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Interactive Effects of Tillage and Mulch Type on Soil and Crop Canopy Temperature and Yield of Sorghum (*Sorghum bicolor*, L)

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ABSTRACT

This paper investigates the interactive effects that tillage and mulch types have on soil and crop canopy temperature and the subsequent influence on final grain yields of a sorghum (Sorghum bicolor var rakodzi) crop stand. Two experimental sites, one farmer managed, and the other researcher managed were established in Mbire District of Mashonaland West Province in Zimbabwe during the 2020/2021 Zimbabwean farming season. A 3x4 factorial experiment laid in a Randomized Complete Block Design with three replications, was conducted to investigate the hypothesis that tillage and mulch have no effect on soil and crop canopy temperatures. Significant interactions ($P<0.05$) occurred between mulch and tillage types to influence canopy temperature at critical stages of late vegetative and grain filling at 25 and 75 days after sowing, respectively. Mulch and tillage types also interacted significantly ($p<0.05$) at critical stages of booting and grain filling at 50 and 75 days after sowing respectively to subsequently influence final grain yield. Sorghum straw used as mulch in raised beds resulted in the highest grain yields of 2.89 tons Ha^{-1}. Conversely, lowest grain yields were realized from raised beds with no mulch as 1.89 tons Ha^{-1}. Thus, it was established that tillage and mulch can interact to affect both crop canopy and soil temperature at crop critical stages that will in turn impact on crop final grain yields. Farmers in the semi-arid regions of Zimbabwe are encouraged to be cognisant of this interactive effect to maximise sorghum crop productivity.

Key Words: Grain Filling, Crop Canopy Temperature, Climate Change Abatement, Soil Temperature.

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1. INTRODUCTION.

Functioning soil is necessary for ecosystem service delivery, climate change abatement, food and fibre production and freshwater storage. (Koch et al., 2012). Soil security is a new concept that has arisen during a time of emerging international response to the increasingly urgent problems that face the global soil stock. Soil security refers to the maintenance and improvement of the world's soil resources so that they can continue to provide food, fibre and fresh water, make major contributions to energy and climate sustainability, and help maintain biodiversity and the overall protection of ecosystem goods and services (Koch et al., 2012). An increasingly recognised function of soils is the storage of carbon to reduce the atmospheric increase in carbon dioxide and thereby abate climate change. Chatskikh et al. (2008) reported that soil tillage intensity can affect both crop growth and soil carbon (C) as well as nitrogen (N) turnover and balances. Emissions of Green House Gases (GHG) such as CO_2 and N_2O is also be influenced indirectly by tillage intensity. Agronomic practices such as tillage, residue management and crop rotation determine the quantity of carbon (C) retained in the soil (Blanco-Canqui and Lal 2007). In addition, the amount of residue left on the surface is determined by the number of passes, the type and geometry of the tillage equipment (Moitzi et al. 2014). The retention of crop residue at the soil surface can result in an increase in carbon and nitrogen concentrations in the uppermost 50 mm of soil (Kahlon et al. 2013).

Concern about soil conservation has been raised by soil scholars who have also raised awareness among farmers, policy makers and society about the same. Since the 1990s, the concept of soil quality has become popular in the soil science field (Karlen, 2016). Whilst the soil quality indicators as influenced by tillage and agronomic practices such as crop residue retention have been studied extensively, not much study has been done on how soil temperature and its proxy, crop canopy temperature can be influenced by different tillage and agronomic practices. Moreover, the importance of soil temperature has not yet gained the attention it deserves, and the topic is not as popular as other issues within the environmental discourse and people's awareness. The objective of this study was to investigate how the commonly used different tillage types and mulch materials influenced soil and crop canopy temperature of a given crop stand. Furthermore, the study investigated whether there were any subsequent effects on the final grain yields of crops in this instance sorghum *(sorghum bicolor L)* as influenced by soil and canopy temperatures. The soil plant atmosphere model together with the scaling theory for soil hydraulic heterogeneity were referred to in this study to establish sensitivity of variation of canopy temperature to field averaged soil cover and crop rooting growth behaviours. For instance, the soil, plant and atmosphere relations explicitly solve on continuity equation for water flux resulting from root uptake, changes in plant water storage and transpirational flux. Dynamical equation for root zone soil water potential and plant water storage models the progressive drying of soil, and daytime dehydration and night-time hydration of the crop. (Choudhury, 1983). Crop models must be improved to account for large effects of heat stress effects on crop yields. To date most approaches in crop models, use air temperature despite evidence that crop canopy temperature better explains yield reductions associated with high temperature events. (Webber et al. 2016). Thus, canopy temperature can be used to monitor water stress in crop stands and therefore can be used in water supply systems modelling such as irrigation and soil water conservation techniques such as mulching. Much controversy from scholars has been around the effectiveness of mulching as a water conservation technique being effective on maintaining water potential in some instances and causing waterlogging on the contrary. So, in this context, by determining crop canopy temperature one can know when to add or remove mulch for maximum crop yield, which is essentially the same principle for irrigation scheduling.

1.1 Research Objective.

The primary objective of this study was to establish empirical evidence of how seedbed configuration and commonly used mulch material interact to influence soil and canopy temperature and final yield of sorghum crop stand.

1.2 METHODOLOGY

The research was conducted from November 2020 to March 2021 at two sites in Mbire District of Mashonaland West Province in Zimbabwe. Two experimental sites were established for this research simultaneously giving two geographic locations representative of the district. The first site was researcher managed established at Mushumbi Crop and Livestock Innovation Centre (CLIC) located at 16.171003^0 South of the latitude and 30.566371^0 East of the longitude at 353m above sea level. This site had clay loam soils of pH ($CaCl_2$) 5.9. The climatic conditions of the Mushumbi CLIC site during the research comprised average daily temperature of 27.8^{0}C to 33^{0}C, air humidity was 71-86%, rainfall rate of 490 mm per year with six wet months and 130 rainy days and solar radiation of 41- 86%.

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The second site was farmer managed and established at Mambure CLIC. This was located at 16.201805^0 South of the latitude and 30.34102^0 East of the longitude. This site had sandy loam soils of pH ($CaCl_2$) 5.6. The average temperature ranged between 23^{0}C and 30^{0}C and humidity range was 70-85%, whilst the rainfall rate was 560 mm per year with six wet months and 125 rainy days and solar radiation 35-80%.

Sorghum seed variety rakodzi was obtained from an accredited Zimbabwean crop breeder, K2 company. Micro dosing was done with compound D fertilizer (NPK: 7:14:7) at 100kg Ha^{-1}. ZRF Glyphosate 360 SL herbicide was used to control annual weeds. Partially decomposed Mopani *(Colophospermum mopane L.)* leaves, sorghum *(Sorghum bicolor L.*) crop residues from previous season and local thatch grass (*Hyparrhenia rufa L.)* cut green were used as mulch treatment materials.

An HH2 Moisture Meter Delta-T Devices Cambridge -England was used to record moisture content in %V whilst a Go-better 4 in1 Soil Survey Instrument (Moisture/PH, Light/Temperature) S 40 Plus was used to record soil temperature at approximately 15cm (root zone) depth. Canopy temperature was recorded by pointing a non-contact infrared thermometer on the leaf canopy at about 5 cm from the surface. A calibrated measuring plank was used to measure plant height whilst a Vernier caliper was used to measure internode diameter that was then converted to internode circumference. Leaf length was measured using a two-meter measuring tape, measuring from the leaf collar to the leaf end.

This study used a Randomised Complete Block Design in a 3x4 factorial experiment with three replications using slope as the blocking factor. Factor A was tillage with three levels (T1=basin, T2 =raised beds, T3 =flat beds rip lines) whilst factor B was mulching with four levels (M1=sorghum straw, M2=Mopane leaves, M3=grass, M4=no mulch). Plant spacing was 30cm x 55cm. Crop plants were thinned to one plant per station to give a plant population of 60 606 plants Ha^{-1}. The basin dimensions were 15x15x15cm^{-3} whilst the open planting holes and rip lines were to the same depth of 15cm. Three replications were established at each site under rain fed conditions and treatment combinations randomly assigned to 12 plots per replication. Canopy and soil temperatures were measured during critical growing stages of growing point differentiation, booting, grain filling, physiological maturity at 25, 50, 75 and 100 days after planting respectively. Soil moisture, internode and leaf length, leaf width and plant height were also measured. Yield and yield components measured were, pinnacle length and circumference as well as weight of final grain weight.

Regression analysis was then performed to investigate the relationship between canopy temperature at critical stage of grain filling and final yield. Regression analysis was also performed to investigate on the relation between soil temperature and final yield at critical stage of grain filling. Yield was regressed on the soil temperature variable to test the hypothesis that soil temperature significantly predicted final yield.

2.0 RESULTS

2.1 Crop Canopy Temperature as Dependent Upon Soil Cover and Crop Rooting Response Behaviours

Mushumbi site exhibited significant interaction ($p<0.05$) between tillage and mulch to influence canopy temperature at 25 Days After Sowing (DAS). The highest and lowest interaction means were recorded for the combination of basin tillage with grass mulching and basins mulched with mopane leaves recording 35.91 ^{0}C and 35.16 ^{0}C, respectively (Fig.1). Significant interaction ($p<0.05$) also occurred at 50 DAS where raised beds with no mulch recorded the highest mean of 35.76^{0}C whilst basins with no mulch recorded the lowest mean of 34.64^{0}C. At 75 days after sowing, significant interaction ($p<0.05$) resulted in basin with grass mulching recording the highest canopy temperature of 36.66^{0}C whilst basins with no mulch recorded the lowest canopy temperature of 35.75^{0}C.

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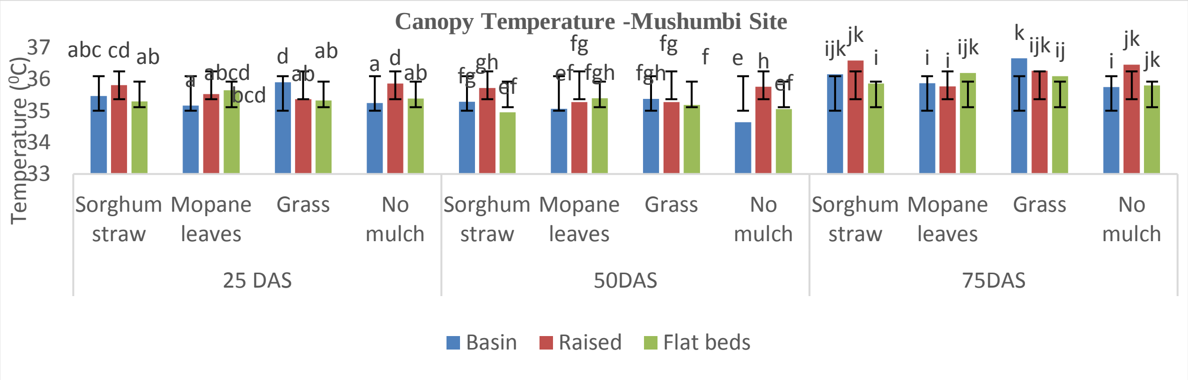

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Figure 1: Crop Canopy Temperature at Mushumbi site as influenced by tillage and mulch types.

At Mambure site, there was a significant interaction ($p<0.05$) between tillage and mulch at 25 DAS with the highest and lowest mean canopy temperatures recorded as 35.68^0C for flat beds mulched with mopane leaves and 33.48^0C for raised beds mulched with mopane leaves, respectively (Figure. 2).

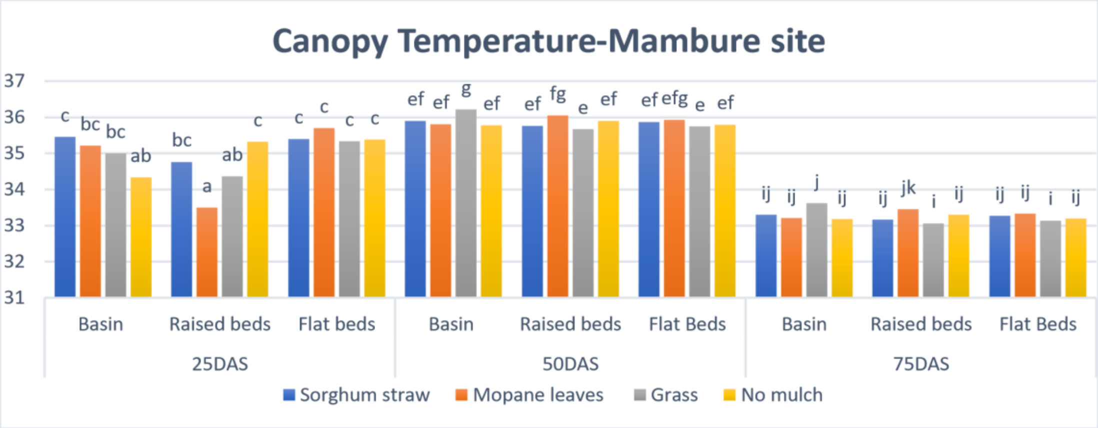

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Figure 2: Canopy temperature at Mambure site as influenced by tillage and mulch types.

Significant interaction ($p<0.05$) was also observed at 50 DAS basin mulched with grass recording the highest temperature of 36.21^0C and raised beds mulched with grass recording the lowest mean canopy temperature of 35.65^0C. At 75 DAS there was significant interaction ($p <0.05$) between tillage and mulch with basin mulched grass recording the highest mean temperature of 33.61^0C whilst raised beds mulched with grass recorded the lowest mean temperature of 33.05 ^{0}C.

2.2 Regression Analysis of Canopy Temperatures and Grain Yield.

The regression of yield on predicting variable, canopy temperature to test $H_{1:}$ that canopy temperature significantly influenced final yield, F (1,34) =91.49, $p<0.005$, confirmed that canopy temperature can significantly influence final yield of sorghum with coefficient of 899.57 and at $p<0.005$. These results clearly indicate direct positive effect of canopy temperature on final yield. Moreover, the R^2 =0.729 depicts that the model explains 72.9% of the variance in final yields. A positive relation with an R^2 value of 72.9 % existed to show that canopy temperature as a proxy of soil plant environment affect final yield of sorghum. Figure 3 below illustrates how final grain yield
responded to canopy temperature at 75DAS.

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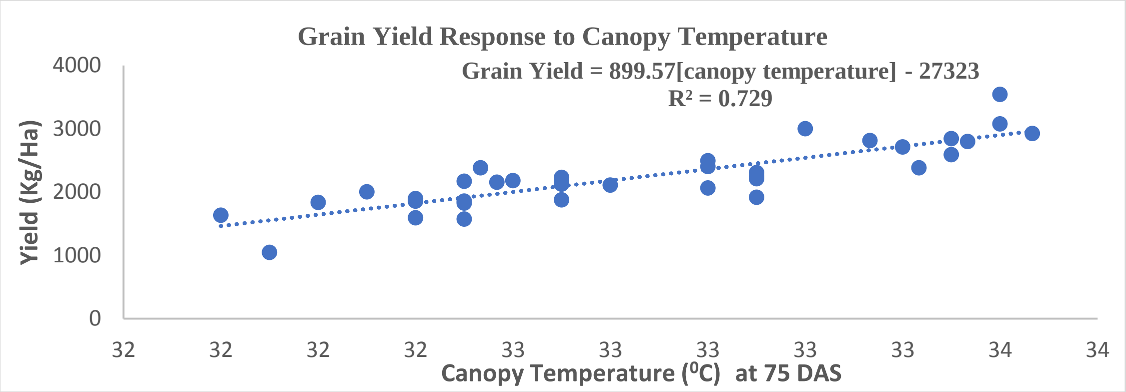


Figure 3: Grain yield response to canopy temperature.

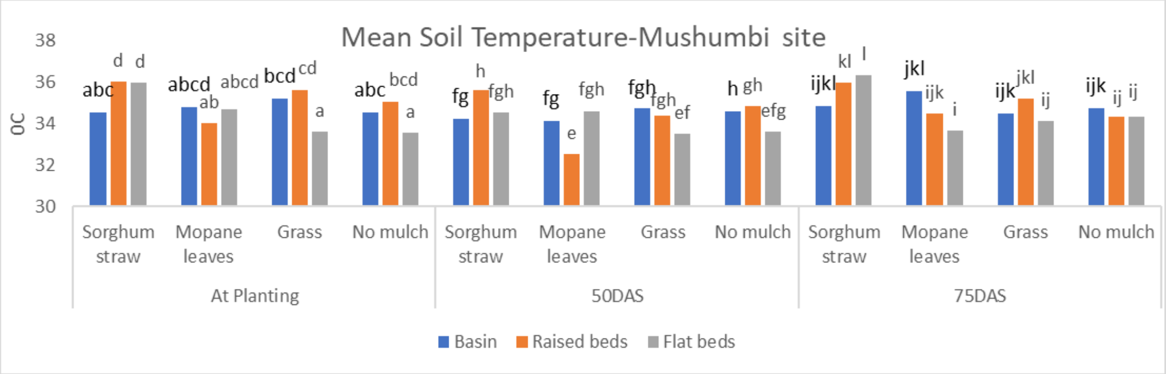
The regression summary illustrates the statistics for that confirm that canopy temperature at 75 DAS can influence final yield of sorghum grain. The high R^2 value of 72.9% illustrates the variance can be explained by the presented regression equation. Table 1 below summarises the regression analysis of grain yields responses to crop canopy temperature.

Table 1: Regression analysis summary.

Hypothesis	Regression weights	Beta coefficient	R^2	F	P-value	Hypothesis supported
	Canopy temperature-yield	899.57	0.729	91.49	0.00	Yes

2.3 Soil Temperature.

At Mushumbi site, there was significant interaction ($p<0.05$) between tillage and mulch to influence soil temperature at 25 days after sowing with the highest mean of 35.12^{0}C recorded for raised beds mulched with sorghum straw and lowest mean of 32.78^{0}C recorded for raised beds mulched with mopane leaves as well as for flat beds mulched with grass. Figure 4 below illustrates how tillage and mulch type affected the mean soil temperature at Mushumbi CLIC site.



* a, b,c…means followed by same letter are not significantly different.

Figure 4: Soil temperature Mushumbi site as influenced by tillage and mulch types.

At 50 DAS, tillage and mulch interacted significantly ($p<0.05$) to influence soil temperature with the highest mean soil temperature (35.61 ^{0}C) recorded for raised beds mulched with sorghum straw and the lowest temperature of 32.52^{0}C recorded for raised beds mulched with mopane leaves. However, no significant interaction ($p<0.05$) occurred between tillage and mulch at 75 DAS. Nevertheless, mulch as an individual factor showed significant effect on soil temperature ($p<0.05$) with the highest recorded mean soil temperature of 35.71^{0}C for sorghum straw and lowest of 34.48^{0}C for no mulch (Figure 5). At 100 DAS, no

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interaction occurred again between mulch and tillage whilst mulch as individual factor showed significant effect ($p<0.05$) with the highest mean temperature of 35.71^{0}C recorded for sorghum straw and lowest of 34.04^{0}C recorded for no mulch (Figure 5).

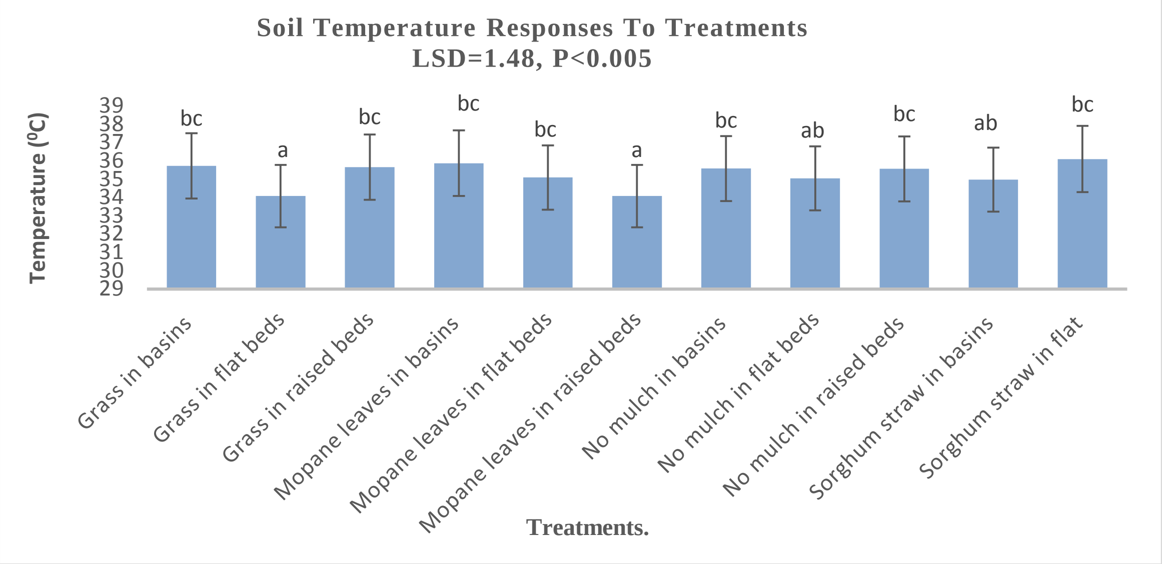

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Figure 5: Soil Temperature variations at Mambure site as influenced by tillage and mulch types.

At Mambure site, interactions ($p<0.05$) between tillage and mulch type existed to influence soil temperature at 25 DAS with the highest mean soil temperature of 36.42^{0}C recorded for raised beds with sorghum straw whilst the lowest of 34.08^{0}C was recorded for both raised beds mulched with mopane leaves and flat beds mulched with grass. Thus at 5% level of confidence we conclude that interaction between mulch and tillage caused significant difference in soil temperature at 25 days after sowing.

At 50 DAS, tillage and mulch interacted significantly ($p<0.05$) to influence soil temperature with highest of 34.41^{0}C for raised beds with sorghum straw whilst the lowest of 31.32^{0}C was recorded for raised beds with mopane leaves. However, no significant interaction was observed at 75 DAS but mulch as an individual factor showed a significant difference ($p<0.05$) with the highest mean soil temperature of 37.21^{0}C recorded for sorghum straw and the lowest of 35.98^{0}C recorded for with no mulch. Tillage did not show individual effect to influence soil temperature. No significant interaction was observed at 100 DAS whilst mulch showed significant difference ($p<0.05$) with the highest mean temperature of 37.41^{0}C recorded for sorghum straw and lowest of 35.74^{0}C recorded for no mulch. Again, no individual significant difference was observed for tillage at 100 DAS.

2.4 Regression on soil temperature and on final yield.

Regression analysis on the effect of soil temperature on final grain yield F (1,34) =54.42, $p<0.005$, which indicated that soil temperature can play a significant role in affecting final yield of sorghum coefficient -240.82, $p<0.005$. These results clearly illustrate the direct positive effect of soil temperature on final yield. Moreover, the R^2 =0.6173 depicts that the model explains 61.73% of the variance in final yields. A positive relation with an R^2 value of 61.73% existed to show that soil temperature as a proxy of soil plant environment affect final grain yield of sorghum. Figure 6 below shows the regression analysis that illustrated that soil temperature influences final grain yield of sorghum.

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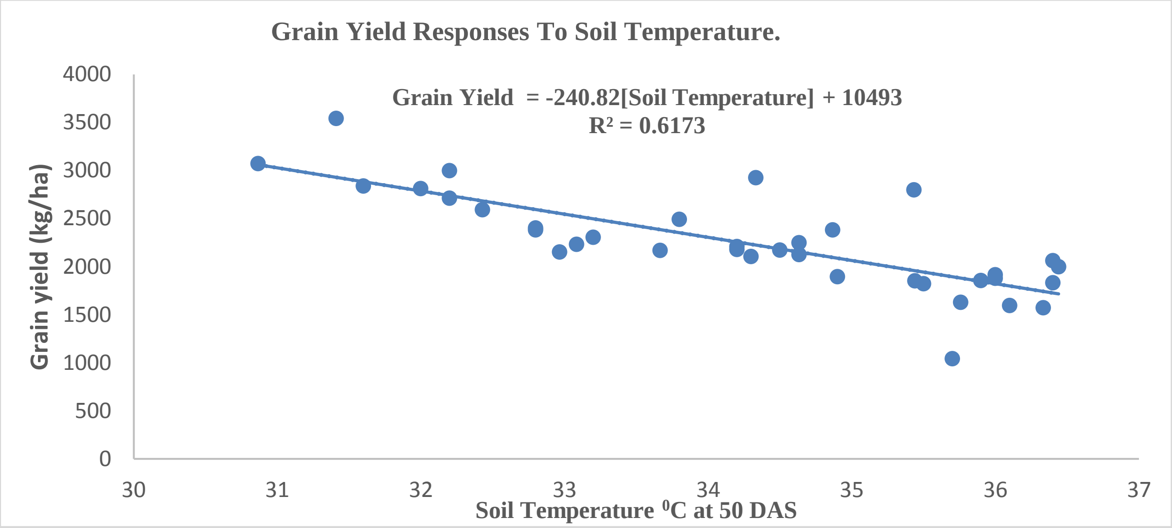

Figure 6: Grain yield responses to soil temperature variations under different mulch and tillage treatments.

2.5 Multiple Regression Analysis of Crop Canopy and Soil Temperature on Final Grain Yield.

Multiple regression was performed to explain the predictive dependency of final grain yield on crop canopy and soil temperature as influenced directly by interaction of tillage and mulch materials. Table 2 below shows the summary of the multiple regression illustrating the effect of crop canopy and soil temperatures on final yields.

Table2: Summary of multiple regression between soil and canopy temperature as they influence final grain yield of sorghum.

Hypothesis	**Regression weights**	**β_1 Coefficient**	**β 2 Coefficient**	**R^2**	**F**	**P value**	**Hypothesis is supported**
β 1 = β 2	Crop canopy temperature: soil temperature - yield	-128.79	628.20	0.83	86.17	0.00	Yes

Grain Yield=-128.79[Soil Temperature] +628.20[Crop Canopy Temperature]-13992.5

2.6 Final Grain Yields Comparison Between Sites.

Comparison of sites in terms of final grain yield was also performed to understand site differences that might occur during the research period. The figures 6 below illustrates whether there were any significant differences that occurred across sites.

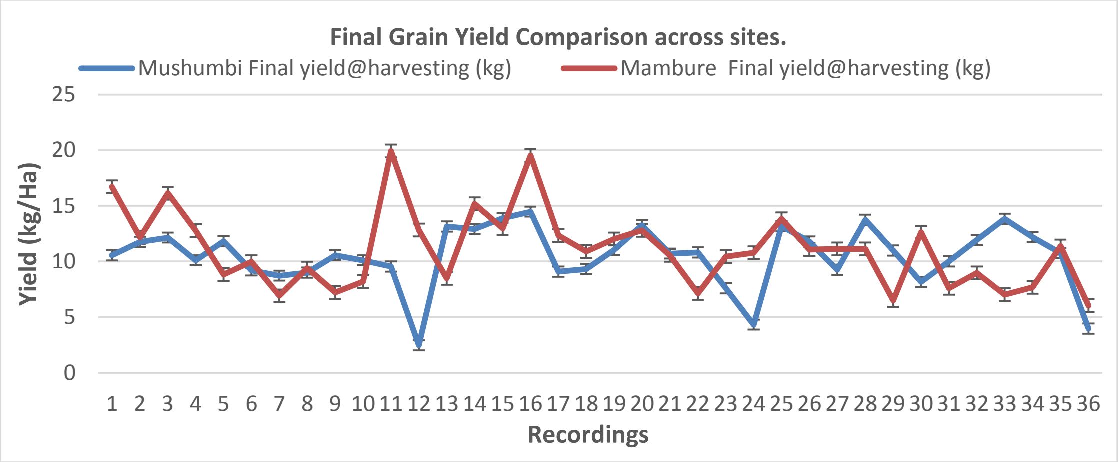

Figure 7: Final grain yield comparison across sites.

A two tailed test was conducted to compared final yields between the two sites. Table 3 below summarises the test statistics of this comparative analysis.

Table3: Summary of statistics for comparison of grain yields between two sites.

Mean	10.45	10.92
Variance	7.70	11.20
Std	2.77	3.3
Observations	36	36
df	66	
t Stat	-0.64	
P(T<=t) two-tail	0.52	
t critical two-tail	1.99	

t-Test Two-Sample Assuming Unequal Variances.

Since t Stat calculated (-0.64) < t critical (1.99) we fail to reject the null hypothesis and conclude that means are significantly different from the two sites.

3.0 DISCUSSION.

This discussion section aims to provide Mbire communal farmers with contextual empirical evidence based environmental conditions, knowledge, and practical experience that ensure optimum sorghum productivity to support adoption of conservation farming and agriculture practices. The study showed that soil temperature at booting stage, 50 days after sowing, influenced final yield whilst crop canopy temperature showed its effect on final yield at grain at grain filling, 75 days after sowing. This supports earlier research that plant metabolism is exposed to the thermal regime of both air and soil which form different diel and seasonal dynamics that will influence production. (Gobel, Coners, Hertel, Willinghofer, Leuschner, 2019). Soil temperature fluctuation can be behind that of air temperature due to relatively high heat capacity and low heat conductance of the soil. A phenomenon of diverging soil and canopy temperature occurred regularly as supported by the results, and this caused a mismatch in the physiological activity of aboveground and belowground organs. Leaf surface temperature exceeded air and soil temperature by some degrees around noon. This happened 50 days after sowing and at the end of the growing season 75 days after

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sowing. This then resulted in the shoots experiencing favourable thermal conditions for photosynthesis, while the roots were often exposed to lower temperatures. Under these conditions presented by basins mulched with grass, although impairment of root growth and resource uptake activity were likely to have occurred, that did not contribute to compromised final yields. Rather under these physical conditions with regards to photosynthate deployment for dry matter gain, maintenance of respiration and nourishment of storage organs which is seed, net photosynthate assimilation to the shots increased whilst that which was translocated to the roots decreased thus resulting in significantly increased grain yields. At this stage of plant growth and under these conditions, developing grain becomes the major competitor for translocate as well to positively influence final grain yields. Many investigators reported that greater biomass accumulation before heading and higher shoot reserve translocation are the decisive factors of higher yield in hybrids. (Md Moinul Haque, Habibur Rahman Pramanik, Jiban Krishna Biswas, K. M. Iftekharuddaula, and Mirza Hasanuzzaman (2015).

Interactions between land and atmosphere directly influence hydrometeorological processes and, therefore, the local niche climate. An increase in soil temperature at booting stage negatively affected sorghum final yield. This proved that the heterogeneity in soil temperature, induced by different mulch material and seed bed configuration combinations influenced soil temperature regimes with possibility of consequently effecting plant available water and final yield. These results quantify the effects of different mulch materials on the microclimate with respect to soil temperature and evaporation, which in turn affect herbaceous plants by modifying factors such as root growth and development, assimilation of photosynthates, and the final yield that be. Inference can be made that soil cover and seed bed configuration combinations affect the spatial and temporal variability of heat and water in the soil. The ability to know how different available mulch material and seed bed configuration influences temperature and water conditions enhances our ability to evaluate management options for soil and water conservation, plant establishment. Contextually, this study shows that in Mbire, low soil temperature was recorded for raised beds mulched with mopane leaves. At 75 days after sowing, the grain filling stage, sorghum still yielded high after receiving heat regime of an average soil temperature of at least 32.0^0C to maximise yields and thrived in day-time temperature of 36.60C. Under these conditions other crops would normally struggle thereby confirming the drought and heat tolerant physiognomic advantage of the sorghum crop.

At grain filling, favorable environmental conditions for optimum productivity for sorghum were attained when farmers used planting basins mulched with grass. Inversely, a combination of raised beds and grass mulch recorded lowest soil temperatures at 75 days after sowing and subsequently low productivity. Raised beds mulched with sorghum straw recorded highest soil temperatures at 50 days after sowing and subsequently low productivity. Mulches had a highly significant effect on average soil temperature that influences final yield of grain. (Liang Zhang, Yuan Meng, Shiqing Li, Shanchao Yue 2020). There is therefore need for further studies to establish which of the two critical stages is more critically influential to final yields than the other between booting and grain filling to be able to determine the tillage and mulch combinations that will give maximum productivity. If it is booting over grain filling, then raised beds mulched with mopane leaves will give more yields whereas if it is grain filling, basins mulched with grass will produce favorable results.

The action research and learning approach in the methodology also worked to stimulate the demand for and supply of necessary conservation agriculture tools, inputs, and services, through demonstrating optimum productivity using locally available resources. This led to increased adoption and the envisaged mass production of the sorghum crop as a value chain followed by mass consumption and subsequent sell of surplus. This followed the documented stages for agrarian recovery that start with proto industrialization in the rural areas, which is a first industrial revolution featuring mass production of labor-intensive light

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consumer goods. (Lili Wang, Yi Wen 2018). If this be successful, this would be followed by a second industrial revolution featuring mass production of the means of mass production (i.e., capital-intensive heavy industrial goods such as steel, machine tools, electronics, automobiles, communication, and transport infrastructures). The above prototype used by the Asian tigers can also apply in the Mbire context presenting a positive impact in the communities and the economy at large. In the Mbire context, this study reveals the possibility of an increased sorghum productivity, mass production and mass consumption leading to household food security and resilience. This will be followed by the rise in demand of and establishing relationships with tillage service providers and private sector agronomic input supply companies, starting at communal to national level.

Socio-economically, the research provides empirical evidence base that by advocating for farmers on how to practice conservation agriculture, an opportunity is provided to significantly increase the yields that can be achieved, the capacity to improve overall management practices and reduce input costs, to increase profits and to expand their area of production. This directly contributes to food security at household level that is followed by mass consumption whereby if supported by government policies and institutional frameworks, rural industrialization will be imminent for economic turnaround for households and the country at large. (Lili Wang, Yi Wen 2018). This will cause massive change in each farming family's productivity. Farming becomes less about perilous subsistence, and more about profits which can either be invested back into making the land even more successful, or into the capital assets and educational, nutritional, and healthy well-being of the family. This increase in productivity is visibly apparent from the very first season of adoption and is the main reason that farmers that participated choose to adopt sorghum production under conservation agriculture.

Environmentally, the research demonstrated that by being able to make land that already seemed to be exhausted profitable again, less pressure is placed on clearing forest for new farming land. Valuable topsoil is buffered for longer, the soil profile retains or rebuilds valuable organic carbon matter better over time and by harvesting water in the basins and rip lines the crops are better able to withstand the increasing climatic shocks experienced. The two major techniques to improve soil health of no or minimum tillage and soil amendments proved to increase productivity as well as soil health.

In the extreme dependence of harvest prognosis on soil temperature, the secrete of high yields to a great extent depends on the successful match of cultures planted, time of their seedling, and further weather conditions to ensure their sufficient performance. Temperature affects biological, chemical, and physical features of soils either decreasing or increasing them. This is why soil temperature importance is the object of keen studies in many scientific fields, especially in biology, physics, chemistry, ecology and agriculture. The analysis of historical soil temperature data for a specific region, monitoring the current state of things, and soil temperature and weather forecasting are the key aspects contributing to success. Either too low or too high degrees kill both soil organisms and plants. Agricultures develop slowly at 72.4 ^{0}C while 122.4 ^{0}C is critical as soil bacteria cannot survive the heat. At 82.4 ^{0}C, vegetation cannot absorb enough moisture since as much as 85% is lost due to evaporation and transpiration. Ruosong Qu, Guanzhen Liu' Ming Yue' Gangsheng Wang' Changhui Peng, Xiaoping Gao (2023).

Soil temperature and plant growth strongly relate. Warmth induces vegetation development in terms of water and nutrient uptake and overall plant growth. Low temperatures inhibit water uptakes due to lower water viscosity and slow down the process of photosynthesis. Besides, lack of warmth is an unfavorable condition for the activities of earth-dwelling microorganisms since their low metabolism means low nutrient release as well as its low dissolution. So, the cooler the land is, the fewer nutrients and water plants can get. As for roots and shoots growth, cold conditions hinder cell reduplications and thus slow down the overall growth. It refers both to cool air and earth.

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Biologically, the average soil temperature for bio activity ranges from 50-75F. These values are favorable for normal life functions of earth biota that ensure proper organic matter decomposition, increased nitrogen mineralization, uptake of soluble substances and metabolism. On the contrary, condition next to freezing slow down activities of soil -dwelling microorganisms, while microorganisms cannot survive below freezing points at all. Decreased microbial activity are the reason for reduced organic matter.

The soil chemistry as influenced by increase in temperature regimes show higher cation exchange capacity due to decomposed organic matter. The warmer the soil, the more water soluble phosphorous it contains for plants. Inversely, low heated earth is poor in phosphorous available for vegetation. As to pH levels, the acidity arises with a higher degree as well as organic acid denaturation.

It is clear, that when the soil temperature exceeds certain optimum points, plants cannot develop properly since the biological and chemical processes in the soil will not be intense enough. Furthermore, these processes are impossible when temperatures reach too high levels. Taking this into consideration, it becomes vital to know optimum values for growing agro-cultures and secure ultimately beneficial conditions for their germination, development, and reproduction. Thus, the analysis of historical soil temperature data for a specific region, monitoring the current state of things, and contextual soil temperature regulating are the key aspects contributing to high crops productivity.

4.0 CONCLUSION

There are techniques and combination of techniques that can be used to increase sorghum productivity in communal areas in Zimbabwe. To take maximum advantage of site -specific conditions and available natural resources, farmers should look at their fields from a whole farm perspective as well as specific locations and then chose and combine the appropriate techniques for each situation.

From the study, it can be concluded that the commonly used different tillage types and mulch materials can influence soil temperature and crop canopy temperature of a given crop stand. Furthermore, there are subsequent effects on the final grain yields of crops in this instance sorghum *(sorghum bicolor L*) as influenced by soil and canopy temperatures. So, the sensitivity of variation of soil and canopy temperature as influenced by tillage and mulch cover to field averaged soil cover can be useful in studies to model soil hydraulic heterogeneity.

The study also demonstrated the feasibility and effectiveness of local innovations such as context-based adaptation and creation of new techniques. These innovations have often been ignored by field extension agents who normally are more familiar with standard techniques. In this study, farmers were able to identify resources and observe influences as they pushed to be innovative. Once this can be done, farmers should then be able to assess the quantity, quality, availability, and accessibility of the resources and then peruse their innovativeness. The study showed that farmers should be able to use information gathered from the land, and the people living on that land, to integrate many techniques that together optimizes land use and productivity. Observing and understanding local influences of available resources and applying results learnt will inform the most effective choice and use of a technique. This applies both to water management and soil health management for increased productivity.

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