG	S2	09WA_15	.	**39.5**	**98.5**	20.0	82.1	2.6	1	**10.0**	**4.8**	49.6	**110.2**	71.9	165.6	219.7	51	39
2016	MCG	S2	09WA_19	2.3	35.2	**97.2**	21.0	80.9	**2.2**	1	**10.4**	**4.7**	48.4	**112.3**	**61.2**	193.8	190.8	40	3
2016	MCG	S2	09WA_52	2.6	33.7	**96.6**	23.0	82.8	2.6	2	**11.2**	**5.0**	47.9	165.5	77.3	130.1	231.2	52	13
2016	MCG	S2	09WA_64	2.3	34.3	**96.6**	19.0	81.9	**2.4**	1	**9.1**	**4.0**	47.9	**119.6**	**67.6**	**92.1**	**167.2**	45	35
2016	MCG	S2	AC_MET	2	**39.2**	**97.3**	30.5	81.9	4.4	1	**11.7**	6.0	53.9	**131.3**	99.5	177.8	304.7	51	24
2016	MCG	S2	CON	1.8	**40.0**	**98.3**	27.0	83.1	2.7	1	**10.9**	**5.2**	50.4	**138.5**	82.9	660.0	225.0	50	21
2016	MCG	S6	06AB_55	1.5	33.5	**95**	16	78.5	3.18	2	**11.8**	5.0	**45.4**	122.8	**62.5**	541.9	**244.7**	52	18
2016	MCG	S6	06AB_62	2.1	34.8	**96.9**	21.5	80.2	2.99	1	**12.1**	**5.6**	48.7	**172.6**	**76.6**	229.0	**288.6**	50	1
2016	MCG	S6	06AB_84	2.2	32.0	**96.8**	20	79.4	2.67	2	**10.5**	4.3	**43.5**	139.0	**59.7**	336.0	**219.3**	48	20
2016	MCG	S6	06BA_06	1.9	34.9	**98**	27.5	80.9	3.37	2	13.6	6.4	49.8	**235.6**	**95.3**	170.2	**313.7**	48	48
2016	MCG	S6	06BA_30	1.5	35.7	**98.1**	28.5	81.7	3.33	2	**11.8**	**5.6**	49.4	**173.7**	**96.3**	139.9	**288.8**	58	25
2016	MCG	S6	06MN_10	2.0	35.1	**98.4**	28	80.1	3.45	1	**12.4**	6.0	49.3	**198.3**	**86.2**	304.3	**316.2**	51	42
2016	MCG	S6	06MN_18	1.5	**38.0**	**97.6**	21.5	80.5	4.38	2	**12.4**	**5.3**	**43.6**	147.6	**77.8**	226.1	**318.2**	53	22
2016	MCG	S6	06MN_51	1.8	33.2	**96.5**	27	77.7	3.57	1	14.3	6.0	**45.1**	**223.0**	**68.7**	248.6	**295.7**	40	28
2016	MCG	S6	06MN_62	1.2	**38.5**	**97.9**	26.0	80.5	4.6	1	**13.0**	6.0	48.2	**159.8**	**90.3**	195.5	**338.7**	54	34
2016	MCG	S6	06N6_66	1.7	32.7	**98.6**	18	80.0	.	3	**11.7**	5.9	54.6	141.0	**90.7**	**106.3**	**322.6**	55	36
2016	MCG	S6	06N6_71	2.0	32.9	**98.4**	29	80.3	3.1	1	**10.6**	4.8	**45.7**	**162.6**	**83.2**	**94.4**	**250.3**	58	44
2016	MCG	S6	06N6_88	1.9	35.4	**97.6**	16	78.7	3.0	2	**11.7**	5.1	**46.7**	133.3	**74.3**	261.0	**273.6**	49	37
2016	MCG	S6	07AB_16	1.9	30.4	**98.1**	21.5	79.5	3.3	2	**10.5**	5.0	48.6	122.1	**72.1**	**114.8**	**251.2**	46	19
2016	MCG	S6	07BA_09	2.1	34.4	**95.8**	26.5	80.6	**2.2**	1	**11.3**	**5.4**	50.0	**225.3**	**97.7**	188.2	**283.6**	55	29
2016	MCG	S6	07BA_24	1.7	34.4	**98.3**	17	79.9	2.7	1	**12.9**	**5.6**	**45.5**	**176.1**	**68.2**	184.8	**360.4**	63	25
2016	MCG	S6	07BA_28	1.5	35.3	**98.4**	15	79.1	3.6	1	**12.4**	**5.2**	**44.9**	**172.4**	**79.4**	133.4	**278.9**	62	54
2016	MCG	S6	07MN_42	1.5	35.5	**97.8**	26	80.5	2.7	2	**13.0**	6.0	47.6	**189.2**	**77.9**	294.6	**295.1**	52	18
2016	MCG	S6	07MN_52	1.2	34.2	**96.9**	24	79.7	2.6	2	13.4	6.5	50.1	**204.3**	**80.7**	335.2	**334.7**	49	10
2016	MCG	S6	07MN_85	1.3	**36.8**	**97.9**	24.0	79.8	3.6	2	13.3	**5.7**	**44.6**	**208.4**	**77.0**	284.3	**303.0**	54	16
2016	MCG	S6	07MN_90	1.8	35.4	**97.1**	22	78.4	3.4	2	**12.7**	5.8	47.5	**194.5**	**94.4**	248.8	**285.1**	51	40
2016	MCG	S6	07MN_94	1.6	32.6	**98.3**	18	78.9	.	3	13.9	6.4	**46.9**	**165.1**	**70.9**	215.2	**323.4**	46	47
2016	MCG	S6	07N6_51	1.7	35.2	**98.9**	26.5	79.0	3.8	3	**12.2**	6.1	52.5	140.5	**85.5**	173.6	**310.8**	48	27

2016	MCG	S6	07N6_80	1.9	34.4	**98**	27	78.8	3.6	2	**11.8**	**5.2**	**45.1**	95.8	**77.4**	140.8	**277.7**	51	3
2016	MCG	S6	07UT_18	1.9	**36.2**	**97.2**	17	80.9	3.6	1	**12.1**	5.0	**42.5**	98.6	**65.5**	319.6	**254.7**	52	5
2016	MCG	S6	07UT_36	1.6	**39.5**	**98.3**	4	77.5	.	3	**10.6**	**5.3**	47.7	142.5	**55.6**	410.6	206.5	37	31
2016	MCG	S6	07UT_71	1.8	33.5	**98.3**	27	79.6	3.4	1	**12.1**	**5.2**	**46.9**	145.8	**77.7**	161.5	**279.4**	66	34
2016	MCG	S6	07UT_83	2	33.1	**93.6**	16	77.5	**2.2**	1	**11.9**	4.2	39.5	134.2	47.6	510.1	181.6	36	27
2016	MCG	S6	07UT_88	1.4	34.3	**91.5**	27	79.2	3.1	1	**12.6**	4.8	39.4	121.7	**83.2**	448.3	**265.9**	48	33
2016	MCG	S6	07UT_93	1.8	34.7	**95.3**	14.8	78.7	**2.1**	1	13.7	5.1	37.6	133.0	**55.3**	510.3	**262.0**	47	44
2016	MCG	S6	07UT_96	2.1	34.1	**91.2**	13	79.2	2.8	2	**11.9**	**5.3**	**45.1**	141.2	**69.4**	347.6	**246.9**	62	36
2016	MCG	S6	08AB_54	1.9	32.7	**98.8**	26	79.6	3.3	1	**11.7**	5.1	**45.1**	**157.6**	**80.3**	133.7	**282.2**	62	36
2016	MCG	S6	08AB_80	1.4	38.2	**97.8**	23.5	80.6	3.6	2	**11.6**	**5.4**	48.3	**156.0**	**88.2**	186.2	**269.2**	56	24
2016	MCG	S6	08BA_44	1.9	32.7	**94.9**	25	80.6	2.7	1	**11.2**	5.1	47.6	**197.0**	**68.1**	189.2	**227.4**	49	55
2016	MCG	S6	08BA_54	2.2	34.1	**97.7**	32	81.0	**2.2**	1	**11.1**	4.9	**45.3**	**199.9**	**69.7**	209.6	**252.7**	54	2
2016	MCG	S6	08BA_60	2.1	31.3	**93.4**	30	80.0	**2.3**	1	**11.8**	**5.3**	48.6	**219.5**	**109.4**	207.5	**262.5**	57	54
2016	MCG	S6	08BA_64	0.8	35.1	**96.5**	22.5	80.5	4.1	1	**12.5**	5.9	49.5	139.8	**86.0**	160.5	**310.9**	55	47
2016	MCG	S6	08MN_34	1.6	31.8	**92.5**	29	80.2	4.6	2	**12.0**	**5.7**	50.8	115.0	**91.9**	**113.5**	**317.4**	51	43
2016	MCG	S6	08MN_49	1.7	32.5	**94.9**	34	80.8	**2.2**	1	**10.9**	**5.2**	51.3	132.3	**68.8**	**92.8**	**234.0**	57	4
2016	MCG	S6	08MN_59	.	34.1	**98.2**	24	80.4	3.2	1	13.1	6.6	52.9	**197.1**	**81.3**	155.0	**298.1**	54	5
2016	MCG	S6	08MN_67	1.8	34.6	**96.4**	30.5	79.0	2.7	2	13.4	**5.3**	41.6	**218.2**	**73.1**	338.2	**245.5**	54	18
2016	MCG	S6	08MN_78	1.7	34.5	**96.6**	23.5	80.7	3.1	2	**11.7**	**5.3**	**46.5**	**180.4**	**74.8**	208.0	**278.8**	56	43
2016	MCG	S6	08MN_84	.	30.1	**88.3**	31	80.8	**2.3**	1	**10.9**	4.9	47.2	**185.6**	**78.1**	**91.7**	**229.0**	55	18
2016	MCG	S6	08N6_09	2.1	33.8	**98**	20	81.9	3.2	2	**10.2**	4.8	50.5	113.4	**67.1**	306.1	**229.5**	38	7
2016	MCG	S6	08N6_21	1.8	30.6	**94.9**	32.0	80.5	2.7	1	**10.6**	4.9	48.3	139.9	**86.8**	**103.5**	**240.7**	53	23
2016	MCG	S6	08N6_35	1.8	34.6	**98.6**	22	79.2	.	3	**11.4**	**5.4**	49.9	114.8	**64.0**	261.4	**269.6**	48	32
2016	MCG	S6	08N6_52	2.6	34.4	**97**	31.5	79.3	3.5	2	**11.6**	5.8	51.6	130.0	**92.1**	**48.5**	**330.8**	54	19
2016	MCG	S6	08N6_77	2.5	32.8	**98.3**	29.5	79.5	3.5	2	**12.3**	**5.5**	**46.3**	**178.0**	**81.9**	182.9	**269.7**	57	11
2016	MCG	S6	08N6_91	2.1	32.3	**98.9**	18	81.5	3.2	2	**10.9**	**5.6**	53.0	**154.2**	**91.5**	**113.0**	**331.4**	59	11
2016	MCG	S6	08N6_96	2.1	35.1	**97.8**	22	80.9	.	3	**12.7**	6.8	55.8	**204.2**	**81.8**	289.2	**357.4**	49	22
2016	MCG	S6	08UT_10	1.6	**37.6**	**98.9**	14.0	77.9	.	3	13.4	5.8	**44.0**	130.1	**71.3**	273.2	**297.6**	40	23
2016	MCG	S6	08UT_80	1.9	33.1	**89.6**	24	78.7	2.6	1	**11.4**	4.4	39.9	115.0	49.8	352.0	**210.8**	36	56
2016	MCG	S6	09BA_37	1.9	32.3	**98.1**	23.0	81.6	3.2	2	**10.6**	4.9	49.4	131.0	**81.6**	**129.1**	**278.4**	49	26
2016	MCG	S6	09BA_50	1.8	33.0	**96.6**	28	79.3	**2.4**	1	13.5	**5.7**	**44.8**	**208.4**	**80.9**	223.7	**275.2**	59	44
2016	MCG	S6	09MN_04	2.5	32.0	**98.6**	29.5	79.7	**2.0**	1	**12.3**	5.1	**42.7**	**223.5**	**80.5**	250.5	**235.4**	57	22
2016	MCG	S6	09MN_30	1.5	31.7	**87.5**	25	79.7	3.2	1	**11.4**	5.0	**46.1**	**166.9**	**96.1**	199.8	**286.0**	53	15
2016	MCG	S6	09MN_50	1.9	34.5	**97.4**	30	79.9	.	3	**12.8**	6.3	51.1	**188.9**	**77.5**	319.5	**332.6**	49	5
2016	MCG	S6	09MN_70	1.6	**36.5**	**98.2**	22.5	80.5	4.5	3	**12.7**	**5.5**	**45.9**	**163.7**	**88.2**	**109.0**	**338.6**	55	43
2016	MCG	S6	09N6_36	1.8	34.6	**97.7**	21	79.3	3.5	2	**12.3**	5.8	48.4	**161.6**	**79.9**	256.8	**288.6**	56	50
2016	MCG	S6	09N6_59	1.7	35.8	**98.2**	26	80.3	3.5	2	**12.5**	**5.6**	**46.5**	**195.7**	**81.1**	**139.9**	**280.9**	58	19
2016	MCG	S6	09N6_63	1.9	33.9	**99.5**	25	81.3	**2.2**	1	**11.2**	4.8	**44.8**	**172.7**	**75.7**	168.1	**263.2**	54	24
2016	MCG	S6	09N6_69	1.5	34.0	**98.6**	25.5	79.8	4.2	3	**12.7**	**5.6**	**45.4**	145.0	**78.2**	231.4	**305.3**	60	12
2016	MCG	S6	09UT_13	1.7	**36.0**	**97.7**	15.5	79.0	3.8	2	**11.7**	**5.2**	47.4	**153.1**	**72.8**	334.0	**262.9**	57	8
2016	MCG	S6	AC_MET	1.8	**37.1**	**97.2**	23.7	81.1	4.1	2	**11.9**	5.1	**44.9**	**152.5**	**93.7**	218.3	**313.7**	59	14
2016	MCG	S6	CDC	1.6	**36.7**	**96.9**	24.5	80.6	3.5	2	**12.1**	**5.5**	47.1	**158.7**	**79.5**	275.4	**280.4**	53	18
2016	MCG	S6	CON	1.8	**39.4**	**99.2**	25	81.7	3.3	1	**11.3**	4.9	**46.2**	122.0	**82.7**	215.8	**237.8**	51	36
2016	MCG	S6	S_610B	1.4	33.2	**96.5**	27	80.6	**2.4**	1	**12.3**	**5.7**	49.8	148.0	**70.8**	181.3	**300.6**	59	15
2016	MCG	S6	S_622B	1.4	**39.3**	**97.5**	24.5	80.7	3.7	1	**12.7**	6.0	48.7	124.1	**91.9**	268.0	**300.8**	51	29
2016	MCG	S6	SIDNEY	1	**39.9**	**97.1**	17	77.4	**2.3**	1	14.1	**5.5**	**40.6**	116.2	**47.0**	535.2	187.7	33	57
2016	MCG	S6	STONE	1	34.9	**86.9**	18.0	77.4	2.8	1	13.3	4.4	34.4	108.0	**52.7**	423.6	185.4	27	58
			Min	0.8	30.1	86.9	4.0	77.4	2.0	1.0	10.2	4.2	34.4	95.8	47.0	48.5	181.6	26.5	2.0
			Max	2.6	39.9	99.5	34.0	81.9	4.6	3.0	14.3	6.8	55.8	235.6	109.4	541.9	360.4	66.0	58.0
			Avg	1.8	34.5	96.6	23.5	79.8	3.2	1.6	12.1	5.4	46.8	160.0	77.7	237.2	277.8	51.7	27.8
			Std. Dev	0.3	2.2	2.7	5.6	1.1	0.7	0.7	1.0	0.5	3.9	34.9	12.6	112.0	40.3	7.4	15.4
			Std. Error	0.0	0.3	0.3	0.7	0.1	0.1	0.1	0.1	0.1	0.5	4.2	1.5	13.5	4.8	0.9	1.9
			Ideal Range	.	36-45	> 80%	.	.	1.8-2.5	.	≤ 13.0%	5.2-5.7%	42-47%	> 150	> 50	< 120	> 210	.	.
			# Lines Met Criteria	.	.	215	.	.	28	.	152	65	110	103	238	36	210	.	.