# The potential of different forms of mulch on soil moisture, soil temperature and yield of sorghum in Zwenshambe, Botswana

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# APPROVAL

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# STATEMENT OF ORIGIONALITY

The work contained in this thesis was compiled by the author at Botswana University of Agriculture and Natural Resources between January 2018 and March 2021.It is original except where the references are made and it will not be submitted for the award of any other degree or diploma of any other University.

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Author’s Name and Signature Date

# Acknowledgement

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Abstract

Due to climate change, rainfed arable conditions have become quite unpredictable in semi-arid conditions of Botswana. Several countries have been experimenting with different climate smart technologies with a view to find suitable ones for the continued production of staple food crops such as sorghum. Conservation Agriculture (CA) which incorporates three practices (minimum soil disturbance, mulching and crop rotations) has received a lot of interest as one of the promising climate smart initiatives. A study to explore the effect of mulching within CA on the production of field crops was undertaken in Zwenshambe which is located at $20^0$ 30'21.38''S latitude and $27^0$26'9.32" E longitude in the North East District of Botswana in Southern Africa. The site has an estimated terrain elevation above sea level of 1261 meters. The soils are sandy loam with a few stones. The natural vegetation is mainly mophane wood land with a few acacia species with mostly Eragrostis lehmanniana grass and a few patches of cynodon dactylon. The specific objectives of the study were to determine the effect of 4 different mulches on soil temperature, soil moisture retention and biomass yield of sorghum. The study consisted of 5 treatments namely: i) no mulch as the control, ii) maize straw mulch (Zea mays) iii) Grass mulch (Eragrostis lehmanniana), iv) Mophane leaves and v) Orange plastic mulch (250µm).A Complete randomised Block Design was used with each treatment having 4 plots measuring 6m × 4m. Soil temperature was measured using soil thermometer of range -10 to $50^0$c at a depth of 10cm every 2 weeks. Gravimetric soil moisture measurements were taken every 2 weeks by collecting one soil sample from each plot using a spade at a depth of 10cm. The biomass yield of sorghum was recorded at the end of 90day from sowing seeds.

Despite variations to soil temperature and soil moisture retention effects by the different treatments, none of the mulches displayed any significant differences at ($p<0.05$). The means for soil temperature under the different mulches were no-mulch-26.13 $^0$C , mophane leaves and twigs-26.75 $^0$C, Orange plastic mulch-26.84 $^0$C, grass mulch-26.16 $^0$C and maize straw mulch-26.06 $^0$C while means for soil moisture retention were no-mulch-1.98%, mophane leaves and twigs-2.18%, orange plastic mulch-2.39%, grass mulch-2.04% and maize straw mulch-1.96%.The orange plastic mulch and mophane leaves and twigs mulch (colophospermum mopane) significantly ($p<0.05$) increased the biomass yield of sorghum. The means for yield were no-mulch-43.65g/m$^2$, mophane leaves and twigs mulch-67.68g/m$^2$, orange plastic mulch-72.43g/m$^2$, grass mulch-50.73g/m$^2$ and maize straw mulch-33.83g/m$^2$. Means were separated using LSD.

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# CHAPTER 1.0: INTRODUCTION

## 1.1 Background

Botswana is one of the countries in Africa that will experience the most extreme changes in temperature and precipitation under global warming scenarios of 1.5°C - 3°C above pre-industrial levels. These changes will have significant negative impacts on agriculture and other water dependant sectors (ASSR 2018).

Climate Change is a shift in worldwide or regional climate patterns, especially a change discernible from the mid to late 20th century onwards and ascribed largely to the increased levels of atmospheric carbon dioxide resulting from the use of fossil fuels, (Lexico 2019). Climate change is a change in the sequence of weather, and related shifts in oceans, land facets and flat mass of floating ice taking place over long term scales of decades or longer (Australian Academy of Science, 2020). Climate change results in a number of changes in Botswana, including drought and reduced yields which hampers efforts to make agriculture a meaningful contributor to GDP. Botswana was anticipated to undergo a temperature upsurge of up to 2 degrees Celsius by 2015 and a downswing in river flows by 13% (United Nations Development Programme 2012). The danger presented by climate change means that the stress caused by water shortage and land decadence will aggravate. The way forward will be to work cordially with Government to be prepared to tackle climate change through adaptation measures (Leepile 2010). There is also need for more research on effects of climate change as more information can be gathered and solutions can be sought as the country cannot come up with solutions to effects that are unknown or are perceived to exist. The government could support applied research in dryland agriculture and distribute research findings through agriculture extension service (Batisani and Yanal 2010). Farmers regardless of their scale of production have to receive current information on issues of climatic shift and interventions. (Jiri et al. 2016) stated that scientific prognostication has to some extent failed to influence small holder farmers as they could not access the information unprejudiced. There is need to develop varieties of crops that are adapted to high temperatures and low moisture in order to deal with climatic change. This has been done for some time in Botswana but the publicity of these new varieties is not aggressively promoted.

General circulation models for rainfall in Botswana predict a rainfall decline presumably with high rains locally (School of Business, Economics and Law University of Gothenburg 2008). Crop production in Botswana has been the riskiest part of the Agricultural sector due to its overdependence on rainfall. Arable production is a doubtful, rain fed system with low output due to low and erratic rains (UNDP, 2012). In addition, Agriculture in Botswana is affected by unfavourable weather conditions, such as high diurnal temperatures, insufficient market entry and marketing facilities and lack of proper technology and skills. Only about 0.7% of the total land area in Botswana is arable crop production and is hindered by traditional farming methods, repeated droughts, erosion and disease (FAO, 2019). Cereal production in Botswana is limited by poor soils and insufficient rainfall. These circumstances are likely to exacerbate through the 21st century on account of low rainfall and high temperatures that are estimated by global Circulation models scheme over the next several decades (Chipanshi et al. 2003). The temporal and space-based or spatial patterns of rainfall and temperature in Southern Africa are likely to change significantly and include up to 20% less rainfall by 2025 (Leepile 2010). Irrigation is one adaptation strategy for climate change in Botswana. Ministry of Agriculture operates two small holder irrigation schemes at Glen valley(200ha), using treated waste water, and Dikabeya (60ha), using reservoir water, a third one at Kubung which is at design stage. Irrigation in Botswana is predominately for horticulture, mostly vegetables and citrus crops (Department of water Affairs and the centre for Applied Research, 2014).

Emphasis on more drought resistant crops in drought-prone areas could help in reducing vulnerability to climate change (Akinnagde and Irohibe, 2014). The primary objective of crop improvement programmes is to develop improved varieties and hybrids with drought tolerant, acceptable agronomic and food qualities, resistance to diseases and insect pest (Mazhani 1995).

Conservation agriculture is a concept that the Government of Botswana is currently exploring as it has the potential to improve Sorghum yields.

## 1.2 The concept of conservation agriculture

Conservation Agriculture(CA) involves three principles of reduced soil disturbance or soil can be disturbed as little as possible e.g. direct planting to conserve soil and moisture, crop rotations and mixing the various crops to maintain soil fertility and soil cover or mulching throughout the growth of the crop to conserve soil and moisture and mulching when there are no crops growing on the field for soil and moisture conservation e.g. placing grass or leaf or any suitable mulch on top of the soil which is to be planted the following season (Sustainet EA, 2010).

Conservation Agriculture based resource conservation technology has shown to produce more at minimal costs, lessened contamination of the physical and biological components of the earth, support use of organics, better soil quality and assure speedy planting of winter crops, cushion against extreme heat problem in the region (Singh 2018).

CA has the ability to improve crop yields, soil organic matter extent, soil infiltration rates and microsites for multiplication of beneficial soil organisms resulting into increased crop production (Nhamo and Lungu 2017). Of concern on Conservation Agriculture are challenges such as change of mind set, inadequate Conservation Agriculture knowledge and skills, retaining crop residues for mulching, availability of equipment and inputs, weed control and land tenure systems.

In 2009 small holder Conservation Agriculture farmers in Zimbabwe produced an average of 3 tonnes/ha with the best farmers producing 6 tonnes/ha (Wagstuff and Harty 2010). Brandt farm in USA demonstrated that crop yields are improved under long term No till with cover crop combination (Islam and Reeder 2014). Lekoti farmers (Lekoti is a planting basin system in Lesotho which is part of Conservation Agriculture) who before espousing Conservation Agriculture were unable to yield enough maize for themselves, were able to sell surplus grain production to the world food Programme (WFP) (Silici 2010).

The degree of espousal per area in (ha) shows that USA uses Conservation Agriculture in an area of 26.5 million ha, whilst Argentina uses CA in an area of 25.6 million ha and Brazil uses 2.6 million ha to mention but a few countries (Friedrick et al. 2012). Conservation Agriculture can provide more yield on erodible soils on steep slopes, where there is no robust contention for crop remains for livestock feeding (Giller et al. 2009).

In Southern Africa, the use of Conservation Agriculture was highest in Zimbabwe where about a third of the farmers (35%) stated its usage. This was followed by Mozambique (13.6%) and Malawi (6.7%) had particularly much lower espousal rate (Mungo et al., 2017).

The study intends to determine if different mulches would reduce soil temperature, conserve soil moisture and increase the yield of sorghum. According to Qin et al. 2015, the aspect of conservation Agriculture selected for investigation (Mulching) has been singled out as the one that has a highest potential to effectively reduce soil temperature, conserve soil moisture and increase crop yield. They also indicated that soil mulching can significantly raise yields of wheat and maize by 20% to 60% respectively.

## 1.3 Justification of the study

Botswana and the whole world are faced with a challenge of global warming which results in increased soil temperature, reduced soil moisture and associated challenges to crop yields. Even though several interventions are possible, soil moisture retention could be critical for Botswana conditions and as such this study aims to identify the type of mulch to be used in Conservation Agriculture and the benefits to be derived from such use with regard to the effects on soil temperature, soil moisture and yield of sorghum. Mulches were chosen on the basis of availability and affordability being plastic mulch, grass mulch (Eragrostis Lehmanniana), mophane leaves (Colophospermum mopane) and twigs, maize stover (Zea mays) which could be obtained at minimal labour cost. In the area of study maize stover is not used as animal feed therefore, there is no completion for its use. The plastic used was the orange 250-micron thickness one. The grass used was the most prevalent in the field where the experiment was conducted the prevalence of grass was at 0.5kg/m$^2$.Mophane leaves and twigs were also easily available and are not consumed in large quantities by goats, cattle and donkeys that normally roam the area. An advantage of using mophane leaves and twigs is that the tree sprouts faster when browsed by livestock. Mopane trees can produce 1.4 tonnes/ha of leaves per year, therefore it was available for use without danger of range deterioration. Makhado et al. 2018) stated that the total dry matter of mophane in the Limpopo Mopane woodland was 1.4 tonnes/ha. Grass and other herbaceous plants have an advantage in that they can be acquired free of charge except for the cost of labour for harvesting or cutting from the bushes surrounding the fields used for producing crops in the area and if these are put into use the yield in the area is expected to increase. The labour cost for harvesting grass and other herbaceous plant is minimal at a rate of P26.50 per day per person according to Botswana drought relief programme rate. The exercise may take 4 days per hectare if 3 people are engaged. Zwenshambe Agricultural area in the North East District of Botswana has been earmarked by the Department of Crop production as one of the areas where piloting of Conservation Agriculture will be done. Ten Farmers in the area have undergone training on Conservation Agriculture and have started using the technology even though the adoption is minimal, five of them are using Conservation Agriculture. This study will identify the type of mulch that they and other farmers with similar geographical conditions in Botswana and elsewhere can use. It may also act as a stimulus for aspiring farmers in the region to take up CA with a view to improve their crop yields. Results of studies by Narayan et al., (2007) support this assertion by stating that sorghum yields increased from 169kg/ha under Zero tillage without mulching to

1625kg/ha under zero tillage with mulching. Soil temperature may be reduced by 2-7%, as indicated by Olasantan, (1999), soil moisture conserved by 23.3% as observed by Teame et al., (2017) and the yield of sorghum increased by 7.8% as stated by Dong et al., (2018).

## 1.5 Objectives

### Main objective

1.5.1 To determine if conservation Agriculture can be beneficial in Zwenshambe using easily available mulching material.

### Specific Objectives

1.5.2 To determine the effect of four types of mulch (maize straw, grass, orange plastic and mophane leaves and twigs) on soil temperature.

1.5.3 To determine the effect of four types of mulch (maize straw, grass, orange plastic and mophane leaves and twigs) on soil moisture retention.

1.5.4 To determine the effect of four types of mulch (maize straw, grass, orange plastic and mophane leaves and twigs) on sorghum biomass yield.

1.4 Hypotheses

$H_0$: $\mu1=\mu2=\mu3=\mu4=\mu5$

H1: At least one of the means is different from others.

The hypothesis was tested at 95% confidence level.

Mean 1 denotes control (treatment with no mulch)

Mean 2 denotes (treatment with maize straw from maize (Zea mays) which had reached maturity at 1kg/$m^2$ and moisture content of 20%)

Mean 3 denotes (treatment with grass mulch (Eragrostis Lehmanniana), which had not produced seeds yet at 0.5 kg/$m^2$ and moisture content of 20%)

Mean 4 denotes (treatment with mophane leaves and twigs cut fresh from green mophane trees (Colophospermum mopane) at 2kg per $m^2$)

Mean 5 denotes (treatment with orange plastic mulch, micron 250)

## CHAPTER 2.0: LITERATURE REVIEW

### 2.1 Soil Temperature Effect

According to Asaal et al. (1998) a soil with translucent polythene sheet mulch increased soil temperature. Ramakrishna et al. (2006) stated that mulches in Northern Vietnum increase the soil temperature, delay the loss of soil moisture, and control weed growth, which are key aspects contributing to the production of groundnuts. Singh and Kamal (2012) reiterated the same sentiments by stating that mulching with black plastic mulch in tomatoes increases the soil temperature. Bu et al. (2013) also stated that mulch practices could significantly improve cumulative topsoil temperature and soil moisture. Wu et al. (1996) stated that temperature in mulched soil was much higher than that of un-mulched soil. The differences between mulched and bare soil temperatures changed diurnally and changed with soil depth. The temperature was higher during day time than at night, higher at shallow depth than at deep depth. Cook et al. (2006) stated that inorganic mulches increased soil temperature. Iburra-Jemenez et al (2008) mentioned that maximum, minimum and mean soil temperatures under all plastic mulch treatments were higher than in un-mulched soil. Ramakrishna et al. (2006) found out that polyethylene mulched soil likened to chemical and un-mulched treatments unfailingly had significantly higher temperature at 5cm and 10 cm soil depths during autumn, winter and spring.

There are, however, other studies which stated that mulches reduce soil temperature and this was dependent on the type of mulch used. Olasantan (1999) stated that physical effects of mulch lead to a decline in nutrient losses by runoff, soil erosion and leaching and decreasing maximum soil temperature by 2-7$^{o}$C and conserving moisture by 50-120g/kg. Gruda (2008) also stated that wood fibre mulch altered the micro-environment and conserved soil moisture. Truax and Gagnon (1993) stated that the lowest temperatures were found under straw mulch treatments and the highest temperatures were found under the black plastic mulch. . Yue-Yuan et al, (2018) concurred with Traux and Gagon (1993) by stating that Black plastic mulch warmed the soil as compared to straw mulch particularly during the vegetative growth of maize in Australia. Chakraborty et al. (2010) stated that organic mulches resulted in cooler soil at the surface and near the surface during noon-time in India. Schombeck and Evanylo (1998) stated that black paper and untreated kraft paper mulches reduced afternoon soil temperature about

2$^{o}$C, whereas oiled paper amplified soil temperature by about 3$^{o}$C, Black paper slightly elevated morning temperature, while under undyed kraft paper the soil moisture retention was moderate. According to Cook et al. (2006) stated that Soil water and soil temperature regimes were positively enhanced by mulches, thereby improving soil conditions for the growth of maize. As wheat straw application rate increased water retention increased and temperature declined. Sidhu et al. (2007) stated that wheat straw mulching significantly lowered the maximum soil temperature at seeding depth. Murungu et al. (2011) stated that Oat, grazing vetch and forage pea mulch significantly ($P< 0.01$) reduced soil temperature compared to lupin mulch and control plots at 5cm during the emergence period. Murungu et al.(2011) also stated that Oat and grazing vetch mulch lessened soil water from depth > 10cm at planting, yet they conserve soil water after the planting and germination periods. In general literature review point to the fact that inorganic mulches increase soil temperature while organic mulches reduce soil temperature. Iburra-Jemeneze et al. (2008) made a statement that corroborates this idea as they said inorganic mulches increase soil temperatures while organic mulches resulted in cooler soil at surface and near surface during noon-time. El-Shaikh and Fouda (2008) observed that soil temperature increased in polythene mulch and reduced in organic mulches. The efficacy of mulch generally depends on the type of mulch used.

## 2.2 Soil Moisture Retention

Soil moisture retention is a significant factor in improving the optimal soil physical environment. The significance of mulching is to conserve moisture as far as possible. Chen et al. (2007) stated that straw mulching is an effective measure to conserve soil moisture. However, the presence of straw on the soil surface affects soil temperature, which in turn influences crop growth. Zhang et al. (2009) shared the same sentiments by stating that mulching is a promising soil management practice which can proliferate soil water storage levels particularly in dry years, and subsequently increase economic benefits. (Mulumba 2008) stated that mulch use increases total soil porosity, available water capacity, soil aggregation and moisture content at field capacity. According to Cook et al. (2006) mulches improve topsoil water holding compared with no mulch, but no till maintained higher water content. As wheat straw application rate increased water retention increased and temperature reduced. Sharma and Acharya (2000) stated that seed zone (0-7.5 cm) as well as root-zone (0.45 cm) moisture contents at the time of sowing of wheat crop were significantly higher in mulched (with fresh lantana biomass) than in un-mulched plots. Xie et al. (2004) stated that Plastic –mulched wheat attained higher yield due to extracting more soil water. Therefore, it was necessary for plastic mulch use under no irrigation that there is high soil water content in wheat field before sowing.

Lekasi et al. (2001) stated that plastic mulching as a water conservation and control measure, enhanced yield of cabbage. According to Snyder et al.(2015) the plastic films evaluated(clear, black, white on black) demonstrated similar ability to insulate the soil from extremes in both soil temperature and moisture suggesting a potentially reduced need for irrigation and protection against early frost, high temperature, overwatering and drought. In a study conducted by Haque and Clarke (2018) white plastic mulch produced a higher maize yield than blue and black plastic mulch in Bangladesh. In the absence of the white colour it was best to choose a colour close to white than black for this study. Rahman et al. (2005) also stated that rice straw mulching has a substantial effect on moisture conservation. Chakraboty et al. (2008) stated that rice husks mulch was found to offer a better soil physical environment in terms of soil moisture retention, especially during dry periods when the crop was exposed to water stress and optimum soil temperature during crop growth. Prakash et al. (2007) stated that in-situ soil moisture status also increased during summer and winter season under different mulches in contrast to control (no mulch). Ramakrisna et al. (2006) stated that mulch averts soil water evaporation and thus helps hold soil moisture. The polyethylene mulched soil compared to chemical and un-mulched treatments dependably had significantly higher temperature at 5cm and 10 cm soil depths during both seasons. Murungu et al. (2011) stated that Oat, grazing vetch and forage pea mulch significantly ($P < 0.01$) reduced soil temperature compared to lupin mulch and control plots at 5cm during the emergence period. Oat and grazing vetch mulch lessen soil water from depth > 10cm at planting, however, they conserve soil water after the planting and germination periods. According to Teame et al. (2017) the highest soil moisture (30%) was conserved under sesame mulch while the lowest soil moisture content (23.3%) was conserved under Sudan grass. Mulching is an effective barrier against water losses and restricts soil evaporation.

## 2.3 Crop Yield

Mulching is done so that soil temperature is controlled and water is preserved which results in increased crop yields. Sarkar and Singh (2007) stated that Substantial increases in grain yield was observed under straw mulching over soil dust mulching and un-mulched conditions they stated that this could have been due to soil porosity and organic matter content influence on hydrology, thermal status and productivity of agricultural soils. Singh and Kamal (2012) stated that mulching with black plastic mulching in Tomatoes resulted in a 21.7% to 29.8% increase in fruit yield as compared to uncovered soil. This could have been due to high temperature, effective water use and weed control by the black plastic mulch. Sharma and Acharya (2000) stated that application of mulch, regardless of method of application also increased maize yield, grown in sequence with wheat due to water conservation, temperature decrease and higher organic carbon content.

According to Teame et al. (2017) the analysis of variance displayed highly significant ($p<0.001$) difference between organic mulches for yield. Higher seed yield (664 kg/ha) was recorded under Sudan grass mulch and the lowest was recorded under no mulch at 190kg/ha. Teame et al. (2017) further stated that Organic mulched soils conserved more soil moisture due to increased infiltration and better retention and choke weed growth that enabled a better crop growth and development and resulted in higher yield.

# CHAPTER 3.0: MATERIALS AND METHODS

The study area is located around Zwenshambe village -20$^0$30'21.38" S latitude and 27$^0$26'9.32" E longitude in the North East district of Botswana in Southern Africa as indicated in Figure 1. It has an estimated terrain elevation above sea level of 1261 metres. Farmers in the village are subsistence farmers who practice agriculture mainly on part time basis as they have other jobs they do besides planting crops. The soil type is sandy loam.

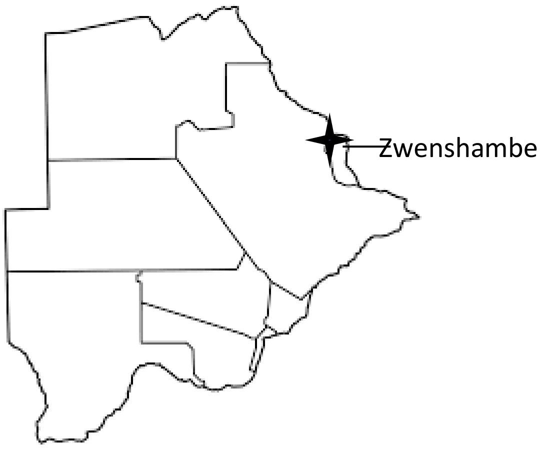


*Figure 1: A map of Botswana with a location of Zwenshambe*

## 3.1 Experimental design

Five treatments were arranged in a complete randomised block design and the experiment was replicated 4 times such that each block was made up of plots of the size 4m by 6m as shown in Figure 2.

**Treatment 1:** control (plots ripped without mulch)

**Treatment 2:** ripped plots with maize straw (*Zea mays* at 24kg per plot or 1kg/m$^2$ at a moisture content of 20%) as shown in Figure 3.

**Treatment 3:** ripped plots with grass straw *(Eragrostis Lehmanniana*) (12kg per plot or 0.5kg/m$^2$ which had not yet produced seeds with a moisture content of 20%) as shown in Figure 4.

**Treatment 4:** ripped plots with freshly cut mophane leaves and twigs (*colophospermum mopane* at 192kg per plot or 2g per $m^2$) as shown in Figure 5.

**Treatment 5:** ripped plots with an orange plastic 250microns (800-850mm width and 0.009mm thickness at 96$m^2$ per plot) as shown in Figure 6.

3.2 Plot Preparation

Before the plots were prepared soil tests for soil pH, Organic matter, Cation Exchange Capacity, potassium, magnesium, calcium, phosphorus clay, soil texture, were done. The experimental area was ripped, NPK fertilizer 2:3:2 at a rate of 100kg/ha was applied to all plots to improve soil fertility. All plots were planted with sorghum at a rate of 15kg/ha at inter row spacing of 30cm and intra row spacing of 90cm.. Weeds were controlled using herbicide called BASAGRAN whose active ingredient is Bendioxide (thiadiazine) at a rate of 1.5L/ha.

The Complete Randomised Block Design was used as it ensures that units in a block are as uniform as possible so that the observed differences between treatments were largely due to true differences between treatments. Blocking of the design of the plot was done to block for soil type as the soil on one side of the experimental site was sandy loam and on the other side was sandy loam with a bit of clay especially due to places where there were termite hills.

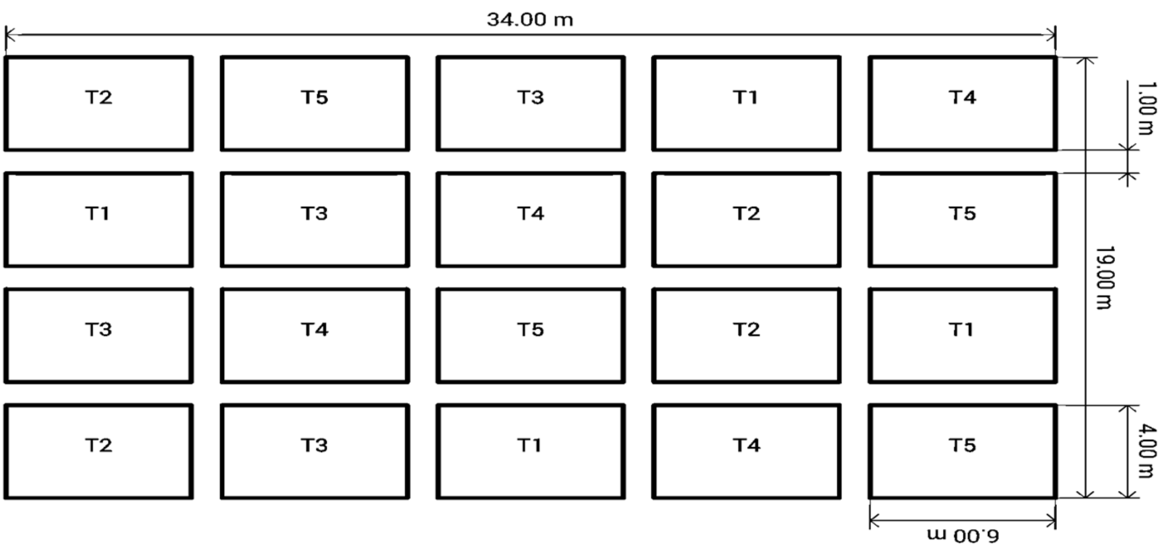


*Figure 2: Layout of the experimental plot*

3.3 Data collection and analysis

Soil temperature was measured using soil thermometer of range -10$^0$C to 50$^0$C, which could measure units of 0.5$^0$C. This was deemed important as it is the crop root zone region. Measurements were taken every 2 weeks by digging within the experimental plot randomly to a depth of 10cm. A soil thermometer was placed in the soil such that the bulb was in the soil and this was done from 9am-10am as it took time to take measurements from all 20 subplots. The thermometer was read while in the ground with its bulb in the soil so the mercury did not move up or down before temperature measurement could be taken. This is the method was used by Wu et al. (2016). The only variation was that temperature readings were taken using the mercury in glass without bent stems (but straight stems), temperature was recorded at one depth (10cm). 10 cm depth for measuring soil temperature is the common depth used by researchers such as Chen et al. (2007) and Syder at al. (2015).A total of 20 temperature readings were taken in any particular day. Atmospheric temperature was measured using the same the mercury in glass thermometer to compare the results.

Soil moisture content measurements were taken using the Gravimetric method every two weeks, as the method is known to be simple and reliable and is used to calibrate other devices for measuring soil water Evans et al. (1996). Soil moisture content was measured by collecting soil samples using a spade at a depth of 10cm. Bu et al (2013) and Asawalam (2003) used content different depth from 0cm to 200 cm to measure soil moisture while Shama and Archarya (2000) used depths from 0-45cm and they all used 5cm to measure soil temperature, however for this study soil around sorghum of the same variety which was growing in the same field was dug to determine root depth and 10 cm was found to be the depth at which 90% of the roots were therefore 10 cm was used as the depth to measure soil temperature and soil moisture the soil samples were then and packaging them into plastic bags and ensuring that they were air-tight to prevent loss of moisture from the soil. This was done from 9am to 10am during the day of data collection. It was ensured that the bags were air-tight by tying with a rubber band. Sampled fresh weight was weighed and dried in an oven for 24 hours at 105$^0$C. The method used was the one by Wu et al. (2016). The gravimetric soil water content was determined using the following formula:

*(1)*

$$Soil\ moisture\ content(\%) = \frac{Fresh\ soil\ weight - dry\ soil\ weight}{dry\ soil\ weight} \times 100$$

The weight of soil was measured using an Adam scale of specification 3kg max weight and 0.5g minimum weight.

The yield of sorghum was taken at sorghum maturity in the form of biomass of sorghum on wet basis. The whole Sorghum plant (with ripe head) was cut just above the ground (so as not to include roots) and immediately weighed. The stock and the grains were measured together and measured using electric scale. Results of yield of sorghum was collected when sorghum had developed heads. The head of sorghum and the stock were all measured, therefore the yield was in terms of biomass of maize was calculated by:

*(2)*

$$Biomass\ of\ Sorghum = \frac{Total\ Biomass\ of\ sorghum}{area\ of\ Plot}$$

The biomass of each plot was the added per treatment and then divided by the number of plots per treatment to get the biomass per treatment plots. An analysis of variance (ANOVA) was carried out on the data using SAS software.

*Plate 3: Picture of a plot mulched with maize (zea mays)*

*Plate 4: Picture of a plot mulched with grass (Eragrostis Lehmanniana)*

*Plate 5: Picture of a plot mulched with mopane) leaves and twigs*

*Plate 6: Picture of a plot mulched with Orange plastic mulch*

## CHAPTER 4.0: RESULTS

### 4.1 Soil temperature

Figure 7 shows the average soil temperature in all treatment plots. It displayed a lot of overlapping. The soil temperatures in no mulch, maize straw mulch, grass mulch, mophane leaves and twigs and orange plastic mulch did not show any significant difference. The over lapping box plots gives a clue that the differences in means are not statistically significant.

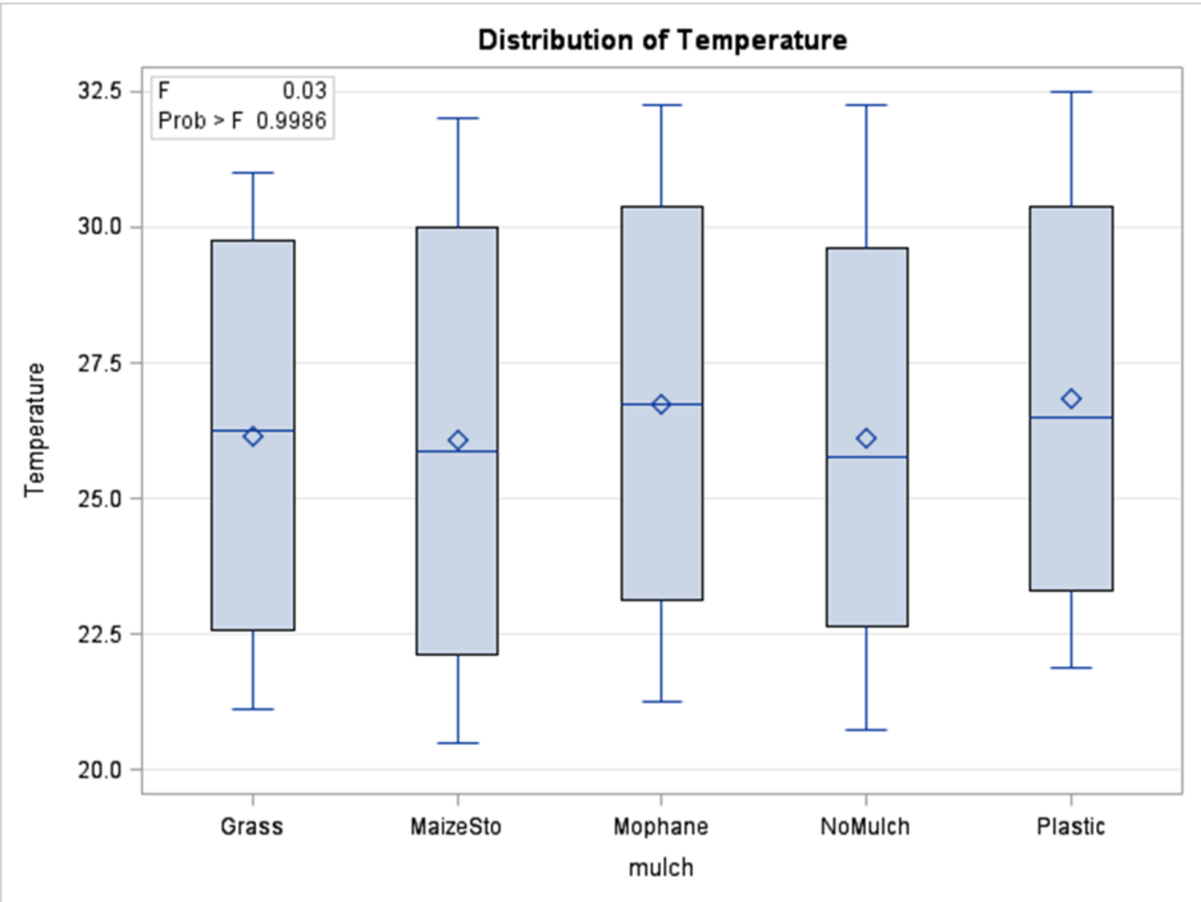


*Figure 7: Distribution of means of soil temperature in degree Celsius*

4.2 Soil moisture retention effect

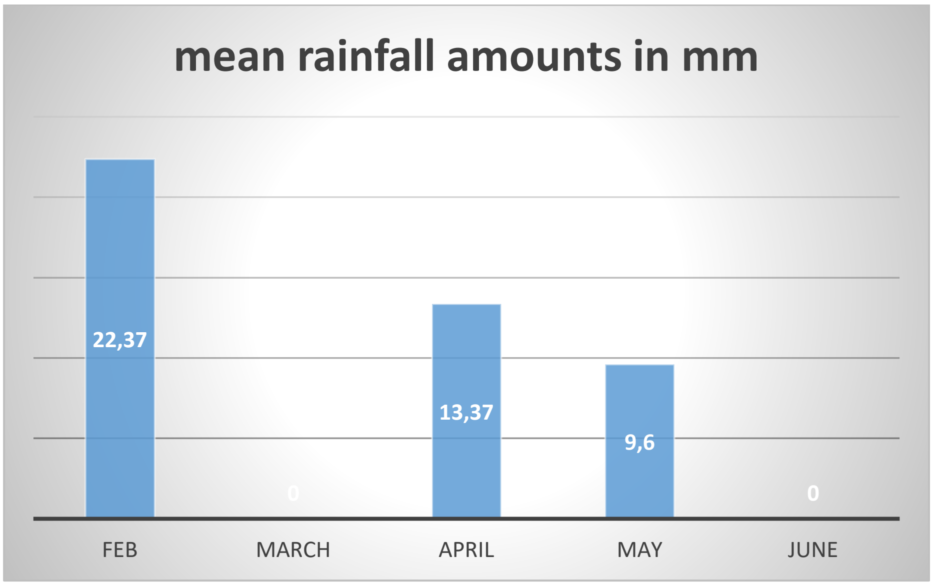


*Figure 8: Rainfall amounts (mm) in Zwenshambe primary school meteorological station during the experiment*

Rainfall data shows that insufficient amounts of rainfall were received at the experimental area as the area received an average amount of 13.37mm in April, 9.6mm in the month of May and no rainfall was received in June.

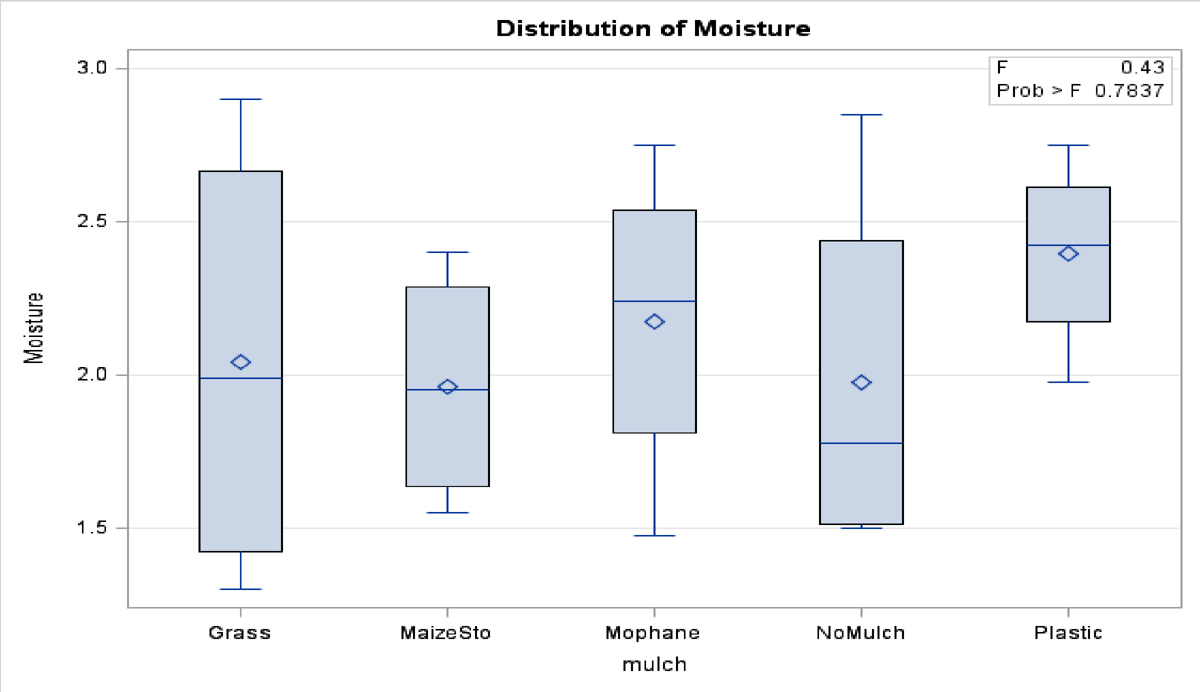


*Figure 9: Distribution of % mean soil moisture content from plots mulched with grass maize straw, mophane leaves and twigs, plastic and mulch*

Soil moisture content (%) under all treatments showed some overlapping which gives an indication that the differences in mean soil moisture content(%) are not significantly different Pr>F are larger than 0.05 that is 0.7837 representing 95% confidence level there is no interaction in this experiment because treatment type is 1(mulch) all other variables are response/dependent variables i.e % moisture content and they all respond to mulch type so there is no issue of interaction unless we had more than one treatment type which is not the case in this experiment.

4.3 Yield of sorghum

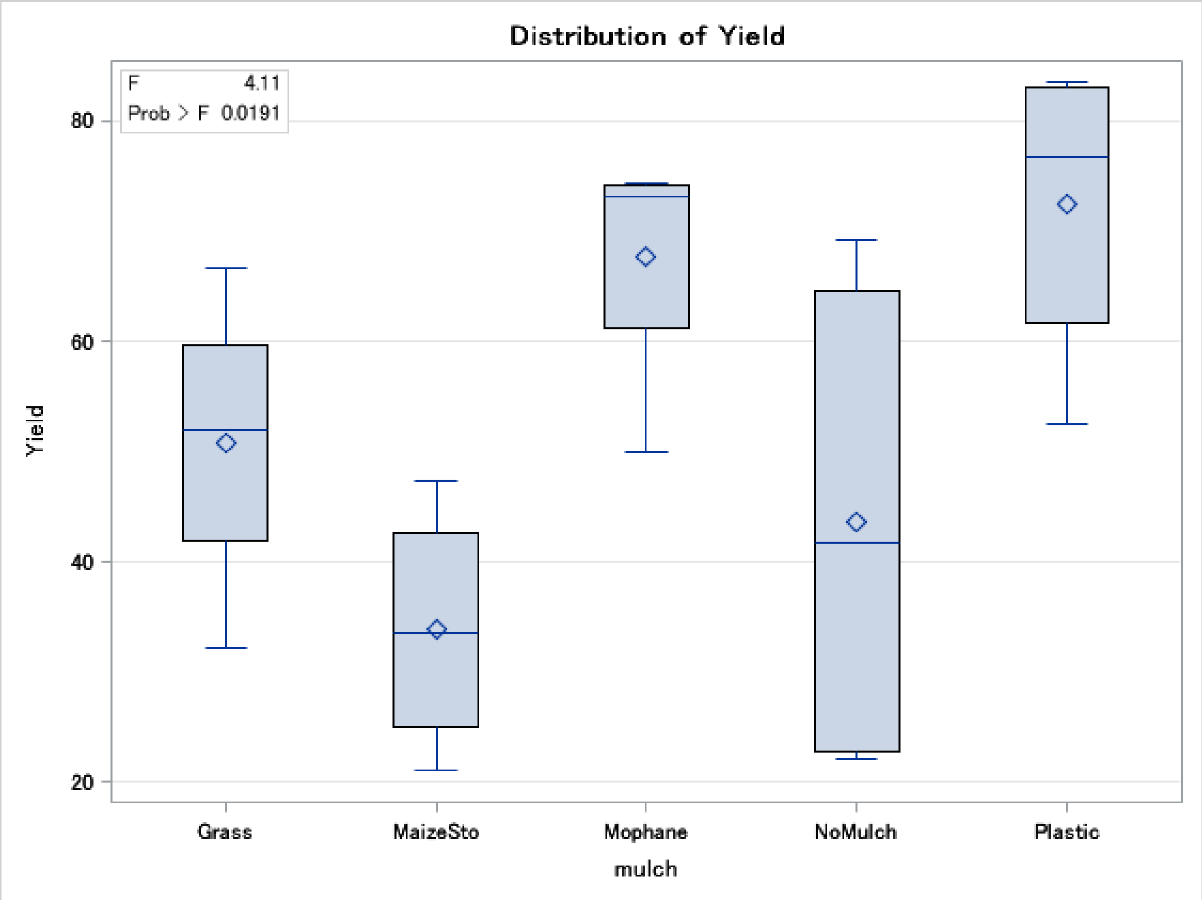


*Figure 10: Distribution of biomass of sorghum under grass mulch, maize stover, mophabe leaves and twigs, no mulch and Orange plastic mulch*

The results of the biomass of sorghum showed a significant difference in means as shown by the LSD graph**.** The anova table shows the existence of such as Pr>F=0.0191 which is less than 0.05 for mophane mulch and plastic mulch.

# CHAPTER 5.0: DISCUSSION

## 5.1 Soil Temperature

Findings from the investigation are consistent with data presented in the literature review to the effect that polythene mulch increases soil temperature**.** El-Shaikh and Fouda (2008) observed that soil temperature was higher in polythene mulch and lower in organic mulches. This phenomenon was observed during this study though the differences with control were not statistically significant.

Orange plastic mulch (Figure 4) had a higher average soil temperature which is consistent with Asaal et al. (1998) who stated that soil with transparent polythene sheet mulch increased both soil temperature and duration. According to Asaal et al. (1998) soil with transparent polythene sheet mulch increased both soil temperature and duration.

Results are also showing a phenomenon observed by Gagnon (1993) who stated that lowest temperatures were observed under straw mulch treatment and highest temperatures were found beneath the black plastic mulch. It was also observed that the results of soil temperature under mulched and unmulched soil were higher than the atmospheric temperature. Kosterna (2014) concluded that the application of polythene fibre covers increased soil temperature. However, there was no significant difference in soil temperature between no mulch, mophane mulch (Figure 3), orange plastic mulch, grass mulch and maize stover mulch.

Al-Rawahy (2011) observed that differences in soil temperature due to individual mulch interactions were not significantly different.

It was also observed that the soil temperature under mulched plots and unmulched plots was slightly higher than the atmospheric temperature by an average of $1^{0}$C during the days of data collection which suggests that soil at 10 cm depth was warmer than the atmospheric temperature. During the study period there was very insufficient amount of rain received at the experimental site which may have affected the results. Mulching may have helped to conserve moisture which may have been evident if there was adequate rainfall as increased amounts of evaporation from the soil have an effect of reducing soil temperature. (Marquis 1966) observed that when soil moisture was high, soil temperature remained moderate but when soil moisture dropped to low levels, temperature rose extremely high. He further observed that the effect of soil moisture in regulating soil temperature probably comes about in at least three ways, (i) on the wetter soil, large proportion of the incoming energy is spent on evaporation and not available to warm the soil, (ii) Additional water in the wetter soil raises the specific heat of the moisture, requiring more energy to raise a given volume of soil by 1 degree, (iii) Additional water in the wetter soil increases its thermal conductivity. Therefore, heat received at the surface is downward more rapidly, the lower layers are warmed more quickly and the surface remains cooler than on the dry soil where surface heat is dissipated more slowly.

Al-Kayssi et al. (1990) concluded that increasing moisture content enables the soil to maintain an appropriate positive heat balance during the night time. It has also shown that the difference between day-time and night time soil temperature was remarkably reduced with increasing soil moisture content. Thus, the increase of soil moisture content provides a protection to the root system against the sharp and sudden changes of soil temperature between the day-time and night time. Lakshmi et al. (2003) concluded that following a dry down, soil moisture decreases and temperature increases.

## 5.2 Soil moisture content

The intention of mulching is to retain soil moisture**.** Zhang et al. (2009) stated that mulching is a promising soil management practice which can increase soil water storage levels especially in dry years, and consequently increase economic benefits. Mulumba (2008) stated that mulch application increases total porosity, available water capacity, soil aggregation and moisture content at field capacity. Cook et al. (2006) stated that mulches improved topsoil water retention compared with no mulch, but no till maintained higher water content. According to Cook et al. (2006) as wheat straw application rate increased, water retention increased and temperature decreased. Therefore, it is fitting to expect mulching to retain soil moisture.

Lalitha et al. (2010) stated that under plastic mulch soil properties like soil temperature, moisture content, bulk density aggregate stability and nutrient availability improved. They also stated that plant growth and yield are also positively influenced by plastic mulch due to the modifications of soil microclimate. Results of this study may not replicated this results significantly due to insufficient rainfall received during the study.

Wang et al. 2016) stated that branch mulching with jujube branch mulch improved water infiltration significantly at ($P<0.05$) and reduced nitrogen and phosphorus loss. They went on to state that *jujube* branch mulch was the best mulch in the study.

The higher soil moisture content of the soil under Orange plastic mulch could be attributed to the effectiveness of the orange plastic mulch in preventing loss of water from the soil. The findings are consistent with Xie et al. (2004) who stated that Plastic –mulched wheat obtained higher yield due to extracting more soil water. Therefore, it was necessary for plastic mulch use under no irrigation that there is high soil water content in wheat field before sowing. Lekasi et al. (2001) stated that plastic mulching as water conservation and control measure, improved yield of cabbage.

Li et al. (2014) stated that mean soil moisture at (0-180 cm) of scale-like pit +branch mulching, scale-like pit +straw mulching, and soil moisture of scale-like pit with no mulching were increased by 14.2%, 9.4% and 4.8% than control respectively. The study showed that scale –like pit + branch mulch had higher soil moisture than the rest of the mulches used. Even though there was no significant difference between the mean soil moisture content and the control results in the current study results show a potential of branch mulching (Figure 3) to conserve soil moisture.

In case of low rainfall as experienced during the study (Figure 8) as rainfall was at an average of 9.07mm in 4 months, mulched plots may inhibit water from reaching the soil. The assertion is supported by (McCall 1925) who stated that the soil mulch has an inhibitory effect on moisture absorption under conditions where individual rains are not of sufficient volumes to fully penetrate the mulch. He went on to state that the mulch inhibits absorption by increasing the amount of evaporation in the newly fallen moisture.

A significant difference between control (unmulched) and orange plastic mulch was expected as water droplets were visible inside the orange plastic mulch during the course of the experiment. Very low rainfall could be attributed to the insignificant differences between means of the different treatment plots and the no mulch plots as mulch mainly reduces evaporation and thus reduce moisture loss from the soil.

## 5.3 Biomass of sorghum

The biomass of sorghum showed a significant difference with control (no mulch) in treatments such as Mophane leaves and twigs mulch (Figure 3), Orange plastic mulch (Figure 4). The treatment with the highest biomass was Orange plastic mulch while the lowest was maize and sorghum stover mulch. Even though results of moisture content under the different mulches did not show any significant difference, water droplets were visible during data collection under plastic mulch which ensured that the fertilizer applied was put to use which resulted in increased use of nutrients and thus increased biomass of sorghum in plots treated with Orange plastic mulch. Haque et al. (2018) stated that plastic mulches especially white plastic mulch was sufficiently capable of reducing salinity effect and increase yield and yield components of maize. Adams (1970) stated that clear plastic mulch increased grain sorghum yield significantly, but mulches had no significant effect on corn yield. Thilagan et al. (2010) stated that under plastic mulch, soil properties like soil temperature, moisture content, bulk density aggregate stability and nutrient availability improve. Plant growth and yield are also positively influenced by the plastic mulch due to the modifications of soil microclimate. Dong et al. (2018) observed that the mean maize and wheat grain yields under traditional plough with straw mulch were increased by 9.8% and 7.4% respectively and the mean maize and wheat yields under plastic mulch treatment were increased by 26.4% and 21.3% respectively.

The yield in orange plastic mulched plots may have also been influenced by reduced evaporation as plastic mulch trapped the moisture and restrained it from escaping into the atmosphere. Kader et al. (2017) stated that although there was no direct infiltration through the plastic mulch greater capillary forces beneath the plastic cover accumulated water from lateral flow from the buffer zone. The plastic cover prevented surface evaporation and, also capillary flux from below the root zone.

Orange plastic mulching has been shown to have an effect of controlling pests and diseases.

In some studies, done on black plastic mulch it was found out that black plastic mulch adversely affected activities of nematodes. Ogwulumba and Ugwaoke (2011) Black plastic mulch increased the temperature of the soil around the roots of the plants by conserving heat from the sun. This adversely affected the activities of the root knot nematodes in the soil thereby creating a conducive environment for the plants to make maximum use of soil nutrients. Therefore, plastic mulch may have controlled some pests which resulted in increased yield of sorghum.

The yield of orange plastic mulched plots could have been improved by the effectiveness of plastic mulch to control weeds. This assertion was made by Johnson and Fennimore (2005) who stated that coloured plastic mulches improved weed control compared to no mulch or clear plastic mulch.

Ma (2018) concluded that overall, compared with traditional cultivation grain yield was significantly increased by 43.1% with plastic film mulch. Orange plastic mulch treatment had the highest yield as mulching was found to have a significant effect on soil ph, Soil organic matter, soil bulk density and improved availability of nitrogen and phosphorus in the soil (Mehmood et al. 2014). Mulches have the physical effect of reduction of nutrients losses by surface erosion and leaching (Eruola et al. 2012). Eruola et al. (2012) further observed that generally irrespective of variety of white yam planted the yam planted under mulched plot were significantly higher in tuber length, tuber diameter, tuber height and yield of yam than un-mulched plots.

Fang et al. (2011) stated that addition of fresh biomass of branches significantly improved annual net N-mineralization estimates and the mulching treatments increased the cumulative N mineralized over the incubation period by 22-30%. This shows that branch mulching has the potential to increase the nitrogen content of the soil which results in increased yield of sorghum.

The other treatment that proved to have a higher potential to improve the yield of sorghum is grass mulch. Grass mulch (Figure 5) produced the third highest yield of sorghum after mophane leaves mulch and twigs (Figure 6) at 50.72g/m$^2$. The main reason for the increased yield of sorghum under grass mulch could be that grass easily decomposes to release soil nutrients for crops as stated by Sinkeviciene et al. (2009) mentioned that grass mulch produced significantly higher crop yields as grass mulch readily decomposes compared to other mulches, and it is a constant and quick supplier of available nutrients for plants. Gupta and Gupta (1983) stated that at 9t/ha of grass mulch there was an increase of 200% in the average production of green gram (Vigna radiata), moth bean (Phaseolus aconitifolius) and cluster bean (cyamopsis tetragondoba).

Teame et al. (2017) concluded that the highest yield (664 kg/ha) was recorded with sudan grass while the lowest grain yield (190kg/ha) was recorded with no mulch. Adeoye (1984) stated that the conservation of moisture under the grass mulch was associated with surface conditions that maintained good infiltration and reduced evaporation. Mulching increased grain yield by 15-22% in maize and by 10% in millet in Nigeria. Ramakrishna (2006) also came to the same conclusion as Adeoyo (1984) that grass mulching increased grain yield by 15-22% in maize and by 10% in millet in Northern Vietnam.

The mulch that did not produce good results was maize stover mulch (Figure 6) which produced maize yield of 33.83g/$m^2$.

# CHAPTER 6.0: CONCLUSIONS AND RECOMMENDATION

## 6.1 CONCLUSIONS

6.1.1 Conservation Agriculture was beneficial in Zwenshambe using available mulching material.

6.1.2 Maize stover mulch (zea mays), grass mulch (Eragrostis Lehmanniana), mophane leaves and twigs mulch and plastic mulch did not significantly reduce soil temperature.

6.1.3 Maize stover mulch (zea mays), grass mulch (Eragrostis Lehmanniana), mophane leaves and twigs mulch (colophospermum mopane) and plastic mulch did not significantly retain soil moisture**.**

6.1.4 Orange plastic mulch and Mophane leaves and twigs mulch (colophospermum mopane) significantly increased the yield of Sorghum by 28.78g/$m^2$ and 24.03g/$m^2$ which translates into 65.9% and 55.0% as compared to no mulch respectively.

6.1.5 The means for plastic mulch and mophane leaves and twigs showed a significant difference with Pr>P thus the null hypothesis is rejected.

## 6.2: RECOMMENDATIONS

6.2.1 The orange plastic and mophane leaves and twigs mulch can be used for mulching since they increased the yield of sorghum in Zwenshambe and surrounding areas with similar conditions.

6.2.2 Since this was a one season study, it is recommended that other studies on the potential of mulching on soil temperature reduction and soil moisture retention be further carried out to verify results from this study.

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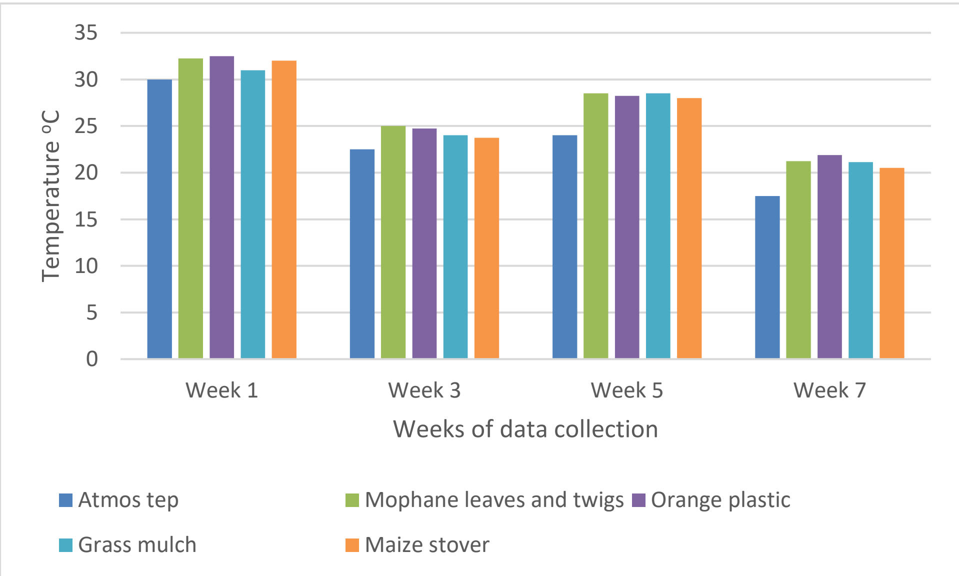
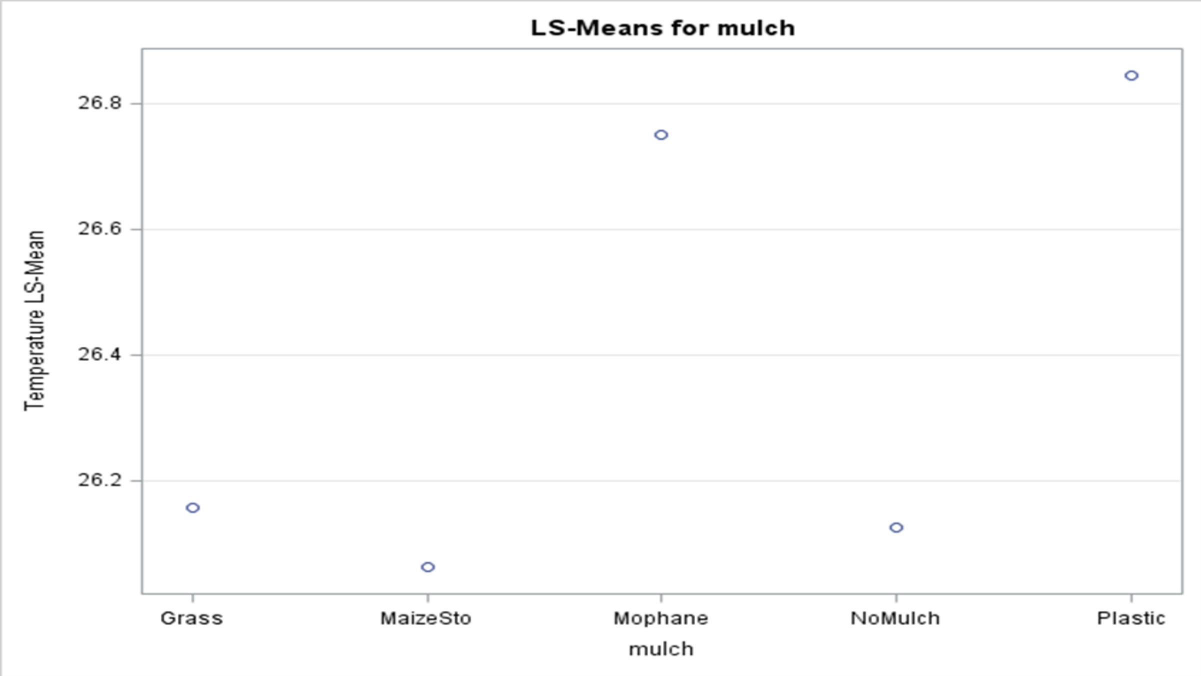
# CHAPTER 8.0: APPENDICES

| DATE | ATP | T1 | T4 | T5 | T3 | T2 |
|---|---|---|---|---|---|---|
| Week 1 | 30 | 32.25 | 32.25 | 32.5 | 31 | 32 |
| Week 3 | 22.5 | 24.5 | 25 | 24.75 | 24 | 23.75 |
| Week 5 | 24 | 27 | 28.5 | 28.25 | 28.5 | 28 |
| Week 7 | 17.5 | 20.75 | 21.25 | 21.88 | 21.13 | 20.5 |
| MEAN | 23.50 | 26.13 | 26.75 | 26.84 | 26.16 | 26.06 |
| **SDEV** | **5.15** | **4.82** | **4.71** | **4.58** | **4.43** | **5.01** |

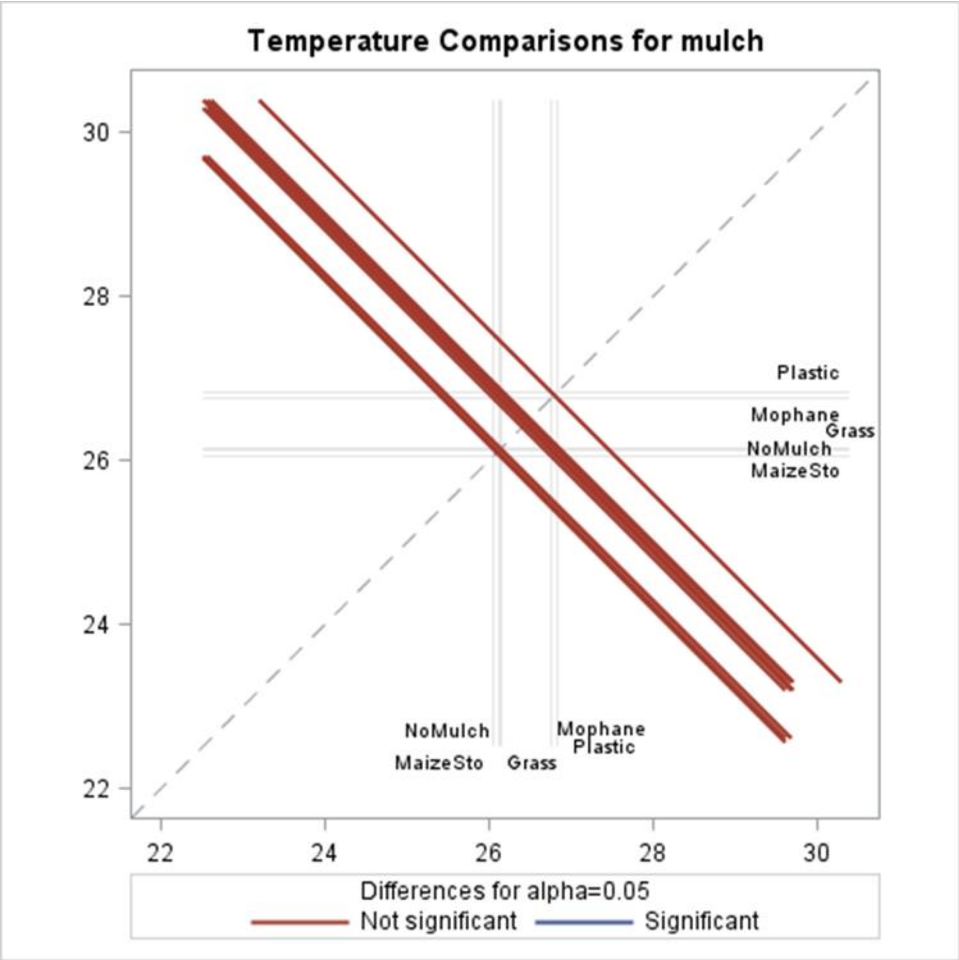
*Appendix 1: Distribution of soil temperature in $^{O}C$ from the experimental plots. ATP – atmospheric temperature, T1-no mulch, T2-maize stover mulch, T3-grass mulch, T4-mophane leaves and twigs mulch, T5-orange plastic mulch*




*Appendix 2: Temperaturre changes under different mulches on different data collection weeks*




*Appendix 3: means of soil temperature under no mulch, maize straw mulch, mophane twigs mulch, orange plastic mulch and grass mulch*




*Appendix 4 : Temperature comparisons for mulch*

Analysis of Mulch type on and temperature response

The GLM Procedure

Dependent Variable: Temperature

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 2.2725700 | 0.5681425 | 0.03 | 0.9986 |
| Error | 15 | 333.5953500 | 22.2396900 | | |
| Corrected Total | 19 | 335.8679200 | | | |

| R-Square | Coeff Var | Root MSE | Temperature Mean |
|---|---|---|---|
| 0.006766 | 17.87137 | 4.715898 | 26.38800 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| mulch | 4 | 2.27257000 | 0.56814250 | 0.03 | 0.9986 |

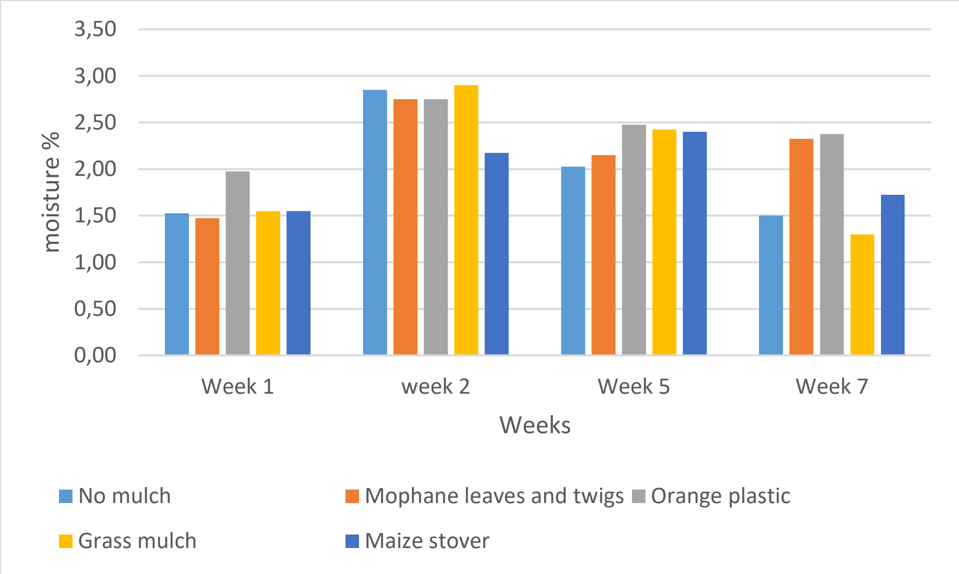
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| mulch | 4 | 2.27257000 | 0.56814250 | 0.03 | 0.9986 |

*Appendix 5: Analysis of mulch type and temperature response*

**Moisture retention**

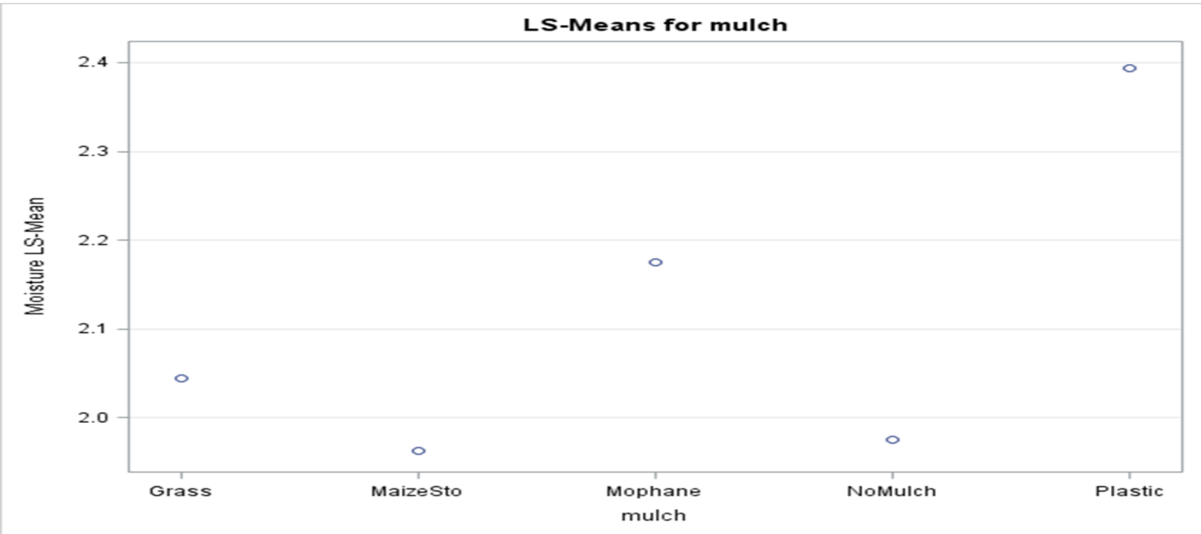
| Week | T1 | T4 | T5 | T3 | T2 |
|---|---|---|---|---|---|
| Week 1 | 1.53 | 1.48 | 1.98 | 1.55 | 1.55 |
| week 2 | 2.85 | 2.75 | 2.75 | 2.9 | 2.18 |
| Week 5 | 2.03 | 2.15 | 2.48 | 2.43 | 2.4 |
| Week 7 | 1.5 | 2.33 | 2.38 | 1.3 | 1.73 |
| MEAN | 1.98 | 2.18 | 2.39 | 2.04 | 1.96 |
| STDEV | 0.63 | 0.53 | 0.32 | 0.75 | 0.39 |

*Appendix 6: Mean soil moisture in % in treatment plots T1-no mulch, T2-maize stover mulch, T3-grass mulch, T4-mophane leaves and twigs, T5 orange plastic mulch.*

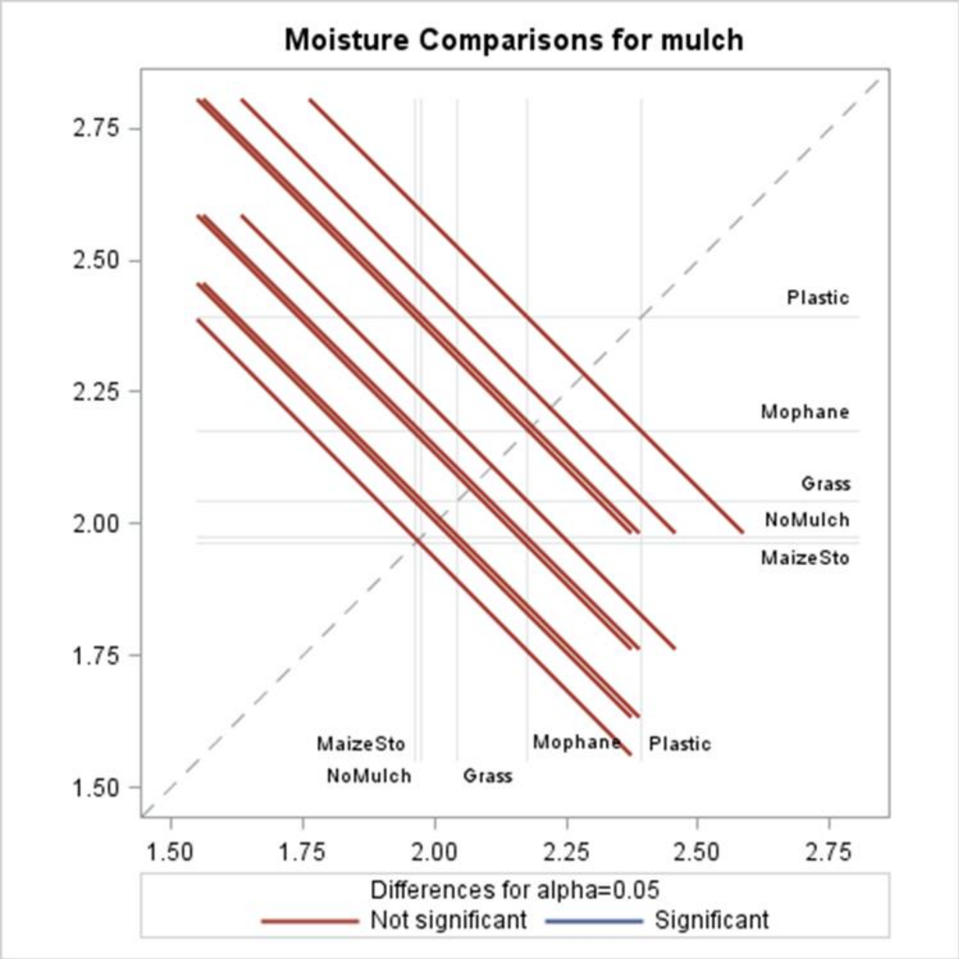



*Appendix 7: % soil moisture content in no mulch, grass mulch, mophane leaves and twigs mulch, maize straw mulch and orange plastic mulch over weeks of conducting the investigation*

**:**




*Appendix 8: % means of soil moisture content under grass mulch, maize stover mulch, mophane leaves and twig mulch and no mulch*




*Appendix 9: Differences in moisture content (%) for mulches at alpha=0.05*

Analysis of Mulch type on and moisture response

The GLM Procedure

Dependent Variable: Moisture

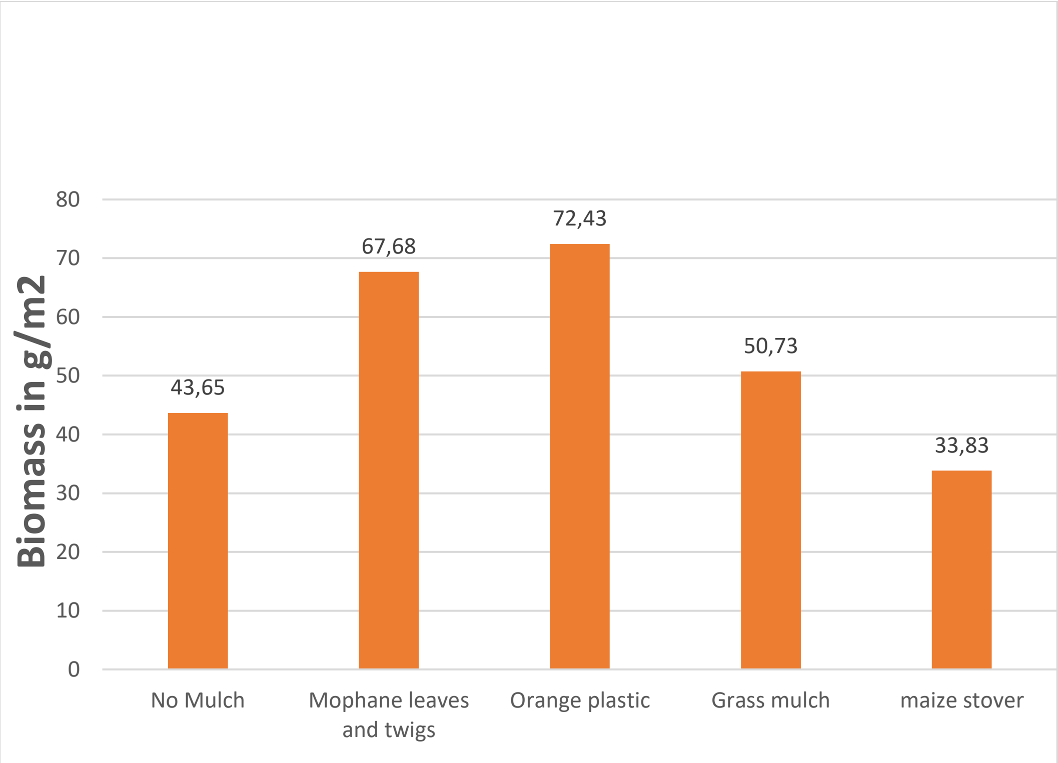
| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 0.51643750 | 0.12910938 | 0.43 | 0.7837 |
| Error | 15 | 4.48781250 | 0.29918750 | | |
| Corrected Total | 19 | 5.00425000 | | | |

| R-Square | Coeff Var | Root MSE | Moisture Mean |
|---|---|---|---|
| 0.103200 | 25.92324 | 0.546980 | 2.110000 |

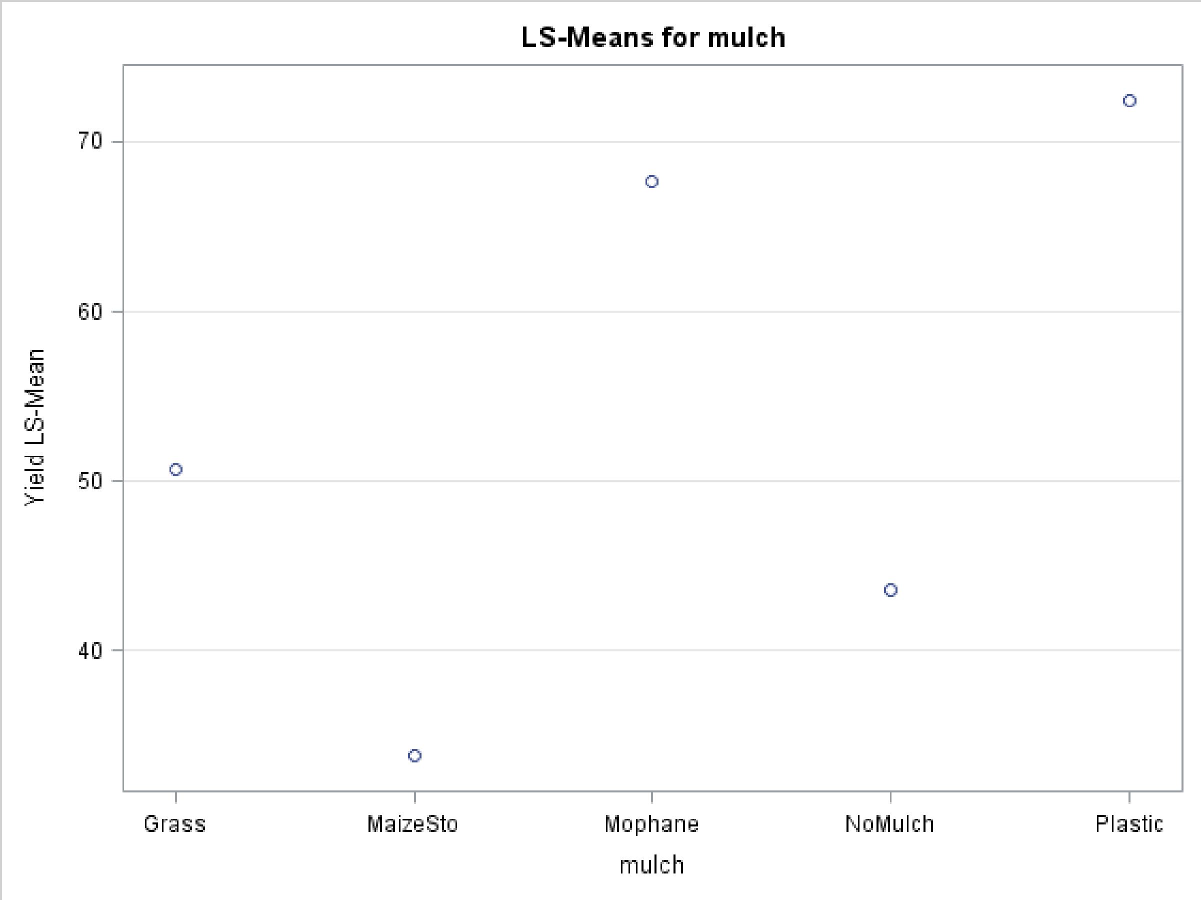
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| mulch | 4 | 0.51643750 | 0.12910938 | 0.43 | 0.7837 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| mulch | 4 | 0.51643750 | 0.12910938 | 0.43 | 0.7837 |

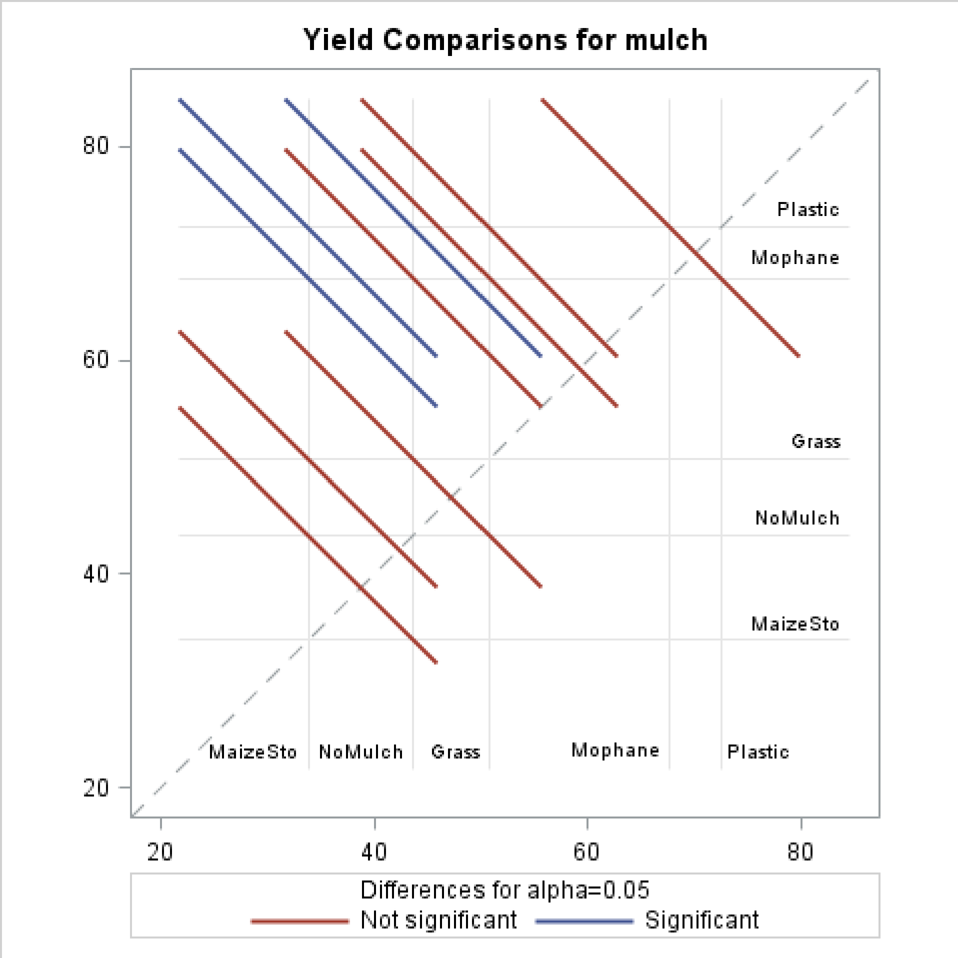
*Appendix 10: Analysis of mulch type on and moisture response*




*Appendix 11: Biomass of sorghum under different mulches in g/m²*




*Appendix 12: LS means for mulch*




*Appendix 13: Yield comparisons for mulch*

Analysis of Mulch type on and yield response

The GLM Procedure

Dependent Variable: Yield

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| **Model** | 4 | 4203.548480 | 1050.887120 | 4.11 | 0.0191 |
| **Error** | 15 | 3833.550500 | 255.570033 | | |
| **Corrected Total** | 19 | 8037.098980 | | | |

| R-Square | Coeff Var | Root MSE | Yield Mean |
|---|---|---|---|
| 0.523018 | 29.79287 | 15.98656 | 53.65900 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| **mulch** | 4 | 4203.548480 | 1050.887120 | 4.11 | 0.0191 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| **mulch** | 4 | 4203.548480 | 1050.887120 | 4.11 | 0.0191 |

*Appendix 14: Analysis of mulch type on yield response*