EFFECT OF THE METHOD AND RATE OF PLANTER APPLIED NITROGEN ON CORN AND GRAIN SORGHUM PRODUCTION

By

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Abstract: In Oklahoma corn (Zea mays) and grain sorghum (Sorghum bicolor L) account for nearly 20% of all the total value of farmed cropland in the state. Fertilizer, specifically nitrogen (N) is one of the greatest input cost and potential environmental risk points for the central Great Plains producers. It is well documented that preplant N is inefficient and both crops benefit from in-season N management. However, it is also documented in some studies that there is a positive response to planter applied N. The placement and timing of in-season applied N is well researched but there is a lack of data on planter applied N fertilizer in the region and none that evaluates the method and rate of such an application. The objective of this study was to test the impact of the method and rate of planter applied N on plant stand and grain yield of corn and grain sorghum in central Oklahoma. The placement methods evaluated were in-furrow, surface dribble, dry surface broadcast, and “2x2” coulter injected. Nitrogen rates evaluated in this study were 9, 18, and 27 kg N ha^{-1}, as well as a non-fertilized check for a total of 13 treatments. Fertilizers utilized in the study included liquid urea-ammonium nitrate (28-0-0) and Urea (46-0-0). The study was repeated over three growing seasons: 2020, 2021, and 2022 with 2 locations per year in central Oklahoma, USA. Stand counts for the corn averaged 20.3 plants per row (each row was 6 m^{-1} in length for both crops) across all sites and treatments. The grain sorghum stands average 36 plants row^{-1}. Overall site years corn grain yields averaged 3.1 Mg ha^{-1} while the grain sorghum trials averaged 1.8 Mg ha^{-1} across the six locations. These yield values were well below expected for a managed research study as the state average for the same period was 8.6 Mg ha^{-1} and 2.37 Mg ha^{-1} for corn and grain sorghum respectively. The results of this study were that neither stand nor grain yield were statistically impacted by neither the N placement method nor N rate in both corn and grain sorghum. While low yields were expected due to reduced N application rates this research experienced exceptionally low yields and no response to N rate suggesting N was not the limiting factor. Across all site years and crops the environment and weather conditions impacted this study reinforcing the concept of Liebig’s Law of the Minimum. In which yield is control by the greatest limiting factor and in the case of the work, the greatest limiting factor was environment.

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CHAPTER I

INTRODUCTION

The United States of America has approximately 37.5 million hectares of corn (*Zea Mays*) and 2.6 million hectares of grain sorghum (*Sorghum bicolor L*) in production in 2021 (USDA-NASS, 2021). Oklahoma has 2.71 million hectares of cropland land, of which approximately 5.2% and 6.4% is in corn and sorghum production, respectively (USDA-NASS, 2022). In Oklahoma, these crops play a vital role in the state's economy. The combined hectares of corn and grain sorghum had a value of approximately $222.6 million in 2022, nearly 20% of the total value of Oklahoma farmed cropland (USDA-NASS, 2022). Corn is used primarily for livestock feed and ethanol production, as well as for human consumption in the form of cornmeal, corn syrup, and other products. Sorghum, on the other hand, is a versatile crop that can be used for food, feed, and fuel. It is commonly used in livestock feed, as well as for producing ethanol and other biofuels.

The standard practice among farmers for nitrogen (N) application in both corn and sorghum production systems is to apply a portion, if not all, of the crops total N need as a pre-plant application, with the remainder applied during the growing season as a side dress application. However, this pre-plant application is done well in advance of planting, providing opportunity for loss prior to crop establishment. In addition, planting is performed early in the spring when the weather is cooler, which limits crop growth and the root system's ability to absorb nitrogen during the initial stages of growth. This again leaves opportunity for N losses. Recent research has shown that delaying N application until as late as V11 for corn may not result in a significant yield loss (about 3% of yield loss) (Scharf, 2002). In grain sorghum, Smith et al. (2021) also showed that delaying N applications to 45 days after planting in grain sorghum does not result in a detrimental loss in yield. A method of avoiding early season N loss and improving its availability is to apply a small amount of N at planting through the use of starter fertilizer (Blandino et al., 2022).

A starter fertilizer is defined as placing nutrients in a concentrated zone close to the seed at the time of planting (Hergert et al., 2012). The same paper document the primary benefits of applying N at planting was an increase in early growth and crop uniformity. There are three primary methods of applying starter fertilizer. Direct seed contact (in-furrow), a subsurface band (2x2) and a dribble surface (Niehues et al., 2004). In-furrow application, which is the application of fertilizer in the seed furrow. This method is typically used for the application of immobile nutrients. The amount of N that can be applied in-furrow is limited due to potential salt injury to the germinating seedling. Many fertilizers contain salts which, when applied at rates in excess, can result in moving out water of the plant cells, which causes seedling injury and reduced stand (Hergert et al., 2012). However, research has shown that the when the amount of salt is applied above the level of 22 kg ha^{-1} a significant decrease in stand occurred (Niehues et al., 2004). The application of starter N is more commonly associated with the 2x2 method, meaning a liquid fertilizer is applied 5cm to the left or right of the seed furrow and 5cm below the surface. This allows for a greater amount a fertilizer to be applied (Niehues et al., 2004; Khosla et al., 2000). However, the 2x2 application requires additional components to be added to the planter, in lieu of adding a 2x2 system some farmers choose to apply the fertilizer as a surface dribble band. These applications can use either a dry or liquid fertilizer source. However timely rains are needed for this method to work. In terms of the source of fertilizer used with surface dribble band, a negative of dry fertilizer compared to the liquid one is volatilization. Surface applied dry fertilizers volatilize fast with rates of 0.37 kg N $ha^{-1}h^{-1}$ to 3.0 kg N $ha^{-1}h^{-1}$ depending on the fertilizer source (Keller et al., 1986). In reference to the use of 2x2 or dribble band Mengel et al. (1982) stated that applying liquid urea ammonium nitrate (UAN) and urea (46-0-0) in surface resulted in lower corn yields compared to UAN application in the sub-surface (Mengel et al., 1982).

While there is significant research on planter applied N fertilizer in the corn little work has been performed in the southern Great Plains. This study aims to evaluate the impact of methods and rate of planter applied N rates on the stand and final grain yield of corn and sorghum. Based on the salt index of the fertilizers that were used in this study it is hypothesized that 27 kg N ha^{-1} will have a negative impact on the stand and yield of both corn and grain sorghum. Furthermore, it is also hypothesized that an application of 27 kg N ha^{-1} will not have a negative impact on stand and a positive impact on yield in both corn and grain sorghum.

CHAPTER II

REVIEW OF LITERATURE

Nitrogen in Agriculture

Nitrogen (N) makes up approximately 78% of atmospheric air (Alan Barker, 1990) equating to an estimated thickness of 96.5 km, thus making N more atmospherically abundant than hydrogen (H) and oxygen (O_2). However, the majority of atmospheric N is dinitrogen (N_2) which is not readily available for plant use. Through biological microbial decomposition and synthetic N fixation processes N_2 is converted into plant available forms such as nitrate (NO_3^-) and ammonium (NH_4^+). The mechanisms of the N cycle consist of multiple additions ranging from plant and animal residues, N fixation through natural processes including microbial communities and lightening, and industrial fixations resulting in the application of inorganic fertilizers. The addition of fertilizers can be obtained through organic and inorganic products for example organic methods include manure and/or chicken litter, while inorganic methods utilize synthetic fertilizers such as urea (CH_4N_2O). The method of synthetic N fixation refers to the Haber-Bosch processes that is utilized heavily in the production of commercial fertilizer. (GRC-NASA, 2021). (Scott C. Killpack, 2022). The Haber-Bosch process requires great a deal of temperature and pressure 1200^{o} C, 500 atm to achieve the conversion of N_2 into NH_3.

This temperature is achieved using methane as a fuel and source of hydrogen (H) and carbon (C) for the creation of ammonia (NH_3) gas and urea.

Due to the Haber-Bosch processes ability to generate N fertilizer products which provided more readily available N for plant uptake, the application of inorganic fertilizers become the main practice for crop fertilization. In 2018 approximately 11.6 Mt of N fertilizer were applied in the US (Lori E. Apodaca, 2021). Most of the applied N consisted of three main forms, anhydrous ammonia (82% nitrogen), UAN solution 28%, and urea. Of the 11.6 Mt Anhydrous ammonia accounts for 24%, UAN at 27% and urea at 25% of the total 76% of all N fertilizer applied (Lori E. Apodaca, 2021). Similarly, to any biogeochemical cycles, the nitrogen cycle experiences losses through various pathways including volatilization, denitrification, leaching, and plant loss. These loss pathways are displayed visually in Figure 1.

Nitrogen management in Corn

Nitrogen is required in large quantities for corn production due to its involvement in plant growth and development (Leghari et al., 2016). The goal for dryland corn production is to plant as early as possible in the early spring to avoid the heat of the summer at reproductive stages (Gordon et al., 1998). However, this leads to planting into cooler soil temperatures which adversely impacts a corn plants growth by slowing its development (Wortmann et al.., 2006). Traditional methods of N application involve applying much of the seasonal N requirements prior to planting; however, research has shown this practice leads to an increased risk of N loss (Scharf, 2002). Large preplant applications of N are more likely to result in losses due to the plants low requirements at early stages and its inability to effectively uptake supplied nutrient, however during the reproductive stages tasseling and silking N uptake and requirement are significantly greater than previous stages (Alley et al., 2009). Furthermore, preplant N applications applied to the surface have the potential risk of loss through volatilization. Additionally, research has indicated that different N fertilizers volatilize at different rates, a study conducted using urea, urea-urea phosphate, UAN and ammonium nitrate the study shows the volatilization of the fertilizers over 120 hours, with peak volatilization within the first 24 hours (Keller et al., 1986). A switch from a preplant application to a starter N application can limit the amount of N loss and provide corn with enough N for early growth. There are three typical methods of applying a starter for corn, the methods are a 2x2, in-furrow and dribble surface. With the N needs of corn, the delay of more N might have an impact on the final yield of corn. Scharf (2002) found that there was little to no evidence of irreversible yield loss when N applications were delayed to as late as V11, they noticed about 3% of a yield loss (Scharf, 2002). From a 22 yearlong study in Lancaster, WI results indicated that the optimum N rate is between 179-190 kg ha^{-1} (Vanotti, 1994). However, in dryer environments 20 kg N ha^{-1} for every 1 Mg of corn (Raun et al., 2008).

Nitrogen in Grain Sorghum

Nitrogen is an essential component in the growth and development of grain sorghum. In an irrigated study conducted in southwest Kansas over 55 consecutive years, found the average optimal rate of N was approximately 135 kg ha^{-1} with grain yields of about 8 Mg ha^{-1} (Schlegel et al., 2020). Those yields are well above the yield average of Oklahoma. Zhang et al., (2017) recommends a rate of 33.6 kg N ha^{-1} to achieve a grain yield of 2.1 Mg ha^{-1}. That yield recommendation is 0.6 Mg ha^{-1} higher than the average grain yield of Oklahoma. Grain sorghum production methods are very similar to corn with applying a preplant and following up with a supplemental side dress application midseason. It should be noted that side dress applications made in sandy soils should be made when plants are 30 cm in height and one third of total N was applied at or prior to planting (Wortmann et al., 2013). In a vertisol soil, N applications are split with 33% at planting and 67% at booting (Schwenke et al., 2019). A study conducted in the mid-Atlantic applied four starter-band rates at 11, 34, 56 and 78 kg N ha^{-1} with four side dress rates of 0, 45, 90, and 134kg N ha^{-1} had yields range from 1.7 Mg ha^{-1} to 11.9 Mg ha^{-1} (Khosla, 2000). The reason grain sorghum is often grown in the central plains from South Dakota to Texas (Sorghum 101, 2021) is due to the drought tolerance of the crop. With the drought tolerance it is grown in dryland and irrigated production systems. In these unstable yield environments determining N need at planting is extremely challenging. One strategy is to delay the majority of all N applications until the crops yield potential is more certain. A study performed in Oklahoma documented that there was no yield penalty to N fertilization delayed up to 45 days after planting (Smith et al. 2021). However, an application of limited amount of N at planting maybe an option to aid in early season growth.

Salt content of Fertilizer Sources

Fertilizers are an essential part of agricultural production with N being the most applied nutrient in worldwide (Statistia, 2023). Most fertilizer materials are highly soluble salts, which can cause injury to crops (Laboski, 2008). There are N fertilizers that can facilitate more damage with higher salt index rates, urea (46-0-0) 74.4, UAN (28-0-0)

63.0 and anhydrous ammonia (82-0-0) 47.1 (Mortvedt, 2001). These fertilizers are some of the more used fertilizers in Oklahoma. The salt index is the measure of the salt concentration, which is a measure of the increase in osmotic pressure produced by fertilizer (Mortvedt, 2001; Havlin et al., 2016). Osmotic pressure is the pressure that is required to stop or prevent the flow of a solvent through a semipermeable membrane (Chinard, 1954). The salt can be a problem to germinating seed and seedlings. A previous study found that corn is most sensitive to salt during the seedling phase and not at the germination phase of growth, although the increase in salinity can delay germination (Maas, 1982). In a similar study conducted in grain sorghum Mass et. al, 1985, found that grain sorghum is most sensitive to salinity during the vegetative phases of growth, while later maturity phases are less susceptible to salt injury.

Planter Applied Nitrogen

Planter applied N is a method of applying N as the seed is planted. This can be performed as a “2x2”, in-furrow and a surface application. These applications are typically consisting of N with or without the addition of phosphorus (P). Placing fertilizer with corn seed is a common practice that is used in northern climates to increase early season growth (Kaiser et al., 2013). No-till production can cause soil to be cooler than conventional tilled productions, resulting in reductions in nutrient uptake and crop growth (Gordon et al., 1998). In the event a started fertilizer is unable to meet nutrient demands of corn seedling, a supplemental side dress application is necessary in order to avoid N stress (Alley et al., 2010).

Corn

In a study from Mascagni (1996) using ammonium polyphosphate (APP 10-34-0) fertilizer found that starter application increased plant height and yield. The increase in grain yield regardless of the placement of an in-furrow and a sub-surface band as a 2x2 was also found from a meta-analysis study (Quinn et al., 2020). Minnesota has been historically recommending sulfur (S) applications in coarse-textured soil for corn, this study had starter applications which were applied with a combination of N only, N+P, N+S, and N+P+S the results showed that N, P and S uptake was increased by P and never by N (Kim et al., 2013). Bermeudes (2002) found that the effects of applying fertilizer at planting on yield was inconsistent but resulted in early growth. Applying fertilizer at planting is recommended in complement with a broadcast fertilizer applications in Iowa. Rates of N application vary between in-furrow to a sub-surface band. A similar study conducted by Niehues (2004) evaluated N rates for a surface and in-furrow application ranging from 11 to 134 kg ha^{-1} for a subsurface banding found that in two of three years there was a negative impact on stand (Niehues et al., 2004). In a similar study conducted at South Dakota, they found it difficult to identify notable injury during germination or as a seedling when N was applied in-furrow and sub-surface band (Clark et al., 2023). The type of fertilizer and placement can lower the risk of injury and can increase nutrient uptake. Kaiser et al. (2013) found that when evaluating N fertilizer and N fertilizers with P as AMS, APP, ATS, and DAP, the placement of fertility significantly impacted nutrient uptake. These studies are relevant to this research since they also cover N rates and placement. While most fertilizers that are used in a starter application contain P, this study is using N only fertilizers with a higher salt index than N with P fertilizers. Ammonium polyphosphate (APP) has a lower salt index value than N fertilizers which is why it is used in starter studies. According to Hergert et al., (2012), for both corn and grain sorghum, when N was placed in-furrow in sandy and non-sandy soils the safe rate is 46.7 L ha^{-1}. While when applied in a 2x2 system, the safe rate for sandy soil is 187+ L ha^{-1} and non-sandy soils safe rate is 374+ L ha^{-1} However, there is a rate which the N fertilizer has negative effects while applied in-furrow; An early study found that increasing N above 22 kg ha^{-1} direct seed contact did not increase yield and reduced stand in corn. (Niehues et al., 2004). Contrastingly a study conducted in the norther Great Plains with the N rates of 0, 8, 16 and 24 kg N ha^{-1} found that there was a significant response to N application with no mention of stand loss to application above 22 kg N ha^{-1} (Osborn, 2004). Alley et al. (2010) found that APP can be applied in-furrow at 112 kg N ha^{-1} then later states with liquid urea having lower salt index fertilizer applications still need to be applied with caution to avoid seedling injury (Alley et al., 2010). The reason for higher rates between an in-furrow and a sub-surface band can be explained by the salt index. With the risks of applying N in-furrow is just as effective as other placements and more economical in Nebraska (Wortmann et al., 2006).

Grain Sorghum

When compared to corn, there is a lack of study on starter N and grain sorghum, which is particularly prevalent in Oklahoma. Fertilizer that is placed in close proximity to growing seedlings can accelerate maturity (Gordon et al., 1998). A study conducted in grain sorghum observing the impacts of subsurface banding UAN as started found that it was responsive at eight of the twelve sites (Khosla et al., 2000). Wortmann et al., (2006) found that early corn and grain sorghum growth increased with application of starter N + P but didn't correlate to yield (Wortmann et al., 2006). No increase in yield with the application of APP was also found in a study conducted in Burleson County, Texas applying in-furrow at 56 L ha^{-1} and 2x2 at 168 L ha^{-1} with side dress applications (Church, 2018). Moreover, excess application of N can have a negative impact on yield component. This was explained in a study conducted in Oklahoma. This study found that 28.8 kg N ha^{-1} from APP can be applied in-furrow with no negative effects, however, there is a decrease in stand counts with yield loss when applying 57.3 kg N ha^{-1} (Lofton et al., 2019). The decline with the stand counts and yield can be contributed to salt N fertilizers. Eickhoff (2018) added that as much as 70% of stand can be lost by applying 30 kg N ha^{-1}.

CHAPTER III

METERIALS AND METHODES

This study evaluated both corn and grain sorghum over three growing seasons (2020-2022) with two locations per year. The locations were the Cimarron Valley Research Station (CVRS) near Perkins, OK (35˚59’36”N, 97˚02’33”W), Efaw Research Farm (EFAW) near Stillwater, Ok (36˚08’11”N, 97˚06’24”W) and the Lake Carl Blackwell Research Farm (LCB) near Perry Ok, (36˚ 08’53”N, 97˚17’21”W). The soil descriptions for these locations are in Table 1. The LCB location is irrigated by an overhead linear irrigation system with the surface water of Lake Carl Blackwell as the water source. The EFAW location for both corn and grain sorghum in 2020 and 2021 were rain fed. The 2021 CRVS was rain fed for the corn and had supplemental irrigation applied for the grain sorghum using drip tape place at the base of the plants on the harvest rows. Winter wheat was used as a cover crop and was terminated in March for all locations for both crops. Composite pre-plant soil samples were taken at each site for the seasons of 2021 and 2022 at a depth of 0-15 cm. The soil sample results for EFAW 2021, LCB 2021 and 2022 and CVRS 2022 are in Table 2.

This experiment was structured as a 4 x 3 factorial design arranged in a randomized complete block design with two factors: the placement method and N rate. The methods tested are an in-furrow (IF), surface dribble (SD), dry surface broadcast

(DSB), and 2x2 coulter injected (CI). Three N rates 9, 18, and 27 Kg N ha^{-1} was evaluated in this study across all four methods, with a non-fertilized check for a total of 13 treatments (Table 3) shows how the trials was structured. In the 2020 and 2021 crop years the studies were replicated three times while in 2022 a fourth replication was added. UAN (28-0-0) was the fertilizer N source for the planting methods of IF, SD, and CI and urea for the DSB application.

Plot size for the experiment was 3m, or four rows, wide by 6m long with a 3 m alley separating replications. A John Deere Max Emerge 2, 4-row planter on 76.2 cm row spacing was used in this study for all locations using the eSet corn plates, 90-hole, single row plates. The grain sorghum plates used are a 45-hole, single row plate. Liquid fertilizer application was performed using two different processes. A 95-liter tank with an electric pump that moves the liquid to 3 changeable orifices that are with seed, 2x2 and dribble surface. The electric pump was used in 2020 and 2022 for both locations. A CO_2 pressurized system that had in-furrow and 2x2 orifices was used in 2021 due to a mechanical failure of the electric pump system. The insecticide boxes on the planter were used to apply the dry fertilizer. The insecticide boxes were calibrated each season for the urea being used. The planting information, harvest date, seed variety, time to mid pollination, population and planting date are in included in Table 4 and Table 5.

Stand counts were performed approximately three weeks after emergence to allow late germinated seed to emerge. Stand counts were completed by counting the emerged plants in the harvest rows (the middle two rows) of the plot (6 m) separately, and then the stand counts were averaged for an average population per plot. The grain sorghum was chemically terminated with glyphosate when the majority of the plots have reached 50-75% black layer of the grain. This allowed timely harvest to avoid environmental and pest damage. Harvest was performed using a Kincaid 8xp plot combine equipped with a 2-row corn header and a Harvest Master weigh system to collect moisture, weight, and test weight of the samples. All weather data is collected from the Oklahoma Mesonet website (McPherson *et al.*, 2007). The irrigation in mm, precipitation in mm, total water in mm and average temp for all locations is located in Table 6 and Table 7.

Statistical Analysis

Collected data was statistically analyzed using SAS 9.4 software (SAS Institute Inc, Copyright © 2020) at an (α=0.05) to check the significance for the Year, Location, Replication, and Treatment using Proc GLM. If the year and location are significant, then that data was ran by site year and treatment to look for site year treatment interaction. If the year and location are not significant then all locations and years were combined and analyzed.

CHAPTER IV

RESULTS AND DISCUSSION

Outside factors

Of the six site-years that were planted two, LCB 2021 and CVRS 2022, were not harvested due to wildlife destruction with only early season measurements collected.

Impact of Environment and Weather Pattern

For all three cropping seasons included in this study the weather patterns adversely impacted the results. In the 2020 season all crops and location experienced a greatly shorten growing season due to extreme heat and low humidity during grain fill. The impact of this was coupled with a later than normal planting date for the corn crop, which is typically planted in early April. For example, the LCB location was planted on May 9th and being a 119-day corn should have been at blacklayer on or near Sept 1st, which is then followed by a three-to-four-week dry down period prior to harvest. However, the crop was harvested on Sept 3rd. A water balance was performed for each of the crops utilizing the Mesonet Irrigation planner, See Table 8. The water balance is calculated by subtracting the daily rainfall by the estimated daily evapotranspiration. For this project the calculation started on the day of planting and concluded at black layer for the corn crop and date of desiccation for the sorghum crop. In 2020 the water balance for the corn crops at EFAW and LCB was -297mm and -318mm respectively.

In both 2021 and 2022 the corn planting occurred in a timely basis in early April and crop maturity occurred as expected. And while the 2021 cropping season saw an improved water balance compared to 2020, the sites experienced a negative water balance with -192mm at EFAW and -191 at LCB. The cropping season of 2022 experienced extreme drought with the LCB water balance being -321mm.

As will be reporting later in this manuscript, the grain yields for all crops and site years were well below expected, even with the lack of N fertilization above planted placed N. The adverse weather conditions experienced during this studies time frame likely had a great impact upon the results. Similarly, Lobell et al (2020) recently found that yield sensitivity to soil water storage increased by 55% on average across the US Corn Belt since 1999, with larger increases in drier states. Suggesting that as the crop genetic potential has increased the resiliency to drought has decreased. In a study conducted by Ren et al. (2008) semi-arid corn production was evaluated across a regime of rainfall levels, 230 mm, 340 mm and 440 mm. This work also documented that with the decrease of rainfall from 440mm to 340mm the corn yield was reduced by more than 2 Mg ha-1, the yield difference between 340mm and 230mm was an additional 2 Mg ha-1 yield penalty. The average rainfall for our studies was 340 mm with a range of 280mm to 390mm. The Ren et al. (2008) study, however, evaluated those rainfall rates under an even distribution. Unfortunately, our weather conditions resulted in inconsistent rainfall patterns and extended periods of drought.

The 2021 growing season a onetime application of 19mm cm of irrigation was applied at LCB, unfortunately the irrigation system was not functional for the remainder of the season. The irrigation system was repaired for the 2022 season; however, the water source is the Lake Carl Blackwell, and the pumps were only able to access water for the period of 27 days. During that period 152 mm of irrigation applied for a rainfall and irrigation total of 530mm. Even with the addition of irrigation the net water balance for the location was -169mm.

Corn Stand

As mentioned previously no stand measurements were recorded in 2020, therefore the following data comes from the four site years in 2021 and 2022. The measured stand averages for all locations and treatments are in Table 9. However, stand measurements from all trial locations were normalized against the non-fertilized check of each location, by rep, so that the data could be evaluated across locations and years as a percentage of stand loss. The normalized stand count results were analyzed with an ANOVA test using the generalized linear model procedure (Proc GLM) to determine significance of the main effects of location, year, replication, and treatment. Results indicated effects year, location, replication, and treatment were not significant at a p-values of 0.3650, 0.7676, 0.0729, and 0.4981 respectively. The main effects are located in Table 10.

However, further analysis utilizing Tukeys multiple comparisons procedure indicated a significant difference between the non-fertilized check and treatment SD_27 (p-value 0.0105). While previous research had suggested that stand loss is not likely with surface dribble applications of N (Stecker et al., 1993) this work suggests otherwise.

However, a significant amount of research has shown the negative impact of N rates applied in-furrow above a rate of 22 kg N ha^{-1} (Niehues et al., 2004) and yet in this study there was no impact on stand with increasing rates of in furrow applied N.

Corn Grain Yield Results

Final grain yield was successfully collected from 2020: EFAW and LCB, 2021: EFAW, and 2022: LCB. As mentioned earlier the 2020 and 2021 LCB and 2022 CVRS locations were lost to wildlife damage. Therefore, for the analysis the grain yield for the four successful site years were evaluated for main effect significance via ANOVA for Year, Location, Replication, and Treatment. Unlike stand count, grain yield had significant year and location effects. This is not surprising as the years with stand results do not correspond to the years with grain yield results. Due to the significance effect of years and sites on corn grain yield, the ANOVA results data will be discussed by site year. A visual of the p-values are located in Table 11 and Table 12.

The 2020 grain harvest was, as mentioned before, greatly influence by late season drought and heat, for both EFAW and LCB grain yields across the trials averaged 0.9 Mg ha^{-1} and 0.7 Mg ha^{-1} respectively. The non-treated checks for both locations were within 0.1 Mg ha^{-1} of the average with EFAW check recording 0.9 Mg ha^{-1} and the LCB check yielding 0.8 Mg ha^{-1}. The range in grain yield was 0.6 Mg ha^{-1} and 0.9 Mg ha^{-1} for the two locations. The EFAW 2021 grain yields were greatly improved with a mean trial grain yield of 6.0 Mg ha^{-1}. As noted previously 2021 recorded the lowest net negative water balance of all years with -192mm at EFAW. The none treated check plot produced

5.1 Mg ha^{-1}, three treatments (DS_9, DS27, CI_9) produced a final grain yield of 7.3 Mg ha^{-1} even with 2.2 Mg yield increase these treatments are still not significantly different from the check. And while the 2022 LCB crop had limited irrigation the extreme heat during anthesis, and grain fill significantly impact yields. The trial averaged 4.9 Mg ha^{-1} with a range of yields from 3.6 to 6.0 Mg ha^{-1}. The none treated check did produce 4.2 Mg ha^{-1}. While there were yields difference of greater than 1 Mg ha^{-1} from the check treatment in some site years, the by site year ANOVA analysis for TRT as the main effect, showed no significant impact of treatment on yield.

When the data was analyzed with a Tukey's LSD, three of the site years presented a difference in the corn grain yield within the treatments used. However, none of the significant treatment comparisons included the check, meaning that no treatment is significantly different to the non-treated check. Suggesting that no treatment significantly influenced grain yield beyond the check. In further investigation of the significant comparisons, no pattern of method or rate existed. Significant comparisons tended to be random over site year. Site year mean yields and t test values are include in Tables 13.

Corn Stand and Yield Discussion.

Iowa State Extension states that corn will use between 1.0- and 10-mm day^{-1} depending on the environment, soil texture and moisture with evapotranspiration maximized at V18 (Licht et al., 2017). During the summer of 2020, the potential evapotranspiration for tall crops was at the peak of 0.81 cm and at the lowest point of 0.22 cm per day. There was limited amount of moisture in the soil to be used until July 30th, which was post anthesis. The warm days with low humidity and no dews with the lack of water was a large impact of the grain yield of the crop in 2020. From the point of planting to black layer, a total of 278mm and 302mm of precipitation occurred at the EFAW and LCB locations respectively.

Planting in 2021 and 2022 was performed in optimum soil moisture conditions with a range of 0-5 cm fractional soil moisture content of 80-100% Table 8, (Mesonet 2023). In addition, all locations received a precipitation event within five days of planting. It appears that adequate soil moisture limits salt injury. This can be explained by the fact that the combination of optimum planting conditions and timely post planting rain fall reduced the potential negative impact of salt injury from the in-furrow treatments.

In 2020, rapid accumulation of growing degree units (GDUs) occurred and despite the delayed planting date the crops reached the growth stage of silk maturity (1430 GDUs) on July 10th and 13th at EFAW and LCB respectively. Growing degree units or growing degree days is the calculation of plant growth using temperature max and temperature min multiply by 2 then subtract the base temperature of the specific crop (McMaster et al., 1997). During the period prior to silk maturity and black layer, the air temperature did not reach the dew point and the relative humidity was below 50% most of the time frame. Also, over that period, plant available water in the 81.28 cm profile averaged 25.4 mm. Stone et al (2006) stated that a minimum of 277mm and 175 mm of water is required by corn and sorghum, respectively, to support vegetative development alone. For each additional 25 mm of precipitation above this threshold, on an average, corn yields increased by 1.06 Mg ha^{-1}. Therefore, based on Stones work the amount of rainfall that was received was enough for the minimum requirement at both locations with LCB receiving an additional 30mm. The low humidity and with the above average daily high temperatures also likely impacted pollination.

The weather conditions from 2020 to 2021 were very different resulting in an average yield increase of there was an average of 5.1 Mg ha^{-1} over the 2020 season. The minimum daily temperatures ranged from 24.9° C to 12.8° C, with the average being 19.8° C. The maximum plant available water in the top 81.28 cm of soil was at 135mm at the beginning of the reproductive stage. With the timely rainfalls during pollination, this benefitted the pollination process allowing for proper ear formation. Then rainfall in the later part of the season allowed for proper grain fill.

In 2022, the hybrid that was used is DKC 63-99RIB planted at the 8th of April, this hybrid has a GDU to mid pollination of 1340 from planting. That GDU puts it at June 20th to reach mid pollination, with variety in maturing the dates of June 11th to July 4th. The temperatures at the beginning of the pollination period started in the lower 70's then moved up to 81 for the minimum temperature. During the mid-pollination point the minimum temp was 72, with a relative humidity of 47 percent. From the start of the pollination period there was 16.7 cm of plant available water in the top 81 cm of soil. The maximum plant available water continued to decrease throughout the entire pollination period to 4.3 cm of water. The weather conditions are not the best for good yields in this growing season, the difference between this season and the 2020 season at LCB was that irrigation was applied during the growing season till mid-august when the water supply dried up. Through all of the growing seasons for the corn the main factor for the yield has been the weather.

In 2022 the project was able to irrigate the LCB location for a limited period. As mentioned previously, the irrigation draws from a pump pulling surface water from the Lake Carl Blackwell. During the early growing season, the lakes surface level was below that of the pump location. However, from May 1 to May 25th, the region received more than 200 mm of precipitation which raised the lake level significantly. Irrigation was initiated on June 22nd and was continued on a regular interval until July 18th when the lake level once again dropped below the point of intake. While 152mm of water was applied during this time frame, which encompassed anthesis, pollination and early grain fill, the region experienced daily maximum temperatures regularly in excess of 36.0 °C. High temperature affects pollen and grain fill; in heat stress of at least 37.7^{o} C, pollen can be killed (Nielson, 2002). Another study from 1950-2004 in the eastern United States supported that by stating that the temperatures become harmful to pollen once they exceed 30^{o} C (Schlenker et al., 2006). Concerning grain fill begins to decline at temperatures greater than a critical maximum temperature of about 25-35^{o} C (Wilhelm et al., 1999). Average grain yield for LCB 2022 was 4.88 Mg ha^{-1}, with the none treated check yielding 4.2 Mg ha^{-1} and the CI_27 producing the greatest yield of 6.0 Mg ha^{-1}. Except for the dribble surface band treatments, there was a yield increase with increasing N rate for all methods. ANOVA analysis was performed for this site-year evaluation the influence of method, rate and method x rate interaction on final grain yield. None were found to be significant (data not shown). Therefore, the data was run by N rate with grain yields of 4.5, 5.07, and 5.2 for the 8, 16, and 24 kg N ha^{-1} rates accordingly. However, the resulting ANOVA producing a p value of 0.3023 and the t Test showing no significance. It is hypothesized that the extreme heat likely impacted the crop in such a negative manor that treatment impacts where likely masked. Season long LCB 2022 temperature averages and LCB long term averages are visualized in Figure 3.

In each season the weather adversely impacted the final grain yield. As Leibig (1840) described in the Law of the Minimum, yield influenced by the greatest limiting factor. In this case, it is proposed that environment so greatly influenced yield no effect of treatment could be discovered.

Sorghum Results

Impact of Environment and Weather Pattern

As previously mentioned in corn results and discussion part, the environment had significant impact upon the 2020, 2021, and 2022 growing seasons. As the sorghum studies were performed in close proximity to the corn studies in all site years, the growing environments were effectively the same. In 2020 the planting dates for corn and sorghum was within one day, while in the 2021 and 2022 seasons the corn was planted in early April and sorghum in late April.

Much like the corn crop in 2020, the sorghum crop maturation was also expedited, and the plants reached maturity nearly three weeks earlier than expected. The extreme heat the crop experienced during the period of anthesis through grain fill is hypothesized to be the cause of the expedited maturity. During this season the water balance estimated by the Mesonet irrigation planner showed a water balance of -122mm and -104mm at the EFAW and LCB locations.

During the next two seasons 2021 and 2022, the Mesonet irrigation planner projected a negative yet much improved water balance of -12mm, -29mm, -19mm for EFAW21, LCB21, and CVRS22 respectively. The water balance for LCB 22 was -84mm which did not include the 152mm of irrigation applied between June 22nd and July 18th. As will be discussed in the following section, the 2022 LCB location was the only site year to record grain yields in excess of 2 Mg ha^{-1}, showing the significant impact of the irrigation, albeit limited.

Sorghum plant stand results.

As mentioned previously, no stand measurements were recorded in 2020. Therefore, the following data comes from the four site years in 2021 and 2022. The measured stand averages for all locations and treatments are in Table 14. However, stand measurements from all trial locations were normalized against the non-fertilized check of each location, by rep, so that the data could be evaluated across locations and years as a percentage of stand loss. A visual is located in Table 15. The normalized stand counts results were analyzed with ANOVA test using the generalized linear model procedure (Proc GLM) to determine significance of the main effects of location, year, replication, and treatment. Results indicated effects year, location and replication were significant at a p-values of 0.0403, 0.0354, and 0.0009. A visual of the p-values are located in Table 16. Therefore treatment, method, and rate impact on stand was evaluated by site year. When evaluating the impact of treatment, method and rate of planter applied N on sorghum stand, none were found to be statistically significant for any of the four sites years which stand was recorded.

Sorghum grain yield results.

Sorghum grain yield was successfully collected from all six site years. However, of the six site years, only LCB 2022 recorded trial average grain yields greater than 2.0 Mg ha^{-1}. The ANOVA analysis of sorghum grain yield results showed significantly impact of year and location on the results (Table 17). Due to the magnitude of yield difference between site years was enough to warrant analysis by site year. Average treatment grain yield by location is presented in Table 18. The 2020 EFAW location averaged 0.24 Mg ha^{-1} did not have a single treatment record a yield over 0.40 Mg ha^{-1}. With this greatly restricted yield level the lack of treatment effect was not unexpected, p= 0.1487. While LCB 2020 recorded better yields than EFAW, the trial average of 1.79 Mg ha^{-1} was well below the expected yield for the region and location. At this site year, the check yielded 1.90 Mg ha^{-1} and only three treatments yielded numerically more. Neither ANOVA nor t-Test showed any significance of treatment, method or rate on corn grain yield.

In 2021 the EFAW and LCB locations had average trial grain yield of 1.54 Mg ha^{-1} and 1.73 Mg ha^{-1}. At EFAW the non-treated check was numerically the lowest yielding treatment at 0.90 Mg ha^{-1}. The LCB non-treated check yielded near trial average with 1.80 Mg ha^{-1}. For both locations, there was no significance found for treatment, method, or N rate effect.

In 2022 grain yields of LCB were considerably high with a trial average of 4.03 Mg ha^{-1}, with the non-treated check recording the highest yield at 4.80 Mg ha^{-1}. It should be noted that the treatment DS_9 was lost due to planter malfunctions. The ANOVA analysis of LCB 22 produced no significant impact of treatment, method, or N rate. However, the t-Test showed the non-treated check did yield statistically better than four other treatments, IF_9, DS_27, DSB_9, and CI_9. Suggesting the application of the lowest rate of N, 9 kg N ha^{-1}, may have led to yield loss which was confirmed with t-test analysis of N rate in which 0 was statistically different from 9. The t-test also identified the non-treated check being statistically different from the 27 kg N ha^{-1} rate. The average yield for the four N rates (0, 9, 18, 27) applied was 4.80, 3.6, 4.1, and 4.075 Mg ha^{-1} accordingly. The average grain yield of the trial at CVRS in 2022 was 2.0 Mg ha^{-1}, with the non-treated check producing 2.0 Mg ha^{-1}. In this location there was no significance of treatment, method, nor N rate. There was also no trends of yield to any of these parameters.

Sorghum Discussion

Planting in 2021 and 2022 was performed in optimum soil moisture conditions with a range of 0-5 cm fractional soil moisture content of 80-100% Table 19, (Mesonet 2023). In addition, all locations received a precipitation event within five days of planting. As with the corn crop stand it is hypothesized that the combination of optimum planting conditions and timely post planting rain fall reduced the potential negative impact of salt injury from the in-furrow treatments.

As five of the six site years had average grain yield levels of less than 2.0 Mg ha^{-1}, it is evident that the most limiting factor in these environments was not N availability. While residual N was not recorded in 2020, soil test from 2021 indicated plant available N at the time of planting was well in excess of what is needed for a crop with yield levels below 2.0 Mg ha^{-1}. In 2022, the CRVS location was utilized instead of EFAW as the sandy loam soil of the CRVS location is typically more N response than the silty clay loam found at EFAW. While planting conditions were nearly optimum, by June extreme drought and heat started negatively impacting the study region. At LCB linear irrigation was available and 152mm of water was applied from June 22nd to July 18th. At Perkins drip tape was placed near the two middle (harvest) rows of each plot and the area was irrigated on a three-day rotation during the month of July. Over the period, 127mm of water was applied. While the crop at LCB was able to reach yield levels above 4.0 Mg $ha^{-1,}$ the CRVS location did not exceed 2.0 Mg ha^{-1}. It was noted that non irrigated trials at CVRS situated in close proximity to this study did to have a harvestable crop at the end of the season.

CHAPTER V

CONCLUSION

This study was initiated to evaluate the impact of method and rate of planter applied N on corn and grain sorghum stand and grain yield. It was hypothesized that N rate of 27 kg N ha^{-1} in furrow placement would have a significant negative impact on stand and grain yield for both crops while the 27 kg N ha^{-1} 2x2 would have no impact on stand but the greatest increase in grain yield above the non-treated check. Across six site-years for both crops, there was limited impact of method or N-rate on any measured parameter. Suggesting that there was no negative effect on plant stand when N rates were above historically suggested rates and that there was no response to the N added at time of planting. However, what the results of this study demonstrate is the overwhelming influence the environment has on crop production. In relation to the impact on plant stand, in all site years for each crop the soil moisture conditions at time of planting as near optimum with 0-5cm fractional soil moisture levels at or above 80%. In addition, most locations experienced timely rainfall shortly after planting. As previous works have shown, adequate soil moisture and timely precipitation can counteract the negative effect of salt applied near seed. The growing conditions from the time initiation of reproductive growth through grain fill in all site years were far from optimum. Each season recorded excessive heat and drought which resulted in a negative water balance for each site year for both crops. Even with the application of irrigation in 2022, the environment was a great limiting factor than N availability. Resulting in a lack of treatment difference in method or rate of planter applied. While this work cannot be used to propose planter-applied N fertilizer, it can be used to demonstrate that in the middle Great Plains, the environment often has the biggest influence on yield compared to the agronomic practice management.

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TABLES

Table 1. Soil series classifications of the three experimental locations the Cimarron Valley Research Station (CVRS), Lake Carl Blackwell (LCB), and EFAW utilized in the in the study evaluating the effect of the method and rate of planter applied nitrogen on corn and sorghum grain yield in Oklahoma over the 2020, 2021, and 2022 growing seasons. The soil series names and description were obtained from web soil survey from the Natural Resource Conservation Service, United States Department of Ag.

Location/Year	Soil Series	Description	Crop Residue
EFAW 2020-2021	Norge loam	Fine-Silty, mixed, active, thermic Udic Paleustolls	Wheat
LCB 2020-2022	Port-Oscar Complex	Fine-silty, mixed, superactive, thermic Cumulic Haplustoll	Wheat
Perkins 2022	Teller	Fine-loamy, mixed, active, thermic Udic Argiustolls	Wheat

Table 2. Soil test results for pH, organic carbon percentage, total N percent, nitrate, ammonia, phosphorus and potassium. The samples were taken from 0-15 cm zone for each of the experimental location and year of the 2021 and 2022 experiment.

Year	Location	pH	Organic Carbon %	Total N %	NO_3-N	NH_4-N	P	K
					kg ha^{-1}		Ppm	
2021	LCB	6.9	0.74	0.07	4.48	13.29	19.00	151.00
2021	EFAW	5.7	0.86	0.10	21.65	27.63	25.00	187.00
2022	LCB	6.1	-	-	22.40	-	36.00	194.00
2022	CVRS	6.4	-	-	7.84	-	40.00	189.00

Table 3. Treatment structure utilized at the Cimarron Valley Research Station (CVRS), Lake Carl Blackwell (LCB), and EFAW experimental locations during the 2020, 2021, and 2022 growing seasons for both corn and sorghum in the study evaluating the effect of the method and rate of planter applied nitrogen on corn and sorghum grain yield in Oklahoma.

Treatment	N Rate (Kg N ha^{-1})	Method	Treatment ID
1	0	----	Zero
2	9	With Seed	IF_9
3	18	With Seed	IF_18
4	27	With Seed	IF_27
5	9	Dribble Surface	SD_9
6	18	Dribble Surface	SD_18
7	27	Dribble Surface	SD_27
8	9	Dry Surface	DSB_9
9	18	Dry Surface	DSB_18
10	27	Dry Surface	DSB_27
11	9	2x2	CI_9
12	18	2x2	CI_18
13	27	2x2	CI_27

Table 4. Corn planting dates, the date of harvest, growing degree days from planting to mid pollination, the hybrid used, the population for the three experimental site locations (EFAW, LCB, CVRS) for this study evaluating the effect of the method and rate of planter applied nitrogen on corn and sorghum grain yield in Oklahoma in the years 2020, 2021 and 2022.

Location	Planting Date	Harvest Date	GDUs to Mid-Pollination	Corn Hybrid	Population (Seeds ha^{-1})
EFAW	9-May-20	31-Aug-20	1430	P1690AM	49,400
LCB	9-May-20	3-Sep-20	1430	P1690AM	49,400
EFAW	6-Apr-21	26-Aug-21	1375	DKC 66-29	64,220
LCB	6-Apr-21	----	1375	DKC 66-29	64,220
LCB	8-Apr-22	24-Aug-22	1340	DKC 63-99RIB	56,810
CVRS	8-Apr-22	----	1340	DKC 63-99RIB	56,810

Table 5. Grain sorghum planting dates, the date of harvest, growing degree days from planting to mid pollination, the hybrid used, the population for the three experimental site locations (EFAW, LCB, CVRS) for this study evaluating the effect of the method and rate of planter applied nitrogen on corn and sorghum grain yield in Oklahoma in the years 2020, 2021 and 2022.

Location	Planting Date	Desiccation date	Harvest Date	Days to Flower	Variety	Population (Seeds ha^{-1})
EFAW	9-May-20	4-Aug-20	7-Sep-20	70	DKS51-01	111,150
LCB	9-May-20	4-Aug-20	8-Sep-20	70	DKS51-01	111,150
EFAW	6-Apr-21	16-Aug-21	25-Aug-21	62	DKS33-07	111,150
LCB	6-Apr-21	25-Aug-21	1-Sep-21	62	DKS33-07	83,980
LCB	8-Apr-22	8-Aug-22	18-Aug-21	63	AG 1203	108,680
Perkins	8-Apr-22	29-Aug-22	7-Sep-22	63	AG 1203	108,680

Table 6. Corn irrigation, rainfall and total water amount in mm and average temperature in C for all site locations (EFAW, LCB, CVRS) for this study evaluating the effect of the method and rate of planter applied nitrogen on corn and sorghum grain yield in Oklahoma in the years 2020, 2021 and 2022.

Location	Irrigation (mm)	Rainfall (mm)	Total (mm)	Temp Avg. (C)
EFAW 2020	0	278	278	30.3
LCB 2020	0	389	389	30.3
EFAW 2021	0	302	302	28.3
LCB 2021	19	354	373	28.5
LCB 2022	152.4	378	530.4	31.4
CVRS 2022	0	496	496	31.7

Table 7. Grain Sorghum irrigation, rainfall and total water amount in mm and average temperature in C for all site locations (EFAW, LCB, CVRS) for this study evaluating the effect of the method and rate of planter applied nitrogen on corn and sorghum grain yield in Oklahoma in the years 2020, 2021 and 2022.

Location	Irrigation (mm)	Rainfall (mm)	Total (mm)	Temp Avg. (C)
EFAW 2020	0	300	300	30.3
LCB 2020	0	399	399	30.3
EFAW 2021	0	261	261	28.3
LCB 2021	19	347	366	28.5
LCB 2022	152.4	381	533.4	31.4
CVRS 2022	127	496	623	31.7

Table 8. Corn 0-5 cm soil moisture at planting in percent fractions, the date of first precipitation, the amount of in mm of the first precipitation and the water balance for the three experimental site locations (EFAW, LCB, CVRS) for this study evaluating the effect of the method and rate of planter applied nitrogen on corn and sorghum grain yield in Oklahoma in the years 2020, 2021 and 2022.

Location	Planting Date	Soil Moisture % Fraction	Date of 1st Prec	Prec mm	Water balance
EFAW 2020	9-May-20	1	12-May-20	4.318	-297
LCB 2020	9-May-20	0.6	12-May-20	3.048	-192
EFAW 2021	7-Apr-21	0.90	9-April-21	7.62	-318
LCB 2021	6-Apr-21	0.80	9-April-21	34.544	NA
LCB 2022	8-Apr-22	0.80	23-April-22	15.24	-321
CVRS 2022	8-Apr-22	1.00	23-April-22	3.302	NA

Table 9. Corn stand count averages for the three experimental site locations (EFAW, LCB and CVRS) for the years 2021 and 2022 used in the evaluation of this study evaluating the effect of the method and rate of planter applied nitrogen on corn and sorghum grain yield in Oklahoma by treatment.

Stand Count Averages (plants row $6m^{-1}$)				
	2021	2021	2022	2022
	EFAW	LCB	LCB	CVRS
Zero	23.5	16.8	29	18.2
IF_9	23.0	19.6	29	17.5
IF_18	22.0	24.9	23	14.5
IF_27	22.5	15.2	23	18.5
DS_9	23.0	18.2	22	15.7
DS_18	18.3	23.2	24	18.2
DS_27	18.0	10.1	26	14.2
DSB_9	23.0	14.5	26	17.3
DSB_18	22.3	19.4	27	15.7
DSB_27	23.2	11.8	20	20.5
CI_9	22.0	13.0	17	20.0
CI_18	16.5	16.8	20	17.0
CI_27	23.0	12.8	27	16.3

Table 10. Proc GLM Corn stand main effect analysis ANOVA table for year, location, rep, treatment and site year (SR) on treatment from the three experimental site locations (EFAW, LCB and CVRS) for the years 2021 and 2022 used in the evaluation of this study evaluating effect of the method and rate of planter applied nitrogen on corn stand and grain yield in Oklahoma with a significance level of 0.05 (α=0.05).

Source	DF	Type 1 SS	Mean Square	F value	Pr > F
Year	1	0.032	0.032	0.83	0.365
Location	1	0.003	0.003	0.09	0.7676
Rep	3	0.272	0.091	2.37	0.0729
Treatment	12	0.437	0.036	0.95	0.4981
SR*Treatment	13	0.432	0.033	0.83	0.6234

Table 11. Corn Grain Proc GLM main effect analysis yield ANOVA table for year, location, rep, treatment and site year (SR) on treatment from the three experimental site locations (EFAW, LCB and CVRS) for the years 2021 and 2022 used in the evaluation of this study evaluating effect of the method and rate of planter applied nitrogen on corn grain yield in Oklahoma with a significance level of 0.05 (α=0.05).

Source	DF	Type 1 SS	Mean Square	F value	Pr > F
Year	1	0.880	0.880	6.4	0.0125
Location	2	3.092	1.546	11.24	<.0001
Rep	3	0.827	0.276	2	0.116
Treatment	12	2.463	0.205	1.49	0.1328
SR*Treatment	12	1.670	0.139	0.99	0.4602

Table 12. Corn yield treatment p-values from the four sites (EFAW and LCB) harvested for the years 2020, 2021 and 2022 used in the evaluation of this study evaluating effect of the method and rate of planter applied nitrogen on corn and sorghum grain yield in Oklahoma with a significance level of 0.05 (α=0.05).

Site Year	Treatment P-value
1	0.9012
2	0.2845
3	0.5254
6	0.2129

Table 13. Corn yield average averages for the three experimental site locations (EFAW, LCB and CVRS) for the years 2021 and 2022 used in the evaluation of this evaluating the effect of the method and rate of planter applied nitrogen on corn and sorghum grain yield in Oklahoma by treatment.

	Yield Averages (Mg ha^{-1})			
	2020 EFAW	2020 LCB	2021 EFAW	2022 LCB
Zero	0.9	0.8	5.1	4.2
IF_9	0.8	0.4	6.5	4.2
IF_18	0.9	0.4	4.3	4.9
IF_27	0.8	0.6	5.0	5.0
DS_9	1.2	1.2	7.3	4.7
DS_18	0.7	0.9	5.7	5.1
DS_27	1.1	0.5	7.3	5.6
DSB_9	0.6	0.5	6.1	5.6
DSB_18	1.1	0.8	6.3	5.9
DSB_27	1.0	0.8	4.8	4.3
CI_9	0.9	0.3	7.3	3.6
CI_18	1.0	0.6	5.9	4.4
CI_27	0.8	0.8	5.8	6.0

Table 14. Grain sorghum stand count averages and level of significance at a significance level of α = 0.05 for the three experimental site locations (EFAW, LCB and CVRS) for the years 2021 and 2022 used in the evaluation of this study evaluating the effect of the method and rate of planter applied nitrogen on corn and sorghum grain yield in Oklahoma by treatment. No letters indicate same level of significance.

	Stand Count Averages (plants row $6m^{-1}$)			
	2021 EFAW	2021 LCB	2022 LCB	2022 CVRS
Zero	20	42	46	41
IF_9	23	38	44	39
IF_18	20	41	42	43
IF_27	22	38	45	38
DS_9	24	39	10	40
DS_18	17	41	44	42
DS_27	25	43	44	34
DSB_9	27	36	48	40
DSB_18	19	41	45	37
DSB_27	19	37	43	38
CI_9	24	41	41	39
CI_18	21	43	46	36
CI_27	22	52	45	38

Table 15. Grain sorghum stand normalized averages and level of significance at a significance level of α = 0.05 for the three experimental site locations (EFAW, LCB and CVRS) for the years 2021 and 2022 used in the evaluation of this study evaluating the effect of the method and rate of planter applied nitrogen on corn and sorghum grain yield in Oklahoma by treatment.

Normalized Stand Averages (plants row 6m-1)				
	2021	2021	2022	2022
	EFAW	LCB	LCB	CVRS
Zero	1.00	1.00	1.00	1.00
IF_9	1.13	0.91	0.97	0.98
IF_18	0.98	1.01	0.92	1.07
IF_27	1.13	0.94	0.97	0.95
DS_9	1.23	1.06	.	4.58
DS_18	0.88	1.02	0.96	1.05
DS_27	1.24	1.03	0.95	0.85
DSB_9	1.33	0.87	1.04	0.98
DSB_18	0.96	1.03	0.98	0.93
DSB_27	1.01	0.91	0.94	0.95
CI_9	1.21	1.00	0.90	0.96
CI_18	1.02	1.06	1.01	0.90
CI_27	1.10	1.27	0.97	0.95

Table 16. Proc GLM Grain Sorghum stand main effect analysis ANOVA table for year, location, rep, treatment and site year (SR) on treatment from the three experimental site locations (EFAW, LCB and CVRS) for the years 2021 and 2022 used in the evaluation of this study evaluating effect of the method and rate of planter applied nitrogen on corn stand and grain yield in Oklahoma with a significance level of 0.05 (α=0.05).

Source	DF	Type 1 SS	Mean Square	F value	Pr > F
Year	1	0.119	0.119	4.27	0.0403
Location	2	0.190	0.095	3.41	0.0354
Rep	3	0.452	0.161	5.77	0.0009
Treatment	12	0.194	0.016	0.58	0.8568
SR*Treatment	12	0.441	0.037	1.23	0.2649

Table 17. Grain Sorghum Yield ANOVA table for year, location, rep, treatment and site year (SR) on treatment from the three experimental site locations (EFAW, LCB and CVRS) for the years 2021 and 2022 used in the evaluation of this study evaluating effect of the method and rate of planter applied nitrogen on corn grain yield in Oklahoma with a significance level of 0.05 (α=0.05).

Source	DF	Type 1 SS	Mean Square	F value	Pr > F
Year	2	11.56	5.778	26.55	<0.0001
Location	2	3.885	1.943	8.92	0.0002
Rep	3	1.993	0.664	3.05	0.0293
Treatment	12	1.815	0.151	0.69	0.7557
SR*Treatment	12	0.890	0.074	0.32	0.9852

Table 18. Grain sorghum yield average averages and level of significance at a significance level of α = 0.05 for the three experimental site locations (EFAW, LCB and CVRS) for the years 2021 and 2022 used in the evaluation of this study evaluating the effect of the method and rate of planter applied nitrogen on corn and sorghum grain yield in Oklahoma by treatment. No letters indicate same level of significance.

	Yield Averages (Mg ha-1)					
	2020 EFAW	2020 LCB	2021 EFAW	2021 LCB	2022 CVRS	2022 LCB
Zero	0.3	1.9	0.9	1.8	2.0	4.8
IF_9	0.2	1.5	1.3	1.8	2.0	3.4
IF_18	0.2	2.1	1.5	1.7	1.9	3.9
IF_27	0.2	2.1	1.3	2.1	2.6	4.2
DS_9	0.2	1.4	1.3	1.4	1.8	.
DS_18	0.2	1.9	2.1	2.0	2.2	4.3
DS_27	0.2	1.7	1.9	1.6	1.6	3.7
DSB_9	0.2	1.6	1.8	1.6	2.1	3.7
DSB_18	0.4	1.8	1.8	1.2	1.8	4.0
DSB_27	0.2	2.7	1.7	2.3	1.8	4.1
CI_9	0.2	1.5	1.3	1.7	1.7	3.7
CI_18	0.4	1.4	1.5	1.6	1.9	4.2
CI_27	0.2	1.7	1.6	1.7	1.9	4.3

Table 19. Grain Sorghum 0-5 cm soil moisture at planting in percent fractions, the date of first precipitation, the amount of in mm of the first precipitation and the water balance for the three experimental site locations (EFAW, LCB, CVRS) for this study evaluating the effect of the method and rate of planter applied nitrogen on corn and sorghum grain yield in Oklahoma in the years 2020, 2021 and 2022.

Location	Planting Date	Soil Moisture % Fraction	Date of 1st Prec	Prec mm	Water balance
EFAW 2020	9-May-20	1	12-May-20	4.318	-122
LCB 2020	9-May-20	0.6	12-May-20	3.048	-12
EFAW 2021	7-Apr-21	0.9	9-April-21	7.62	-104
LCB 2021	30-Apr-21	1	9-April-21	4.572	-29
LCB 2022	26-Apr-22	0.8	29-April-22	5.08	-84
CVRS 2022	26-Apr-22	0.9	28-April-22	12.7	-19

FIGURES

Figure 1. Nitrogen Cycle (Zhang and Raun 2006)

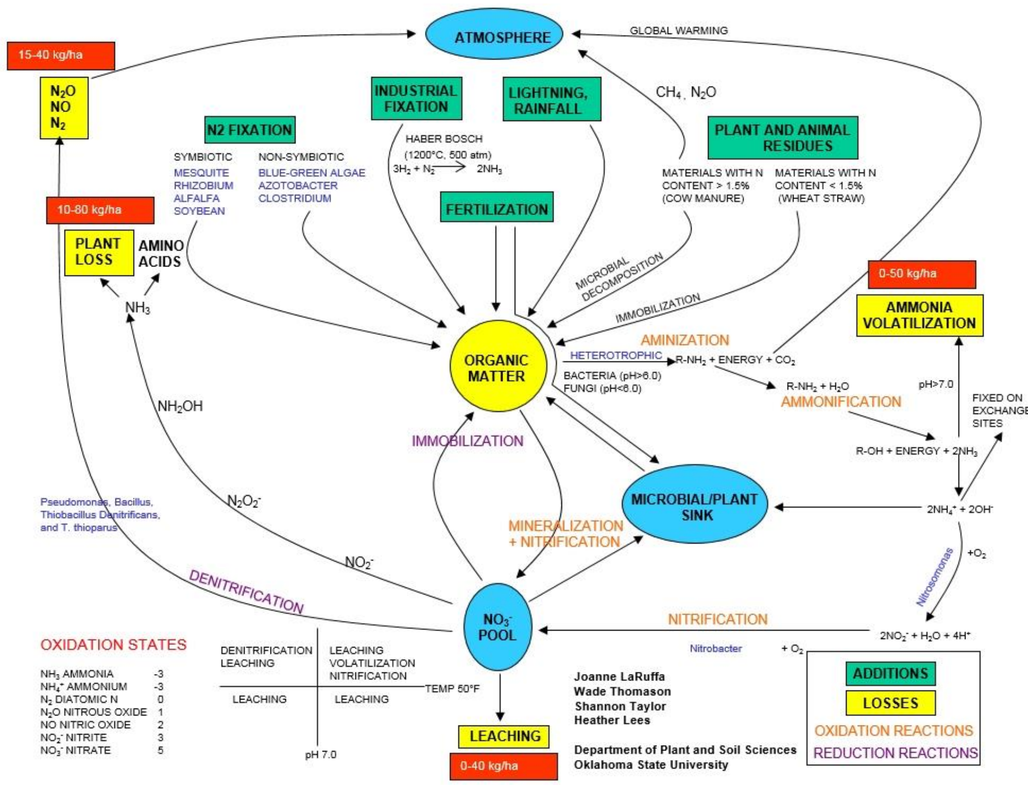


Figure 2. Normalized Corn Stand, LSD from the three experimental site locations (EFAW, LCB and CVRS) for the years 2021 and 2022 used in the evaluation of this study evaluating effect of the method and rate of planter applied nitrogen on corn stand and grain yield in Oklahoma with a significance level of 0.05 (α=0.05).

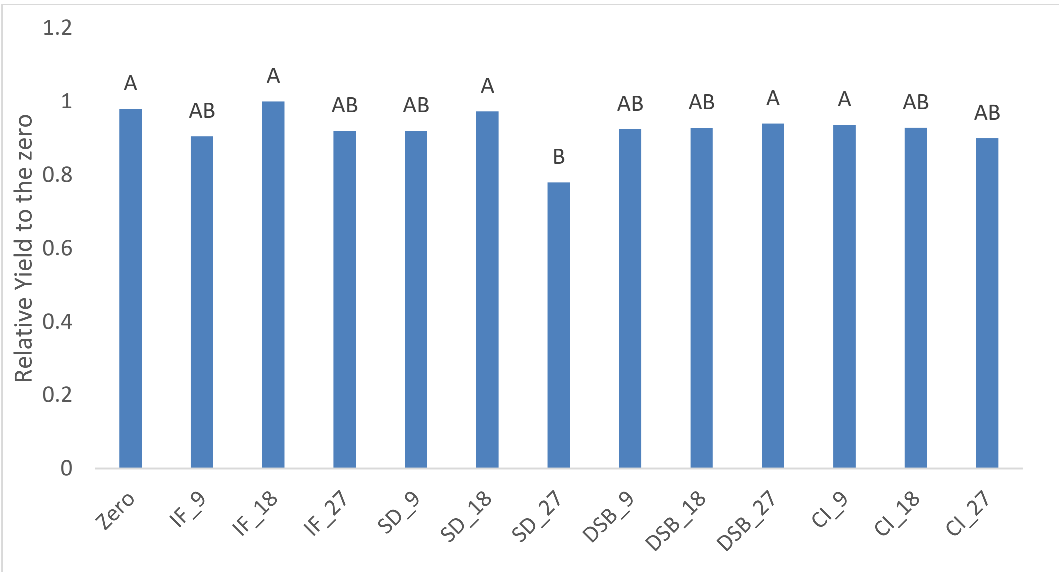
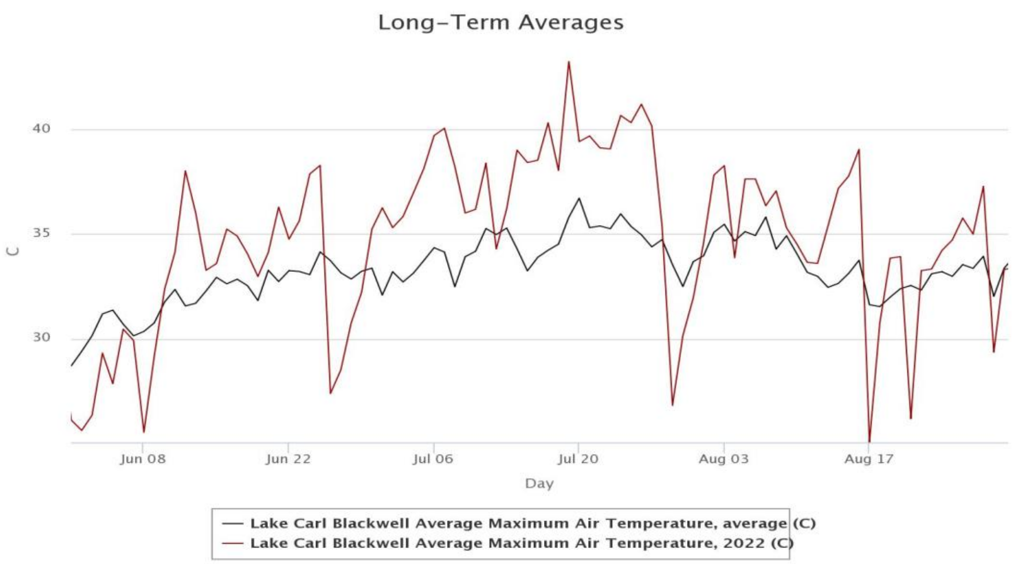


Figure 3. Temperature averages for LCB 2022 and LCB long term average and the comparison.



APPENDICES

Corn Site ID

LOC	SR	YR
1	EFAW	2020
2	LCB	2020
3	EFAW	2021
4	LCB	2021
5	CVRS	2022
6	LCB	2022

Corn Raw Data

sr	yr	loc	rep	trt	meth	N	yld	stnd	N-yld	N-stnd
1	1	1	1	1	0	0	0.720299	.	0.762336	.
1	1	1	1	2	1	8	0.549552	.	0.581623	.
1	1	1	1	3	1	16	1.735674	.	1.836968	.
1	1	1	1	4	1	24	1.566799	.	1.658237	.
1	1	1	1	5	2	8	1.148704	.	1.215742	.
1	1	1	1	6	2	16	0.776742	.	0.822073	.
1	1	1	1	7	2	24	1.306515	.	1.382763	.
1	1	1	1	8	3	8	0.399332	.	0.422637	.
1	1	1	1	9	3	16	1.361687	.	1.441155	.
1	1	1	1	10	3	24	1.071197	.	1.133712	.
1	1	1	1	11	4	8	0.970571	.	1.027214	.
1	1	1	1	12	4	16	1.478457	.	1.56474	.
1	1	1	1	13	4	24	1.17234	.	1.240758	.
1	1	1	2	1	0	0	0.753607	.	0.797587	.
1	1	1	2	2	1	8	1.124556	.	1.190185	.
1	1	1	2	3	1	16	0.370011	.	0.391605	.
1	1	1	2	4	1	24	0.654213	.	0.692392	.
1	1	1	2	5	2	8	1.69965	.	1.798842	.
1	1	1	2	6	2	16	0.661163	.	0.699749	.
1	1	1	2	7	2	24	1.291239	.	1.366596	.

1	1	1	2	8	3	8	0.69294	.	0.73338	.
1	1	1	2	9	3	16	1.035047	.	1.095452	.
1	1	1	2	10	3	24	0.61098	.	0.646637	.
1	1	1	2	11	4	8	0.937401	.	0.992108	.
1	1	1	2	12	4	16	0.716352	.	0.758158	.
1	1	1	2	13	4	24	0.582004	.	0.61597	.
1	1	1	3	1	0	0	1.360668	.	1.440077	.
1	1	1	3	2	1	8	0.693976	.	0.734477	.
1	1	1	3	3	1	16	0.469106	.	0.496483	.
1	1	1	3	4	1	24	0.315858	.	0.334291	.
1	1	1	3	5	2	8	0.693596	.	0.734075	.
1	1	1	3	6	2	16	0.641117	.	0.678533	.
1	1	1	3	7	2	24	0.655243	.	0.693482	.
1	1	1	3	8	3	8	0.746869	.	0.790457	.
1	1	1	3	9	3	16	0.917868	.	0.971434	.
1	1	1	3	10	3	24	1.276941	.	1.351464	.
1	1	1	3	11	4	8	0.914922	.	0.968317	.
1	1	1	3	12	4	16	0.701243	.	0.742167	.
1	1	1	3	13	4	24	0.65324	.	0.691363	.
2	1	2	1	1	0	0	0.590858	.	0.707284	.
2	1	2	1	2	1	8	0.206384	.	0.24705	.
2	1	2	1	3	1	16	0.330953	.	0.396166	.
2	1	2	1	4	1	24	0.217419	.	0.26026	.
2	1	2	1	5	2	8	0.619988	.	0.742154	.
2	1	2	1	6	2	16	0.625517	.	0.748772	.
2	1	2	1	7	2	24	0.90294	.	1.08086	.
2	1	2	1	8	3	8	0.575517	.	0.68892	.
2	1	2	1	9	3	16	0.315502	.	0.377671	.
2	1	2	1	10	3	24	0.682302	.	0.816747	.
2	1	2	1	11	4	8	0.23603	.	0.282538	.
2	1	2	1	12	4	16	0.389801	.	0.46661	.
2	1	2	1	13	4	24	1.144469	.	1.369981	.
2	1	2	2	1	0	0	1.05224	.	1.259579	.
2	1	2	2	2	1	8	0.192795	.	0.230784	.
2	1	2	2	3	1	16	0.309743	.	0.370777	.
2	1	2	2	4	1	24	0.926738	.	1.109347	.
2	1	2	2	5	2	8	0.93931	.	1.124396	.
2	1	2	2	6	2	16	0.708803	.	0.848469	.
2	1	2	2	7	2	24	0.093071	.	0.11141	.
2	1	2	2	8	3	8	0.452779	.	0.541997	.
2	1	2	2	9	3	16	0.961811	.	1.151331	.
2	1	2	2	10	3	24	0.298585	.	0.357419	.
2	1	2	2	11	4	8	0.54369	.	0.650821	.

2	1	2	2	12	4	16	0.473916	.	0.567299	.
2	1	2	2	13	4	24	0.524766	.	0.628169	.
2	1	2	3	1	0	0	0.863073	.	1.033138	.
2	1	2	3	2	1	8	0.826812	.	0.989731	.
2	1	2	3	3	1	16	0.465095	.	0.556739	.
2	1	2	3	4	1	24	0.636169	.	0.761523	.
2	1	2	3	5	2	8	2.066874	.	2.474142	.
2	1	2	3	6	2	16	1.46069	.	1.748511	.
2	1	2	3	7	2	24	0.505953	.	0.605648	.
2	1	2	3	8	3	8	0.500421	.	0.599026	.
2	1	2	3	9	3	16	1.058152	.	1.266655	.
2	1	2	3	10	3	24	1.299009	.	1.554972	.
2	1	2	3	11	4	8	0.257117	.	0.307781	.
2	1	2	3	12	4	16	0.916277	.	1.096824	.
2	1	2	3	13	4	24	0.729221	.	0.87291	.
3	2	1	1	1	0	0	0.298327	23	0.058336	1
3	2	1	1	2	1	8	5.726893	22	1.11986	0.956522
3	2	1	1	3	1	16	2.753408	21	0.538412	0.913043
3	2	1	1	4	1	24	2.567565	21	0.502072	0.913043
3	2	1	1	5	2	8	6.758809	24.5	1.321645	1.065217
3	2	1	1	6	2	16	5.687768	17.5	1.112209	0.76087
3	2	1	1	7	2	24	6.636544	23.5	1.297737	1.021739
3	2	1	1	8	3	8	3.090859	22	0.604399	0.956522
3	2	1	1	9	3	16	6.010547	23.5	1.175327	1.021739
3	2	1	1	10	3	24	4.279275	22.5	0.836787	0.978261
3	2	1	1	11	4	8	6.220843	23	1.216449	1
3	2	1	1	12	4	16	6.778372	22	1.32547	0.956522
3	2	1	1	13	4	24	3.75109	22	0.733503	0.956522
3	2	1	2	1	0	0	6.773481	23	1.324514	1
3	2	1	2	2	1	8	6.563185	24	1.283392	1.043478
3	2	1	2	3	1	16	4.166791	24.5	0.814791	1.065217
3	2	1	2	4	1	24	5.966532	24	1.16672	1.043478
3	2	1	2	5	2	8	8.460738	20.5	1.654447	0.891304
3	2	1	2	6	2	16	5.223161	22	1.021358	0.956522
3	2	1	2	7	2	24	6.76859	23.5	1.323558	1.021739
3	2	1	2	8	3	8	8.167302	23	1.597067	1
3	2	1	2	9	3	16	6.049672	21.5	1.182977	0.934783
3	2	1	2	10	3	24	5.643752	22.5	1.103602	0.978261
3	2	1	2	11	4	8	7.859194	20	1.536819	0.869565
3	2	1	2	12	4	16	5.130239	14.5	1.003188	0.630435
3	2	1	2	13	4	24	7.01312	24	1.371374	1.043478
3	2	1	3	1	0	0	8.270005	24.5	1.61715	1
3	2	1	3	2	1	8	7.194073	23	1.406758	0.938776

3	2	1	3	3	1	16	5.94697	20.5	1.162894	0.836735
3	2	1	3	4	1	24	6.484936	22.5	1.268091	0.918367
3	2	1	3	5	2	8	6.670778	24	1.304431	0.979592
3	2	1	3	6	2	16	6.162156	15.5	1.204973	0.632653
3	2	1	3	7	2	24	8.499863	7	1.662098	0.285714
3	2	1	3	8	3	8	6.969105	24	1.362767	0.979592
3	2	1	3	9	3	16	6.773481	22	1.324514	0.897959
3	2	1	3	10	3	24	4.56293	24.5	0.892254	1
3	2	1	3	11	4	8	7.942334	23	1.553076	0.938776
3	2	1	3	12	4	16	5.668205	13	1.108384	0.530612
3	2	1	3	13	4	24	6.636544	23	1.297737	0.938776
4	2	2	1	1	0	0	.	21	.	1
4	2	2	1	2	1	8	.	22	.	1.047619
4	2	2	1	3	1	16	.	21	.	1
4	2	2	1	4	1	24	.	17	.	0.809524
4	2	2	1	5	2	8	.	15	.	0.775862
4	2	2	1	6	2	16	.	15	.	0.714286
4	2	2	1	7	2	24	.	13	.	0.619048
4	2	2	1	8	3	8	.	14	.	0.666667
4	2	2	1	9	3	16	.	18	.	0.857143
4	2	2	1	10	3	24	.	10	.	0.47619
4	2	2	1	11	4	8	.	13	.	0.619048
4	2	2	1	12	4	16	.	27	.	1.285714
4	2	2	1	13	4	24	.	15	.	0.714286
4	2	2	2	1	0	0	.	15	.	1
4	2	2	2	2	1	8	.	20	.	1.333333
4	2	2	2	3	1	16	.	26	.	1.733333
4	2	2	2	4	1	24	.	22	.	1.466667
4	2	2	2	5	2	8	.	22	.	1.466667
4	2	2	2	6	2	16	.	25	.	1.666667
4	2	2	2	7	2	24	.	17	.	1.133333
4	2	2	2	8	3	8	.	19	.	1.266667
4	2	2	2	9	3	16	.	11	.	0.733333
4	2	2	2	10	3	24	.	16	.	1.066667
4	2	2	2	11	4	8	.	24	.	1.6
4	2	2	2	12	4	16	.	22	.	1.466667
4	2	2	2	13	4	24	.	22	.	1.466667
4	2	2	3	1	0	0	.	17	.	1
4	2	2	3	2	1	8	.	19	.	1.117647
4	2	2	3	3	1	16	.	26	.	1.529412
4	2	2	3	4	1	24	.	12	.	0.705882
4	2	2	3	5	2	8	.	17	.	1
4	2	2	3	6	2	16	.	24	.	1.411765

4	2	2	3	7	2	24	.	7	.	0.411765
4	2	2	3	8	3	8	.	13	.	0.764706
4	2	2	3	9	3	16	.	24	.	1.411765
4	2	2	3	10	3	24	.	11	.	0.647059
4	2	2	3	11	4	8	.	8	.	0.470588
4	2	2	3	12	4	16	.	13	.	0.764706
4	2	2	3	13	4	24	.	9	.	0.529412
5	1	3	1	1	0	0	.	19	.	1
5	1	3	1	2	1	8	.	17	.	0.894737
5	1	3	1	3	1	16	.	19	.	1
5	1	3	1	4	1	24	.	18	.	0.947368
5	1	3	1	5	2	8	.	18	.	0.981818
5	1	3	1	6	2	16	.	19	.	1
5	1	3	1	7	2	24	.	12	.	0.631579
5	1	3	1	8	3	8	.	19	.	1
5	1	3	1	9	3	16	.	9	.	0.473684
5	1	3	1	10	3	24	.	21	.	1.105263
5	1	3	1	11	4	8	.	20	.	1.052632
5	1	3	1	12	4	16	.	19	.	1
5	1	3	1	13	4	24	.	18	.	0.947368
5	1	3	2	1	0	0	.	18	.	1
5	1	3	2	2	1	8	.	16	.	0.888889
5	1	3	2	3	1	16	.	6	.	0.333333
5	1	3	2	4	1	24	.	20	.	1.111111
5	1	3	2	5	2	8	.	20	.	1.111111
5	1	3	2	6	2	16	.	16	.	0.888889
5	1	3	2	7	2	24	.	18	.	1
5	1	3	2	8	3	8	.	19	.	1.055556
5	1	3	2	9	3	16	.	19	.	1.055556
5	1	3	2	10	3	24	.	19	.	1.055556
5	1	3	2	11	4	8	.	21	.	1.166667
5	1	3	2	12	4	16	.	21	.	1.166667
5	1	3	2	13	4	24	.	20	.	1.111111
5	1	3	3	1	0	0	.	18	.	1
5	1	3	3	2	1	8	.	20	.	1.111111
5	1	3	3	3	1	16	.	20	.	1.111111
5	1	3	3	4	1	24	.	19	.	1.055556
5	1	3	3	5	2	8	.	9	.	0.5
5	1	3	3	6	2	16	.	20	.	1.111111
5	1	3	3	7	2	24	.	14	.	0.777778
5	1	3	3	8	3	8	.	15	.	0.833333
5	1	3	3	9	3	16	.	20	.	1.111111
5	1	3	3	10	3	24	.	22	.	1.222222

5	1	3	3	11	4	8	.	20	.	1.111111
5	1	3	3	12	4	16	.	12	.	0.666667
5	1	3	3	13	4	24	.	11	.	0.611111
6	1	3	1	1	0	0	3.912429	26	0.934776	1
6	1	3	1	2	1	8	5.31942	20	1.270941	0.769231
6	1	3	1	3	1	16	5.073281	28	1.212132	1.076923
6	1	3	1	4	1	24	4.224458	20	1.009327	0.769231
6	1	3	1	5	2	8	5.596046	27	1.337034	6.450968
6	1	3	1	6	2	16	4.883452	26	1.166777	1
6	1	3	1	7	2	24	4.56092	21	1.089717	0.807692
6	1	3	1	8	3	8	3.625586	27	0.866242	1.038462
6	1	3	1	9	3	16	4.793167	26	1.145206	1
6	1	3	1	10	3	24	3.310202	28	0.790889	1.076923
6	1	3	1	11	4	8	4.188417	24	1.000716	0.923077
6	1	3	1	12	4	16	2.654342	27	0.634188	1.038462
6	1	3	1	13	4	24	5.155377	21	1.231747	0.807692
6	1	3	2	1	0	0	3.441308	27	0.822213	1
6	1	3	2	2	1	8	2.694941	8	0.643888	0.296296
6	1	3	2	3	1	16	3.946569	27	0.942933	1
6	1	3	2	4	1	24	6.508756	29	1.555103	1.074074
6	1	3	2	5	2	8	5.654342	25	1.350962	0.925926
6	1	3	2	6	2	16	6.290964	26	1.503067	0.962963
6	1	3	2	7	2	24	5.9063	26	1.411161	0.962963
6	1	3	2	8	3	8	6.555616	26	1.566299	0.962963
6	1	3	2	9	3	16	6.509657	25	1.555318	0.925926
6	1	3	2	10	3	24	3.774354	23	0.901786	0.851852
6	1	3	2	11	4	8	3.229288	25	0.771557	0.925926
6	1	3	2	12	4	16	6.25428	27	1.494302	1
6	1	3	2	13	4	24	5.348135	26	1.277802	0.962963
6	1	3	3	1	0	0	4.894404	28	1.169394	1
6	1	3	3	2	1	8	4.102837	22	0.980269	0.785714
6	1	3	3	3	1	16	7.073806	26	1.690107	0.928571
6	1	3	3	4	1	24	4.821173	13	1.151898	0.464286
6	1	3	3	5	2	8	4.958575	23	1.184726	0.821429
6	1	3	3	6	2	16	3.866998	29	0.923921	1.035714
6	1	3	3	7	2	24	4.7811	21	1.142323	0.75
6	1	3	3	8	3	8	5.136412	26	1.227216	0.928571
6	1	3	3	9	3	16	6.76768	27	1.616966	0.964286
6	1	3	3	10	3	24	5.727596	28	1.368464	1
6	1	3	3	11	4	8	2.402064	25	0.573913	0.892857
6	1	3	3	12	4	16	5.493238	26	1.31247	0.928571
6	1	3	3	13	4	24	8.251707	26	1.971537	0.928571
6	1	3	4	1	0	0	4.493534	28	1.073616	1

6	1	3	4	2	1	8	4.659934	26	1.113373	0.928571
6	1	3	4	3	1	16	3.371762	27	0.805597	0.964286
6	1	3	4	4	1	24	4.486816	29	1.072011	1.035714
6	1	3	4	5	2	8	2.57421	25	0.615043	0.892857
6	1	3	4	6	2	16	5.463842	28	1.305447	1
6	1	3	4	7	2	24	6.98087	28	1.667902	1
6	1	3	4	8	3	8	6.953344	25	1.661326	0.892857
6	1	3	4	9	3	16	5.635337	27	1.346421	0.964286
6	1	3	4	10	3	24	4.333391	29	1.035354	1.035714
6	1	3	4	11	4	8	4.526755	27	1.081554	0.964286
6	1	3	4	12	4	16	3.155632	27	0.753959	0.964286
6	1	3	4	13	4	24	5.056378	28	1.208094	1

Grain Sorghum Site ID

LOC	SR	YR
1	EFAW	2020
2	LCB	2020
3	EFAW	2021
4	LCB	2021
5	LCB	2022
6	CVRS	2022

Grain Sorghum Raw Data

sr	yr	loc	rep	trt	meth	N	yld	stnd	N-yld	N-stnd
1	1	1	1	1	0	0	0.37	.	1.197411	.
1	1	1	1	2	1	8	0.185	.	0.598706	.
1	1	1	1	3	1	16	0.22	.	0.711974	.
1	1	1	1	4	1	24	0.1	.	0.323625	.
1	1	1	1	5	2	8	0.155	.	0.501618	.
1	1	1	1	6	2	16	0.292	.	0.944984	.
1	1	1	1	7	2	24	0.564	.	1.825243	.
1	1	1	1	8	3	8	0.236	.	0.763754	.
1	1	1	1	9	3	16	0.579	.	1.873786	.
1	1	1	1	10	3	24	0.248	.	0.802589	.
1	1	1	1	11	4	8	0.221	.	0.71521	.
1	1	1	1	12	4	16	0.669	.	2.165049	.
1	1	1	1	13	4	24	0.193	.	0.624595	.
1	1	1	2	1	0	0	0.446	.	1.443366	.

1	1	1	2	2	1	8	0.206	.	0.666667	.
1	1	1	2	3	1	16	0.101	.	0.326861	.
1	1	1	2	4	1	24	0.417	.	1.349515	.
1	1	1	2	5	2	8	0.257	.	0.831715	.
1	1	1	2	6	2	16	0.169	.	0.546926	.
1	1	1	2	7	2	24	0.128	.	0.414239	.
1	1	1	2	8	3	8	0.25	.	0.809061	.
1	1	1	2	9	3	16	0.27	.	0.873786	.
1	1	1	2	10	3	24	0.217	.	0.702265	.
1	1	1	2	11	4	8	0.252	.	0.815534	.
1	1	1	2	12	4	16	0.128	.	0.414239	.
1	1	1	2	13	4	24	0.283	.	0.915858	.
1	1	1	3	1	0	0	0.113	.	0.365696	.
1	1	1	3	2	1	8	0.21	.	0.679612	.
1	1	1	3	3	1	16	0.216	.	0.699029	.
1	1	1	3	4	1	24	0.222	.	0.718447	.
1	1	1	3	5	2	8	0.254	.	0.822006	.
1	1	1	3	6	2	16	0.215	.	0.695793	.
1	1	1	3	7	2	24	0.05	.	0.161812	.
1	1	1	3	8	3	8	0.131	.	0.423948	.
1	1	1	3	9	3	16	0.203	.	0.656958	.
1	1	1	3	10	3	24	0.176	.	0.569579	.
1	1	1	3	11	4	8	0.208	.	0.673139	.
1	1	1	3	12	4	16	0.426	.	1.378641	.
1	1	1	3	13	4	24	0.2	.	0.647249	.
2	1	2	1	1	0	0	0.897	.	0.470208	.
2	1	2	1	2	1	8	0.657	.	0.3444	.
2	1	2	1	3	1	16	1.686	.	0.883802	.
2	1	2	1	4	1	24	2.601	.	1.363446	.
2	1	2	1	5	2	8	0.3	.	0.15726	.
2	1	2	1	6	2	16	1.176	.	0.61646	.
2	1	2	1	7	2	24	1.078	.	0.565088	.
2	1	2	1	8	3	8	1.026	.	0.53783	.
2	1	2	1	9	3	16	1.482	.	0.776865	.
2	1	2	1	10	3	24	2.069	.	1.084571	.
2	1	2	1	11	4	8	0.868	.	0.455006	.
2	1	2	1	12	4	16	1.421	.	0.744889	.
2	1	2	1	13	4	24	1.353	.	0.709243	.
2	1	2	2	1	0	0	2.738	.	1.435261	.
2	1	2	2	2	1	8	1.621	.	0.849729	.
2	1	2	2	3	1	16	2.252	.	1.1805	.
2	1	2	2	4	1	24	1.658	.	0.869125	.
2	1	2	2	5	2	8	1.56	.	0.817753	.

2	1	2	2	6	2	16	2.331	.	1.221912	.
2	1	2	2	7	2	24	1.689	.	0.885375	.
2	1	2	2	8	3	8	1.458	.	0.764284	.
2	1	2	2	9	3	16	2.774	.	1.454132	.
2	1	2	2	10	3	24	2.782	.	1.458326	.
2	1	2	2	11	4	8	1.526	.	0.79993	.
2	1	2	2	12	4	16	0.841	.	0.440853	.
2	1	2	2	13	4	24	2.245	.	1.17683	.
2	1	2	3	1	0	0	2.088	.	1.094531	.
2	1	2	3	2	1	8	2.352	.	1.23292	.
2	1	2	3	3	1	16	2.459	.	1.289009	.
2	1	2	3	4	1	24	2.09	.	1.095579	.
2	1	2	3	5	2	8	2.219	.	1.163201	.
2	1	2	3	6	2	16	2.173	.	1.139088	.
2	1	2	3	7	2	24	2.215	.	1.161104	.
2	1	2	3	8	3	8	2.452	.	1.28534	.
2	1	2	3	9	3	16	1.13	.	0.592347	.
2	1	2	3	10	3	24	3.162	.	1.657522	.
2	1	2	3	11	4	8	2.254	.	1.181548	.
2	1	2	3	12	4	16	2.045	.	1.07199	.
2	1	2	3	13	4	24	1.487	.	0.779486	.
3	2	1	1	1	0	0	1.104	25	1.232143	1
3	2	1	1	2	1	8	1.032	22	1.151786	0.88
3	2	1	1	3	1	16	1.229	22	1.371652	0.88
3	2	1	1	4	1	24	1.665	17	1.858259	0.68
3	2	1	1	5	2	8	0.958	19	1.069196	0.76
3	2	1	1	6	2	16	1.043	21	1.164063	0.84
3	2	1	1	7	2	24	2.25	21	2.511161	0.84
3	2	1	1	8	3	8	1.09	30	1.216518	1.2
3	2	1	1	9	3	16	0.889	14	0.992188	0.56
3	2	1	1	10	3	24	1.909	11	2.13058	0.44
3	2	1	1	11	4	8	0.864	20	0.964286	0.8
3	2	1	1	12	4	16	0.895	27	0.998884	1.08
3	2	1	1	13	4	24	1.869	26	2.085938	1.04
3	2	1	2	1	0	0	0.607	20	0.677455	1
3	2	1	2	2	1	8	1.307	28	1.458705	1.4
3	2	1	2	3	1	16	1.985	25	2.215402	1.25
3	2	1	2	4	1	24	1.488	25	1.660714	1.25
3	2	1	2	5	2	8	1.165	34	1.300223	1.7
3	2	1	2	6	2	16	3.907	10	4.360491	0.5
3	2	1	2	7	2	24	2.458	26	2.743304	1.3
3	2	1	2	8	3	8	1.387	25	1.547991	1.25
3	2	1	2	9	3	16	3.328	16	3.714286	0.8

3	2	1	2	10	3	24	2.098	21	2.341518	1.05
3	2	1	2	11	4	8	1.323	25	1.476563	1.25
3	2	1	2	12	4	16	2.902	17	3.238839	0.85
3	2	1	2	13	4	24	1.971	17	2.199777	0.85
3	2	1	3	1	0	0	0.977	17	1.090402	1
3	2	1	3	2	1	8	1.436	19	1.602679	1.117647
3	2	1	3	3	1	16	1.272	14	1.419643	0.823529
3	2	1	3	4	1	24	0.845	25	0.94308	1.470588
3	2	1	3	5	2	8	1.779	21	1.985491	1.235294
3	2	1	3	6	2	16	1.421	22	1.585938	1.294118
3	2	1	3	7	2	24	0.987	27	1.101563	1.588235
3	2	1	3	8	3	8	2.895	26	3.231027	1.529412
3	2	1	3	9	3	16	1.227	26	1.36942	1.529412
3	2	1	3	10	3	24	0.995	26	1.110491	1.529412
3	2	1	3	11	4	8	1.668	27	1.861607	1.588235
3	2	1	3	12	4	16	0.819	19	0.914063	1.117647
3	2	1	3	13	4	24	0.972	24	1.084821	1.411765
4	2	2	1	1	0	0	2.249	46	1.272539	1
4	2	2	1	2	1	8	2.905	33	1.643719	0.717391
4	2	2	1	3	1	16	2.159	45	1.221614	0.978261
4	2	2	1	4	1	24	3.235	40	1.830441	0.869565
4	2	2	1	5	2	8	1.748	30	0.989061	0.9375
4	2	2	1	6	2	16	3.12	30	1.765372	0.652174
4	2	2	1	7	2	24	2.217	42	1.254432	0.913043
4	2	2	1	8	3	8	2.397	39	1.356281	0.847826
4	2	2	1	9	3	16	1.658	40	0.938137	0.869565
4	2	2	1	10	3	24	3.747	35	2.120143	0.76087
4	2	2	1	11	4	8	2.93	48	1.657865	1.043478
4	2	2	1	12	4	16	1.745	40	0.987363	0.869565
4	2	2	1	13	4	24	2.594	48	1.467748	1.043478
4	2	2	2	1	0	0	1.793	33	1.014523	1
4	2	2	2	2	1	8	1.532	37	0.866843	1.121212
4	2	2	2	3	1	16	2.013	45	1.139004	1.363636
4	2	2	2	4	1	24	1.955	41	1.106186	1.242424
4	2	2	2	5	2	8	1.508	45	0.853263	1.363636
4	2	2	2	6	2	16	1.915	54	1.083553	1.636364
4	2	2	2	7	2	24	1.303	43	0.737269	1.30303
4	2	2	2	8	3	8	1.201	31	0.679555	0.939394
4	2	2	2	9	3	16	1.327	51	0.750849	1.545455
4	2	2	2	10	3	24	1.551	37	0.877593	1.121212
4	2	2	2	11	4	8	1.5	40	0.848736	1.212121
4	2	2	2	12	4	16	1.906	50	1.078461	1.515152
4	2	2	2	13	4	24	1.847	56	1.045077	1.69697

4	2	2	3	1	0	0	1.26	49	0.712939	1
4	2	2	3	2	1	8	0.944	44	0.534138	0.897959
4	2	2	3	3	1	16	0.899	33	0.508676	0.673469
4	2	2	3	4	1	24	1.022	34	0.578272	0.693878
4	2	2	3	5	2	8	1.083	43	0.612788	0.877551
4	2	2	3	6	2	16	1.096	38	0.620143	0.77551
4	2	2	3	7	2	24	1.233	43	0.697661	0.877551
4	2	2	3	8	3	8	1.061	40	0.600339	0.816327
4	2	2	3	9	3	16	0.646	33	0.365522	0.673469
4	2	2	3	10	3	24	1.687	41	0.954545	0.836735
4	2	2	3	11	4	8	0.812	36	0.459449	0.734694
4	2	2	3	12	4	16	1.174	39	0.664278	0.795918
4	2	2	3	13	4	24	0.733	53	0.414749	1.081633
5	3	2	1	1	0	0	4.05318	43	0.843061	1
5	3	2	1	2	1	8	3.778029	45	0.785829	1.046512
5	3	2	1	3	1	16	4.553149	28	0.947054	0.651163
5	3	2	1	4	1	24	4.267756	39.5	0.887693	0.918605
5	3	2	1	5	2	8	.	.	.	#VALUE!
5	3	2	1	6	2	16	4.580646	39	0.952774	0.906977
5	3	2	1	7	2	24	3.939522	33.5	0.81942	0.77907
5	3	2	1	8	3	8	3.666086	43	0.762545	1
5	3	2	1	9	3	16	3.586691	45	0.746031	1.046512
5	3	2	1	10	3	24	3.232077	32.5	0.672271	0.755814
5	3	2	1	11	4	8	4.253533	39	0.884734	0.906977
5	3	2	1	12	4	16	4.059566	42	0.844389	0.976744
5	3	2	1	13	4	24	3.655637	42.5	0.760372	0.988372
5	3	2	2	1	0	0	4.889714	47	1.01706	1
5	3	2	2	2	1	8	3.227543	45.5	0.671328	0.968085
5	3	2	2	3	1	16	3.615132	47.5	0.751947	1.010638
5	3	2	2	4	1	24	3.639792	45.5	0.757076	0.968085
5	3	2	2	5	2	8	.	.	.	#VALUE!
5	3	2	2	6	2	16	4.815906	41.5	1.001708	0.882979
5	3	2	2	7	2	24	3.434047	45	0.714281	0.957447
5	3	2	2	8	3	8	4.440659	51	0.923656	1.085106
5	3	2	2	9	3	16	3.580598	49	0.744764	1.042553
5	3	2	2	10	3	24	4.765746	41.5	0.991274	0.882979
5	3	2	2	11	4	8	3.320591	34	0.690682	0.723404
5	3	2	2	12	4	16	3.793955	44	0.789142	0.93617
5	3	2	2	13	4	24	4.593597	37.5	0.955467	0.797872
5	3	2	3	1	0	0	5.104981	52.5	1.061835	1
5	3	2	3	2	1	8	2.875673	45	0.59814	0.857143
5	3	2	3	3	1	16	2.960033	46.5	0.615686	0.885714
5	3	2	3	4	1	24	4.30565	48.5	0.895575	0.92381

5	3	2	3	5	2	8	.	.	.	#VALUE!
5	3	2	3	6	2	16	4.604356	49	0.957705	0.933333
5	3	2	3	7	2	24	3.251593	46	0.676331	0.87619
5	3	2	3	8	3	8	3.317622	51.5	0.690065	0.980952
5	3	2	3	9	3	16	4.361357	36	0.907162	0.685714
5	3	2	3	10	3	24	2.637155	46	0.548528	0.87619
5	3	2	3	11	4	8	3.31459	47	0.689434	0.895238
5	3	2	3	12	4	16	4.583723	45	0.953414	0.857143
5	3	2	3	13	4	24	4.457845	50.5	0.927231	0.961905
5	3	2	4	1	0	0	5.182908	42	1.078044	1
5	3	2	4	2	1	8	3.692461	42	0.768031	1
5	3	2	4	3	1	16	4.523747	47.5	0.940939	1.130952
5	3	2	4	4	1	24	4.520226	45.5	0.940206	1.083333
5	3	2	4	5	2	8	.	.	.	#VALUE!
5	3	2	4	6	2	16	3.008478	47.5	0.625763	1.130952
5	3	2	4	7	2	24	4.156314	50	0.864513	1.190476
5	3	2	4	8	3	8	3.451527	46	0.717917	1.095238
5	3	2	4	9	3	16	4.653527	48	0.967933	1.142857
5	3	2	4	10	3	24	5.64442	52	1.174038	1.238095
5	3	2	4	11	4	8	3.779784	44.5	0.786194	1.059524
5	3	2	4	12	4	16	4.324591	52.5	0.899514	1.25
5	3	2	4	13	4	24	4.58137	47.5	0.952924	1.130952
6	1	3	1	1	0	0	2.420527	41	0.949972	1
6	1	3	1	2	1	8	2.564094	39	1.006317	0.95122
6	1	3	1	3	1	16	2.437779	41	0.956743	1
6	1	3	1	4	1	24	3.179095	36	1.247684	0.878049
6	1	3	1	5	2	8	2.926396	39	1.148508	15.30614
6	1	3	1	6	2	16	3.300053	39	1.295156	0.95122
6	1	3	1	7	2	24	2.960488	23	1.161888	0.560976
6	1	3	1	8	3	8	3.207726	42	1.25892	1.02439
6	1	3	1	9	3	16	2.839818	31	1.114529	0.756098
6	1	3	1	10	3	24	2.972452	33	1.166584	0.804878
6	1	3	1	11	4	8	2.472007	23	0.970176	0.560976
6	1	3	1	12	4	16	2.954872	27	1.159684	0.658537
6	1	3	1	13	4	24	2.609917	25	1.024301	0.609756
6	1	3	2	1	0	0	2.747766	36	1.078402	1
6	1	3	2	2	1	8	2.86316	35	1.12369	0.972222
6	1	3	2	3	1	16	2.321983	37	0.911297	1.027778
6	1	3	2	4	1	24	3.63317	38	1.425892	1.055556
6	1	3	2	5	2	8	1.919942	44	0.75351	1.222222
6	1	3	2	6	2	16	2.713124	39	1.064806	1.083333
6	1	3	2	7	2	24	1.833921	36	0.71975	1
6	1	3	2	8	3	8	2.575896	36	1.010949	1

6	1	3	2	9	3	16	2.769236	37	1.086828	1.027778
6	1	3	2	10	3	24	2.288372	42	0.898106	1.166667
6	1	3	2	11	4	8	2.310955	40	0.906969	1.111111
6	1	3	2	12	4	16	2.541314	39	0.997377	1.083333
6	1	3	2	13	4	24	2.972776	44	1.166711	1.222222
6	1	3	3	1	0	0	1.942744	46	0.762459	1
6	1	3	3	2	1	8	2.454528	45	0.963316	0.978261
6	1	3	3	3	1	16	2.235931	54	0.877525	1.173913
6	1	3	3	4	1	24	3.42093	40	1.342596	0.869565
6	1	3	3	5	2	8	2.138243	37	0.839186	0.804348
6	1	3	3	6	2	16	2.259272	47	0.886686	1.021739
6	1	3	3	7	2	24	1.540557	44	0.604615	0.956522
6	1	3	3	8	3	8	2.661835	43	1.044677	0.934783
6	1	3	3	9	3	16	1.36829	48	0.537006	1.043478
6	1	3	3	10	3	24	2.098534	37	0.823601	0.804348
6	1	3	3	11	4	8	1.914452	48	0.751356	1.043478
6	1	3	3	12	4	16	2.472245	40	0.97027	0.869565
6	1	3	3	13	4	24	2.018026	44	0.792005	0.956522
6	1	3	4	1	0	0	3.080953	40	1.209166	1
6	1	3	4	2	1	8	2.138393	40	0.839245	1
6	1	3	4	3	1	16	2.339475	43	0.918162	1.075
6	1	3	4	4	1	24	2.535263	40	0.995002	1
6	1	3	4	5	2	8	2.057902	40	0.807655	1
6	1	3	4	6	2	16	2.523819	45	0.990511	1.125
6	1	3	4	7	2	24	1.787868	35	0.701676	0.875
6	1	3	4	8	3	8	1.960133	39	0.769284	0.975
6	1	3	4	9	3	16	1.98342	35	0.778423	0.875
6	1	3	4	10	3	24	1.776416	41	0.697181	1.025
6	1	3	4	11	4	8	1.87383	45	0.735413	1.125
6	1	3	4	12	4	16	1.632859	39	0.64084	0.975
6	1	3	4	13	4	24	1.742076	41	0.683704	1.025

VITA

Matthew Oran Thomas

Candidate for the Degree of

Master of Science

Thesis: EFFECT OF THE METHOD AND RATE OF PLANTER APPLIED NITROGEN ON CORN AND GRAIN SORGHUM PRODUCTION

Major Field: Plant and Soil Science

Biographical:

Education:

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