MANAGEMENT OF SMUT DISEASE AND ANALYSIS OF NUTRITIONAL VALUE OF SORGHUM (*Sorghum bicolor* (L) Moench) IN CENTRAL TANZANIA

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ABSTRACT

Sorghum smut disease is one of the serious constrain in sorghum production especially when seeds are not treated before planting, where grain yield loss of up to 80% is reported in different parts of the world. A study was conducted to increase potential of sorghum productivity by enhancing smut disease management in Central Zone of Tanzania. Field experiment were laid out in 6 x 4 (Sorghum varieties x fungicides) factorial in a Randomized Complete Block Design (RCBD) with four replications whereby sorghum samples from each variety were analyzed for proximate composition. Results revealed that there was very highly significant difference observed among sorghum varieties tested ($p< 0.05$) on disease incidence and severity. The lowest incidence and severity of 4.57 and 11.41% were recorded on NACO Mtama1which also corresponded with the highest grain yield 3210kg/ha, while the highest incidence (22.18%) and Severity (19.07%) which also corresponded with the lowest grain yield 2380kg/ha were in Langalanga landrace. For fungicides the lowest disease incidence (3.71%) and severity (11.15%) were with application of Apron star while the highest incidence (36.93%) and severity (26.68%) were recorded on control. Apron star, the seed dressing fungicide application led to the highest yield while the lowest was from control with no fungicide application. The proximate analysis revealed that sorghum samples contains appreciable nutrient contents whereby protein content ranged from 7.14 – 10.16 g, fat 3.34 – 5.34 g, Fibre 1.12 – 2.00g, total carbohydrate 74.89 - 78.15g.From the present study, NACO Mtama1 has shown promising results as potential variety for sorghum production and source of resistance to smut disease, while the fungicide Apron Star is recommended for smut management in central part of Tanzania, due to the lowest smut disease incidence, highest grain yield and highest net profit among other methods of sorghum smut management.

DECLARATION

I, Soma Said, do hereby declare to the Senate of the Sokoine University of Agriculture that this dissertation is my original work done within the period of registration and that it has neither been submitted nor being concurrently submitted for a higher degree award in any other Institution.

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This work is a dedication to my mother Fatuma Salum, my father Said Soma, my wife Amina Kengeja and my three children Muhammad, Fatma and Rukaiyya.

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LIST OF ABBREVIATIONS AND ACRONYMS

%	Percentage
^{0}C	Celsius degrees
BS	Base saturation
C:N	Carbon to Nitrogen ratio
Ca2+	Calcium
CEC	Cation Exchange Capacity
CHHO	Carbohydrates
CV	Coefficient of Variation
DAS	Days after Sowing
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
Fig	Figure
GenStat	General Statistics
GM	Grand Mean
ha	Hectare
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
K+	Potassium ion
kg	Kilogram
m.a.s.l	Meters above sea level
m^2	Squared meter
Mg2+	Magnesium ion
N	Nitrogen
Na+	Sodium ion

OC	Organic Carbon
OM	Organic Matter
P	Phosphorus
p	Probability
pH	Potential hydrogen
S.E	Standard Error
TARI	Tanzania Agricultural Research Institute
TEB	Total Exchangeable Bases
TMA	Tanzania Meteorological Agency
TOSCI	Tanzania Official Seeds Certification Institute
URT	United Republic of Tanzania
USDA	United States Department of Agriculture
WAP	Week after planting
WWW	World Wide Web

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Sorghum (*Sorghum bicolor* (L) Moench) is an important staple food crop in the world. It is ranked fifth in the world and fourth in Tanzania in terms of importance among cereal staple food crops after maize, rice and wheat. In Africa it is cultivated in an area of about 24 million hectares with a mean yield of 0.8 t/ha (Marley 2004; Msongareli *et al.*, 2017). In Tanzania more sorghum is grown in the central part of the country (Dodoma and Singida) and also in other semi-arid areas of Tabora, Shinyanga Mwanza and Mara regions. These regions together produce 50% of the country's commercial sorghum output (Brown, 2013). The ability of sorghum to withstand drought, heat, low soil fertility and flooding makes it to be an ideal crop for production in Sub-Sahara Africa, the region which is characterized by random drought, low and erratic rainfall (Mrema *et al.*, 2017).

Sorghum is particularly important in arid and semi arid areas where other standard cereals such as maize, rice and wheat cannot perform well. This is one of the reasons why the majority of farmers in dry lands adopt growing sorghum instead of maize (Simtowe *et al*., 2019).

In the last 30 years average yield of sorghum has remained below 1 t/ha in East Africa compared to the potential yield of 2.5 to 3.5 t/ha (Manyasa, 2016; Kanyeka *et al.*, 2007). Sorghum production has been facing a number of constrains which includes both biotic and abiotic such as insect pest, weeds, susceptibility to diseases and low yielding varieties, birds damage, poor soil fertility, drought and so many others (Mrema*et al*., 2017). According to Kutama *et al.* (2011), about 40 seed-borne pathogens attack sorghum causing more than 32 different types of diseases among them are downy mildew, moulds and smuts. Smut is one of the most important fungal diseases of sorghum in Africa. It is caused by *Sporisorium species* and it is commonly found in areas where no seed treatment is applied before planting (Prom *et al*., 2014).

1.2 Justification

In Tanzania covered kernel smut and head smut are among the diseases of sorghum that had adverse impacts to sorghum production in the central parts of Tanzania (Njoroge *et al.*, 2014). However, the information regarding the levels of how the disease affects sorghum is very limited and therefore the response of different sorghum genotypes are not well documented (Wilson *et al*., 2011). The information on genotypes that are resistant to smut disease of sorghum as well as on the application of fungicides to control the disease is also missing. This study therefore designed to reveal the status of the smut disease in central part of Tanzania and estimate the yield loss due to the disease. It also asses nutritional quality among varieties, recommend on the sorghum varieties with relative higher resistance to the diseases and suggesting proper fungicides for smut management.

1.3 Objectives

1.3.1 Overall objective

Improvement of sorghum productivity and quality by enhancing smut disease management and analysis of nutritional value in Central Zone of Tanzania.

1.3.2 Specific objectives

The specific objectives of this study were to:

i. Identify sorghum varieties with relatively higher levels of resistance to smut disease and proper fungicide for smut disease management.
ii. Determine the grain yield losses associated with smut disease and nutritional quality among the sorghum varieties.
iii. Perform cost-benefit analysis on the use of fungicides and selected sorghum varieties for sorghum smut disease management at Hombolo in Dodoma.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Background Information

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the most important cereals across the world supporting the lives of millions of people particularly in the developing countries (Chala *et al.*, 2010). For maximum sorghum production rainfall between 450 and 650mm is required (Assefa *et al.*, 2010). According to Katy *et al*. (2012) sorghum also grows well on soils with pH 6.0 to 6.6 and relative high fertility level where supplement of fertilizer of 60kgN/ha and 40kg P_2O_5/ha recommended for central part of Tanzania (Kanyeka *et al.*, 2007; Msongareli *et al.*, 2017). Sorghum is grown for different uses such as staple food, feed, fibers and bio-energy worldwide (Wilson, 2011; Fagwalawa *et al.*, 2013; Mrema *et al*., 2017).

Traditional weaning foods in most African countries are based on the local staple food, usually a cereal and sometimes on roots foods (Wakil *et al*., 2009). In Tanzania, sorghum is one of main staple food crops in almost all the semi-arid areas which include regions of Dodoma, Singida, Shinyanga, Tabora and Simiyu, where production is done mostly by subsistence farmers for food, feed and beer production (Monyo *et al.*, 2002).

2.2 Sorghum Diseases

2.2.1 Introduction

The low grain yield in the world is a result of number of factors but according to Kutama *et al*. (2011) part of this loss contributed by the number of diseases attacking this crop worldwide. In Tanzania Njoroge *et al.* (2018) listed 16 disease found in Singida and Dodoma including anthracnose, covered smut, leaf blight, rust, ladder leaf spot, long smut and head smut whereby together with other factors resulted to the low grain yield compared to the attainable grain yield of sorghum which is up to 5 t/ha.

Smut is one of the most important diseases of sorghum especially where untreated seed is planted. Studies have reported that smut disease affect heads or panicles of sorghum, reducing yield and quality of the grain as well as forage value (Prom *et al.,* 2017). The four smut diseases affecting sorghum are head smut, long smut, loose kernel smut and covered kernel smut. In East Africa including Tanzania less studies have been conducted on the smut disease and hence very little information available (Wilson, 2002).

2.2.2 Covered kernel smut

Covered kernel smut is a one of most destructive smut disease, it is a seed borne panicle disease caused by the fungus *Sporisorium sorghi* (Thakur *et al*., 2007). The *Sporisorium sorghi* attacks all groups of sorghums, including Johnson grass and it is most common in sorghum growing areas where no fungicides seed treatment applied (Horne *et al*., 1980). The infection is systemic, which begins at the seedling stage and progresses to the inflorescence (Gwary *et al*., 2009).

Usually, all of the kernels in a smutted head are destroyed and replaced by dark brown, powdery masses of smut spores (teliospores or chlamydospores) covered with a tough, grayish white or brown membrane (Illinois, 1990). The infected kernels (smut sori) break, and the microscopic spores adhere to the surface of healthy seeds where they over-season. For the infection to occur only seed borne spores are responsible (Sisay *et al*., 2012; Thakur *et al*., 2007).When a smut-infested seed is planted, the teliospores germinate along with the seed forming a sporidia that germinate and infect the developing sorghum seedling. Once inside the seedling, the fungus grows systemically, apparently without damaging the plant until heading (Thakur *et al.*, 2017; Horne *et al.*, 1980). At that time, the teliospores replace kernels and are surrounded by a membrane. At maturity, the membrane ruptures releasing the teliospores to contaminate seed or soil.

Usually individual ovules in infected panicles are replaced by conical to oval smut sori (teliospores or chlamydospores) that are covered by constant peridia that are larger than normal grain. At the start each sorus is covered with a light pink or silver-white membrane, which later on ruptures to reveal the brownish-black smut spores (Fetene, 2017).

2.2.3 Head smut (*Sporisorium reilianum*)

The disease is common in many parts of sorghum growing areas all over the world, with different races of *Sporisorium spp*. infecting sorghum, corn and sudan grass. In recent years head smut severity has increased due to cultivation of some susceptible sorghum cultivars or the appearance of more virulent races (Thakur *et al*., 2007). This is a reason why head smuts can hardly be controlled by seed treatment, instead host resistance technique is found to be the best management method (Bai *et al.*, 2016). The head smut pathogen is soil borne and survives in the form of teliospores in smut sori. The pathogen requires a combination of haploid nuclei of opposite mating types to cause infection and grow through the plant as dikarryon (Little *et al*., 2012). The sites of infection for the sorghum seedlings are mesocotyl, then coleoptile and radical, the serious stage of infection is the period prior to seedling emergence (Bai *et al*., 2016). At the flowering time, a diploid phase leads to the production of teliospores in sori, which essential to replace the seeds in the host. At maturity the sporodia rupture, then teliospore over season in the soil as well as in the plant debris as a primary inoculation for the next sorghum season (Little *et al.,* 2012).

When sorghum seed is planted, the following season, the smut spores germinate along with the seed penetrate meristematic tissue in the sorghum seedling as dikaryotic hyphae (Lance, 2013). When the hyphae of *Sporisorium reilianum* attack the sorghum through the roots successfully, they will be inside over the whole growth period with no damage to their host until flowering stage. One infected sorghum plant release millions of spores that increase the possibility of infection in the soil, and can remain viable in the soil for years (Bai *et al*., 2016; Thakur *et al*., 2007).The suitable condition for head smut fungus is moist soil and temperature between 27 to 32^0 C (Thakur *et al.,* 2007).

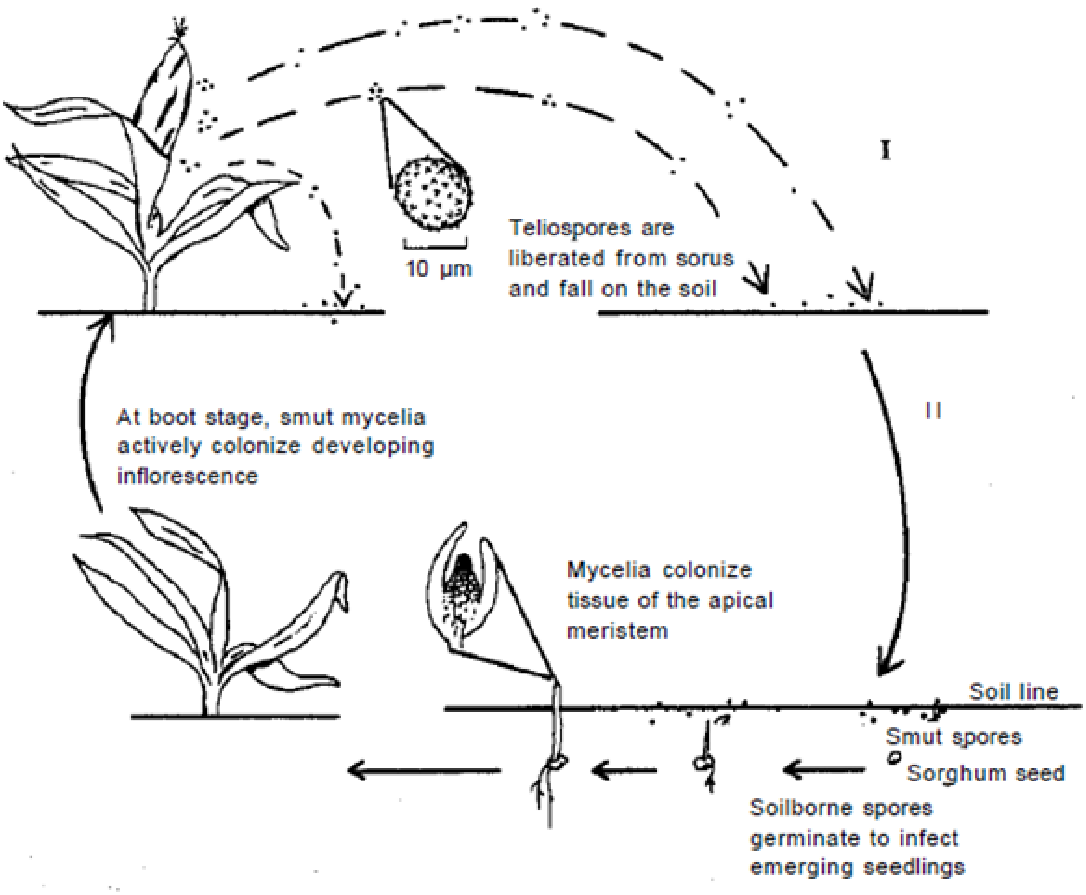

Figure 1: Life cycle of *Sporisolium reilianum*, causal agent of sorghum Head smut (Frederiksen, 2002)

Head smut usually affects the inflorescence with a white peridium initially covers the sorus large ruptured sori reveal distinct vascular strands (Thakur *et al.*, 2007). Infected plants show no elongation of the peduncle with sterile panicles bearing sori of various sizes as well as reduction of plant height and premature tillering (Fagwalawa *et al*., 2013). Other varieties are dwarfed or stunted, the pathogen usually results to complete inability of a plant to produce grain.

2.2.4 Long smut

Long smut is important fungal disease in areas with low moisture due to low rainfall and high temperature caused by airborne fungus (*Sporisorium ehrenbergii)* (Thakur *et al.*, 2007). The teliospores are packed in spore balls that are dark brown and vary in size ranging from 30-230µm diameter. The infection occur when airborne teliospores are by wind or rain washed into the boot and germinate to produce sporidia that infect the spikelets, at maturity. The sori (with millions of teliospores) rupture and the teliospores dispersed within fields. Teliospores adhere to one another to form spore balls, which can survive in the soil for many years and serve as a primary inoculums during a season at booting stage (Manzo, 1977; Prom *et al.,* 2014).

Long smut infected grain appear as elongated, cylindrical, to some extent curved sori, longer than common grain. The sori have a whitish thin membrane that ruptures to release black powdery mass of spore balls that easily can be blown to the soil surface or to another plant by the wind. The long smut sori are longer (2-4 cm) than those of covered kernel smut and are not uniformly distributed on the panicle not like the covered kernel smut sori. (Thakur *et al.,* 2007).

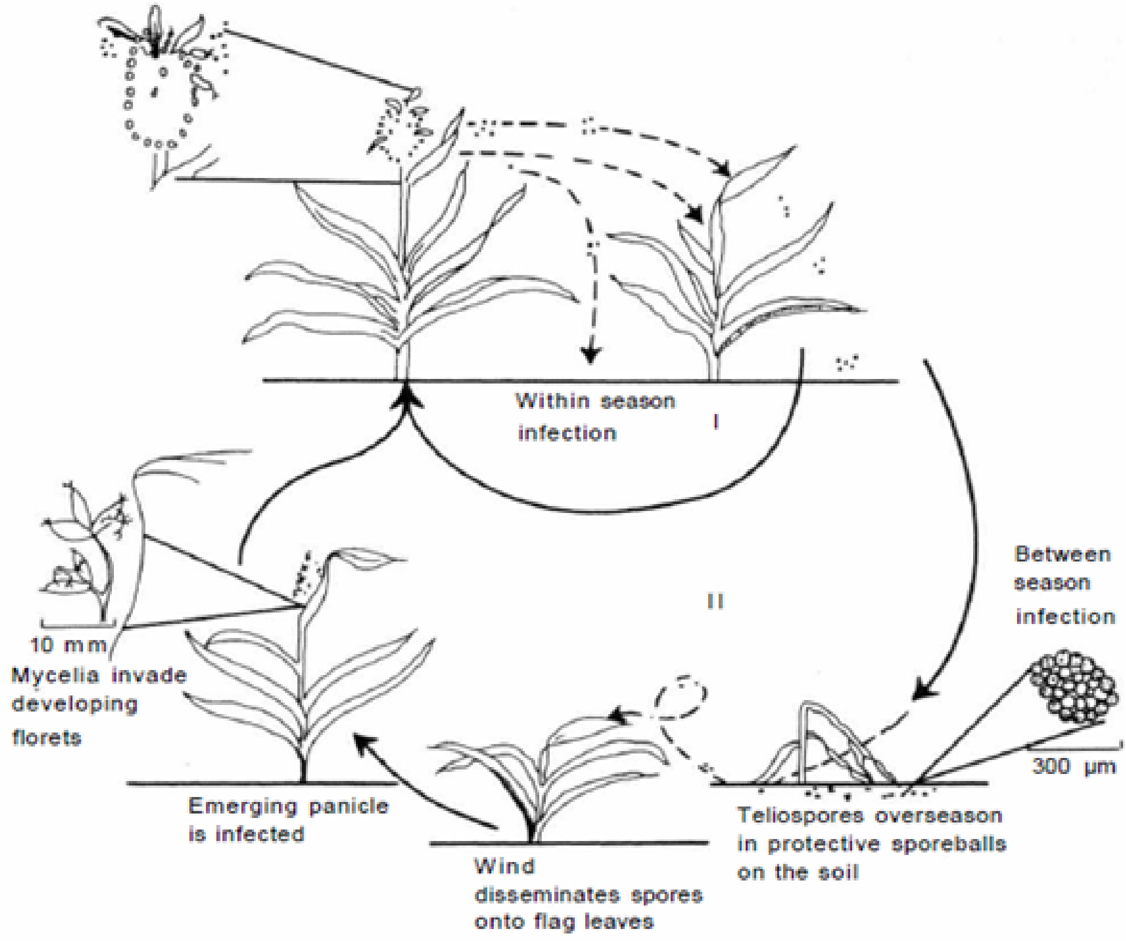

Figure 2: Life cycle of *Sporisorium ehrenbergii,* causal agent of Long smut (Frederiksen, 2002)

2.2.5 Loose kernel smut (*Sporisorium cruentum*)

Loose kernel smut is caused by the fungus *Sporisorium cruentum* with light yellowish brown or dark brown teliospores. It is seed transmitted and cause infection to the sorghum seedling, as well as to the healthy kernel in the field that may develop smut when planted at favourable conditions without treatment. The teliospores germinate by forming a thick, usually 4-celled promycelium bearing lateral sporidia, like in other smut fungi. Spore germination occurs at optimal temperatures of 28-32°C. In this type of smut, galls are long and pointed, at maturity the membrane covering the galls break away releasing a dark round spores in the field (Thakur *et al*., 2007; Horne *et al*., 1980).

Normally, smutted plants are stunted with earlier booting than the non infected plants and most spikes with smutted glumes display hypertrophy and abundant side branches. Most of the time, the tillers are smutted, as well as the primary panicles. Usually all kernels in an infected panicle are smutted and some kernels may be transformed into leafy structures or not infected completely. The smut sori are surrounded by a thin gray membrane (Thakur *et al.,* 2007; Kutama *et al.,* 2011; Moharam, 2018).

2.2.6 Epidemiology and effects to sorghum grain yield

2.2.6.1 Epidemiology of the smuts diseases

Smut infects all groups of sorghum, both seed-borne and soil borne pathogens, infection starts at the seedling stage then progresses to the inflorescence (Little *et al.,* 2012). The infected kernels (smut sori) break and the microscopic spores adhere to the surface of healthy seeds or soil where they over-season. According to Sisay *et al.* (2012) the smut pathogens influenced mainly by temperature ranging between 25 and 32 with high moisture content during the germination except for long smut which is mainly favoured by wind and rain at the flag leaf at booting stage. Temperature above 35 ^{0}C tends to reduce the number of germinated spores and hence low disease incidences (Thakur *et al.,* 2007). According to Polon and Schirawski (2015), the smut pathogen is in different forms with very narrow range of hosts, the head smut pathogen for example exist in two host-adapted forms which causes head smut of sorghum and maize. When a smut-infested kernel is planted, or health seed planted on the infested soil, the teliospores germinate along with the seed. Then, the sporidia germinates and infects the developing sorghum seedling. Once inside the seedling, the fungus grows systemically, apparently without damaging the plant until heading, at that time the teliospores replace kernels on the head (Thakur *et al.,* 2007).

2.2.6.2 Distribution of sorghum smut diseases and their significance in sorghum grain yield

All four sorghum smut diseases are potentially important in several sorghum growing areas in the world (Thakur *et al.*, 2007). Reports from different parts of the world, received showing presence of different types of smut diseases and their effects to the sorghum production of the specific area. Little *et al.* (2012) citing the report of survey conducted in four major regions of Nigeria growing sorghum, to reveal the incidences, severity and distribution of smut diseases in the farmers' fields. The results showed that covered, loose and long smut found in all four regions with covered smut being more dominant in two regions with incidence of 24.8% and 29.5% and head smut was absent in one region. Kutama *et al*. (2011) reported the presence of reduction of growth and grain yield in sorghum varieties grown due to the presence of loose smut while Gwary *et al*. (2007) mentioned yield loss of 20 to 60% reported in Nigeria.

Again in Ethiopia, survey conducted by Taferi *et al.* (2015), in two major sorghum growing districts of South Tigray, showed that, incidence and severity of long smut, head and loose smuts were up to 71%and 77% respectively. In Ethiopia Merkuz (2012) reported a grain yield loss on sorghum local varieties due to smut disease ranging between 6.1% and 80.9%. Again the study conducted in Ethiopia testing different methods for management of Sorghum Covered smut, Fetene (2018) reported grain yield loss ranging between 4.63% and 60.74%.

As a study conducted by Ngugi *et al*. (2002) in Western Kenya, reported presence of different smut diseases in 14 to 75% of the fields visited. Where head smut was most dominant while the loose smut was found in 14 to 24% of the field surveyed. In Egypt, Moharam (2018) reported the presence of loose kernel smut pathogen in Upper Egypt. In all sorghum growing areas several studies have been conducted to reveal the presence of the disease and found different methods to suppress the diseases effects (Kutama *et al*., 2011; Prom *et al.,* 2014; Prom *et al.,* 2017).

In Tanzania there is a limited of published information on the impact of smut disease to the sorghum production. Wilson (2011) reported a study conducted by staffs from Kenya, Uganda and Tanzania between 1995 and 2002 on Covered Kernel smut showing that there was high incidence of disease in all countries which resulted to the high yield loss. Another report of smut disease in Tanzania was by Njoroge *et al.* (2014) which was the first comprehensive report on Sorghum diseases for the countries in 15 year. In the report among the 16 sorghum diseases found in Tanzania, Covered kernel and Head Smut diseases were observed. Also, Hayden and Wilson (2000) reported on the presence of Covered kernel smut in Dodoma Tanzania. The status of smut disease worldwide shows how important this study in central part of Tanzania where sorghum is common staple food and most of farmers grow sorghum without fungicide application.

2.2.7 Efforts on management of sorghum smut diseases worldwide

Several efforts have been made to reduce the effects of sorghum smut diseases on grain yield, quality and foliage those efforts based on either using sorghum varieties resistant to the pathogens or seed treatment using fungicides. In 2007, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), developed screening techniques for sorghum genotypes resistant to smut diseases in which injection method of inoculation found to be the best in screening (Thakur *et al.,* 2007). In Texas different screening techniques tested for sorghum resistances to *Sporisorium relianu* races (Prom *et al.,* 2011). In Nigeria, Gwary *et al.* (2007) tested fungicides seed dressing and resistant sorghum varieties for sorghum smut management. In their report, found the Guzama red and Guzama white genotype with the lowest smut incidence and severity, as well as Apron star as the best fungicide in smut control. Finally they recommended use of integrated of fungicides and resistant varieties for management of sorghum smut. Nzioki *et al.* (2010) evaluated different protocols to determine genetic variability of grain sorghum germplasm to Covered kernel smut pathogen, using inoculation at different stages of sorghum growth 2003 and 2004 cropping season. In the report it was revealed that the best inoculation of the pathogen was at the 10 – 12 leaf growth stage.

A study conducted to assess the effects of varieties, fungicides and sowing dates on the incidence and severity of sorghum smuts in the Sudan Savanna of Nigeria (Gwary *et al.,* 2009). In China Bai *et al.* (2016) reported the progress on the effort to control Head smut pathogen (*Sporisorium reilianum*), the report showed a continuing progress of developing sorghum hybrids resistant to the Head smut. The efforts on controlling smut diseases facing the challenge of raising different physiological races breaking the varieties resistances. For the *Sporisorium reilianum* thirteen physiological races are currently known, six are in USA, three races in Mexico and four races in China (Bai *et al*., 2016). Therefore, the efforts to control smut pathogen require integration of variety resistance, application of fungicides and cultural practices as to overcome the problems of physiological races and pathogens such as soil borne (*Sporisorium reilianum*) and air borne (*Sporisorium ehrenbergii*) which difficulty to control using chemicals. The integration of the two technologies (fungicides and plant resistance) also showed positive results in management of other diseases in sorghum such as Grain mold and Anthracnose (Marley, 2004).

2.3 Sorghum Nutritional quality and Uses

2.3.1 Definitions of nutritional and nutritional value of sorghum

Foods are made up of carbohydrate, protein, fat, vitamins, water and minerals (Adulrahman and Omoyi, 2016). According to Reference. MD (2019) "nutritional value of any food is an indication of the contribution of a food to the nutrient content of the diet. This nutritional value depends on the amount of a food that is digested and absorbed and the quantity of the essential nutrients".

Also according to Medak and Singha (2002), the quality of any food depends upon the presence or absence of relative concentration of various nutrients such as, carbohydrates, proteins, fats, amino acids, vitamins, minerals and anti-nutritional parameters. The nutrient composition of sorghum indicates that it is a good source of energy, proteins, carbohydrates, vitamins and minerals including the trace elements, particularly iron and zinc (Afify *et al*., 2012). In summary, the utilization of the sorghum in Tanzania can be classified mainly into three categories which are human food, animal feed and industrial use.

2.3.2 Grain Sorghum Common Uses

2.3.2.1 Human consumptions

Sorghum acts as a principal source of energy, protein, vitamins and minerals for a lot of people living in drought regions, who cultivate sorghum for consumption at home (Satish and Pandit, 2011). When included in the diet, sorghum is a powerhouse in terms of nutrients, it can provide nearly half of the daily, required intake of protein and a very significant amount of dietary fiber (USDA, 2019). Sorghum nowadays becomes a great alternative to other types of cereals that are commonly consumed across the globe due to huge health benefits associated with it (John, 2019).

Also, sorghum food is acceptable for people with allergic reaction to wheat, this makes it very important as alternative staple crop in the world. It is considered as a safe grain alternative for people with celiac disease and gluten sensitivity (Satish and Pandit, 2011). Gluten is the flexible protein in common grains like wheat, barley and rye that give them a chewy, springy quality when baked into breads or pastas (Marengo, 2019). It triggers inflammatory reactions in people with celiac disease or gluten sensitivity that can cause abdominal pain and digestive issues and eventually lead to joint pain and intestinal damage. For now, the only way to avoid gluten intolerance is to stick to a strict gluten-free diet (Satish *et al.*, 2011).

Recent researches suggest that sorghum grain rich in polyphenol may have anticancer potential. Sorghum may have anticarcinogenic and antitumor properties and may prevent metastasis of cancer such as breast cancer. It observed that sorghum due to the presence of 3-deoxy anthocyanidins and tannins may exhibit anticancer properties (Yang *et al*., 2009). Results indicate that high-polyphenol sorghum bran extracts have potential anticancer properties.

Awika and Rooney (2004) also reported on sorghum being rich source of various phytochemicals including tannins, phenolic acids, anthocyanins, phytosterols and policosanols. These phytochemicals have potential to significantly impact human health. Sorghum fractions possess high antioxidant activity in vitro relative to other cereals or fruits which may offer similar health benefits commonly associated with fruits such as reduction of risk of certain types of cancer in humans compared to other cereals.

According to Makindara *et al*. (2010), in Tanzania marketing of sorghum products is expanding due to revealed importance of grain sorghum products. The study listed number of challenges that hinder utilization of sorghum such as low consumer awareness contaminants from sorghum suppliers and lack of storage facility for processed sorghum products.

2.3.2.2 Animal feed and industrial uses

As the demand expands for feed, cereal production will also increase to meet need of feed industries. But due to the climate issues most of the areas are with drier conditions, sorghum's greater tolerance to low and variable rainfall and to lower soil fertility will give sorghum a productivity advantage over other cereals such as maize. According to Kaijage *et al*. (2014), Tanzanian Grain Sorghum Varieties have high nutritive value and quality to partially replace maize in poultry feeding with supplementation of mineral and amino acids to optimize their nutritive value for poultry and other animals.

In Philippine, cereal grains account for about 50-60% of a typical broiler diet where this feed serve as principal carbohydrate energy source for poultry and the sorghum is considered more economical than yellow corn and other cereals (Mateo *et al.,* 2006). Sorghum without tannin has been demonstrated to be excellent feed but slightly inferior to maize due to knowledge and in some areas is more expensive to use sorghum (Sanders *et al*., 2015).

In general, sorghum can be a vital product in the industrial sector such animal feed, breweries, bakeries and milling for home consumption due to the fact that it is rich in nutrients as well as its ability to tolerate hash condition in which other cereal crops cannot survive (Wilson, 2011).

Plate 1: Different uses of sorghum for human consumption (Makindara *et al*., 2010)

2.3.2.3 Factors that may affect nutritive value of food

Different factors may affect the nutritive value of the food when grown on the soil. According to Institute of Medicine Washington (2019), the nutritional value of a food can be affected by soil fertility and pH where it grown, as well as growing conditions, handling and storage and processing. In other studies such as Bandara *et al*. (2017) nutritional value of the sorghum produced also may be affected by disease infection to the growing plant and sorghum variety grown.

According to Tanzania Official Seed Certification Institute (TOSCI, 2019), twelve improved sorghum varieties registered for cultivation in Tanzania from 1960 to 2014 namely Serena (1960), Tegemeo (1978), Pato (1997), Macia (1998) Wahi (2002), Hakika (2002) Sila (2008), NACO mtama1 (2012), NACO SH1 (2013), NACO SH2 (2013) PAC

537 (2014) and PAC 501 (2014) (TOSCI list of registered sorghum varieties, unpublished). Among the registered improved sorghum varieties, in Central part of Tanzania Macia is the most adopted by farmers followed by Wahi, Hakika, Tegemeo and NACO mtama1together with local variety Langalanga (Kaliba *et al*., 2018).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Areas

The experiment was conducted during the 2018/19 season at Hombolo Agricultural Research Institute (TARI-Hombolo Centre) in Dodoma Region. The study site is geographically located about 58 km North-East of Dodoma Municipality at latitude 5^{0} 45^{1}S and longitude 35^{0} 57^{1} E, with altitude of 1020 m.a.s.l. Hombolo is in semi-arid areas, characterized by erratic and unreliable rainfall with annual mean rainfall of 589 mm per annum and mean annual temperature of 22.7^{0}C. The site also is characterized by unimodal rainfall that extends from November/December to April/May, followed by a long dry period from May to October (Msongareli *et al.*, 2017). The site is characterized with Sandy clay soil with pH 6.04 and very low Nitrogen as well as low Organic matter (Appendix 1).

3.2 Experimental Materials

3.2.1 Sorghum varieties

Six sorghum varieties were used in this experiment, among the six varieties four (Wahi, Hakika, Macia and NACO Mtama1) are improved sorghum varieties and commonly grown in central zone with average potential yield ranging from 2.5 to 4 t/ha. Wahi, Hakika and Macia released by TARI-Ilonga while NACO Mtama1 was released by NAMBURI Company (TOSCI, 2019). Langalanga and Gombela are local landraces that used as local check to compare with the improved varieties. All varieties were collected from (TARI-Hombolo) and their characteristics are indicated in Appendix 2.

3.2.2 Seed dressing fungicides

Fungicides used were, Seed Watch 20WS, Apron Star and Snow Angel 30% DS that were purchased from the Agrochemical stores in Dodoma. The properties of the fungicides used and their recommended rates are given in Appendix 3.

3.3 Experimental Design and Treatments

Field experiment was laid in Randomized complete Block design (RCBD). Treatments allocated as 6 x 4 (Sorghum varieties x fungicides) factorial combinations with four replications. The seeds were coated with the fungicidal treatments (Apron star, Seed Watch and Snow angel) at the recommended rates and for each variety one plot in each replication was kept as a control with no fungicide treatment. The trial was planted in January 2019 under open field growing conditions with no inoculation. The natural disease infection was expected to take place in the trial due to the fact that the site is hot spot for smut disease. The plot size was 3 x 3m in which four to five seeds were planted at spacing of 0.30m x 0.75m. Treatments were assigned randomly in each replication to avoid biasness. In this experiment a total of 24 treatments combinations were used (Table1).

Table 1: Treatment combinations applied in experiment (4 x 6 fungicides sorghum varieties combination)

T1=WAHI x SEED WATCH 20%	*T13=NACO MTAMA 1* x SEED WATCH 20%
T2=WAHI x APRON STAR	*T14=NACO MTAMA* x APRON STAR
T3=WAHI x SNOW ANGEL 30W%	*T15=NACO MTAMA 1* x SNOW ANGEL 30W%
T4=WAHI x No fungicide	*T16=NACO MTAMA* x No fungicide
T5=HAKIKA X SEED WATCH 20%	*T17=GOMBELA1107* x SEED WATCH 20%
T6=HAKIKA x APRON STAR	*T18=GOMBELA1107* x APRON STAR
T7=HAKIKA x SNOW ANGEL 30W%	*TT19=GOMBELA1107* x SNOW ANGEL 30W%
T8=HAKIKA x No fungicide	*T20=GOMBELA1107* x No fungicide
T9=MACIA x SEED WATCH 20%	*T21=LANGALANGA* x SEED WATCH 20%
T10=MACIA x APRON STAR	*T22=LANGALANGA* x APRON STAR
T11=MACIA x SNOWANGEL 30W%	*T23=LANGALANGA* x SNOW ANGEL 30W%
T12=MACIA x No fungicide	*T24=LANGALANGA* x No fungicide

3.4 Agronomic Practices

Land preparation was done three weeks before planting, this included leveling and ridges preparation as well as removal of the previous crop residues from the field. In this site the previous crop cultivated was sunflower. Sorghum seeds were then planted in a field with four to six seeds per hole then thinned to two plants per hill at two weeks after germination.

Fertilizer application was at planting for split application of 20kg N ha^{-1} in form of DAS and 40 kg P_20_5 ha^{-1} in form of DAS. The second N fertilizer split application of 40 kg N ha^{-1} in form of Urea, applied three weeks after germination (the fifth leaf growth stage). Within a season, weeding was done twice to keep the experimental plots free of weeds using hand hoe method where first weeding was three weeks after planting and second was eighth week after planting. Banophos 720 EC (Profenophos 720 g/l) insecticide was applied to control insect pest particularly shoot fly and fall army worms that were seen in the experimental plots.

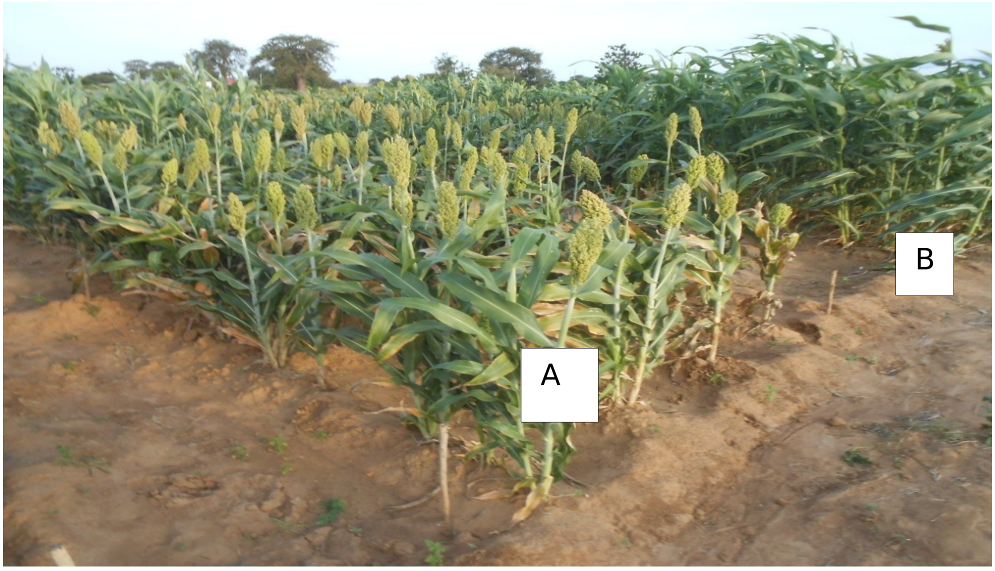

Plate 2: [A] Early maturing (Macia variety) [B} late maturing sorghum variety (Langalanga) on the tied ridges for water conservation

3.5 Data Collection

3.5.1 Weather characteristics during the experiment period

Weather parameters on the experiment site during the sorghum growing season were obtained from Tanzania Meteorological Authority (TMA) Hombolo station. The data were Minimum temperature, maximum temperature, Soil temperature, Relative Humidity and precipitation (Appendix4).

3.5.2 Plant population

3.5.2.1 Plant population at 5th leaf growth stage

Number of planting a net plot after thinning was recorded soon after thinning (when plants had 5 leaf growth stages).

3.5.2.2 Plant stand at dough stage

Number of planting a net plot was recorded at dough growth stage (70 days after planting).

3.5.2.3 Plant stand at harvest

Number of plants in the two middle rows counted at physiological stage just before harvesting.

3.5.3 Crop Growth

3.5.3.1 Seedling vigour score

Visual score of the vigor on a scale of 1-3, where; 1= very vigorous, 2= average and 3= poor was recorded a week after thinning.

3.5.3.2 Days to 50% flowering (Days)

Days to 50% flowering are the number of days that were recorded after observing half of plants in the inner two rows have flowered. (This data was determined by counting the days from planting to when half of the plants in the net plot has flowered).

3.5.3.3 Plant height (cm)

This is the average height of the plants in the two center rows (Average height from the base of the plant to the tip of the panicle, in cm), five plants from each plot were measured and the average recorded to represent height of that plot, it was done during the dough stages using a meter rule of 3m length.

3.5.3.4 Panicle length

It is the length of the panicle from the peduncle to the tip of the panicle (its average of five panicles in the plot randomly selected). Population and growth data collected according to the House (1985) (ICRISAT guide for sorghum breeding).

3.5.4 Smut Disease assessment

3.5.4.1 Smut disease incidence scores

Smut disease incidences scoring started one week after flowering by the proportion of plants showing the symptoms and expressing the result in percentage. The percentage incidence computed by using the following formula as suggested by Gwary *et al*. (2007).

$$\text{Disease Incidence (\%)} = \frac{\text{Total number of infected plants} \in \text{the plot}}{\text{Total number of plants} \in \text{the plot}} \times 100$$

3.5.4.2 Smut disease severity scores

Smut disease severity was scored at physiological maturity by counting total, healthy and infected number of spikes in each infected head within a plot and dividing the number of infected spikes by the number of total spikes in each infected panicle then multiplying by 100 to know the effect of the disease on the proportional percentage of the spikes.

$$S\ (\%) = \frac{number\ of\ infected\ spikes \in a\ panicle}{Total\ number\ of\ spikes \in a\ panicle} \times 100$$

Where: S (%)= disease severity in percent per panicle

This percentage severity of the diseased panicle was changed to a scale (1 - 9 rating scale) as suggested by Gwary *et al.* (2007) and Teklay and Muruts (2015) (Table 2).

Table 2: Smut disease Severity scale (as discussed by Gwary *et al*. (2007)

Scale	Details
1	0 - 15% infected florets
2	16 -20% infected florets
3	21- 29% infected florets
4	30 – 45% infected florets
5	46 – 75% infected florets
6	≥ 75 % infected florets
7	41 – 50 leaves area covered with lesions
8	51 – 75 leaves area covered with lesions
9	≥ 75 % leaves area covered with lesions

Then, the percentage disease severity was obtained by the following formula

$$\text{Disease Severity Index (\%)} = \frac{\sum n \times 100}{N \times 9}\ \%$$

Where:

∑n is sum of all scores, N in the total number of plants in plot and 9 is the highest score on the rating scale (Gwary *et al.*, 2007).

3.5.4.3 Grain Yield and Yield Components

Sorghum panicles were harvested from the two center rows ($3.6m^2$). The harvested panicles were counted, packed, labeled and sun-dried. The moisture content was then measured using moisture meter to be 14%. Then Dry panicle weight, Grain yield (g), 1000 seed weight (g) and grain weight per plant (g) was determined.

3.5.4.4 Dry panicle weight (gm)

The dried panicles of each sorghum variety in each plot were weighed using a beam balance (a weighing scale tool) and the average of weight was recorded as Dry panicle weight (gm).

3.5.4.5 Grain weight per plant

The dried panicles were threshed and the grain obtained weighed using electronic balance then divided by the number of plant harvest. The weight then was recorded as grain weight per plant.

3.5.4.6 Grain yield in grams (g)

The all panicles within a lot were threshed, winnowed and the grain was weighed using a beam balance. The weight then divided by number of plants before multiplied by 32(maximum population for net plot ($3.6m^2$) and recorded as gram per plot area ($3.6m^2$). Later, the weight in gram obtained per plot converted into tones per hector.

3.5.4.7 1000 grain weight (g)

The sorghum grains obtained from each plot, hundred grains were counted randomly and weighed using electronic balance. The weight then was recorded as 1000 seed weight in gm.

3.5.4.8 Yield loss estimation

The yield loss due to disease damage in each plot was calculated using the following formula given by Lilian *et al*. (2016).

$$RL\,(\%) = \frac{YT - Y0}{YT} \times 100$$

Where, RL = relative grain yield loss

YT = mean yield of respective genotype on treated plots,

Y0 = mean yield of the respective genotype in control plot

3.5.5 Determination of nutritional values among sorghum varieties

For each sorghum variety, one sample was randomly taken from each replication which had shown no sign of smut disease. Total of 24 samples obtained four for each variety, the panicles were threshed winnowed and packed in the paper bags, then transported to the Analytical Laboratory of the Department of Food Technology Nutrition and Consumer Sciences (DFTNCS) at Sokoine University of Agriculture (SUA).

Proximate analysis of raw sorghum was determined according to the official methods of the Association of Analytical Chemists (AOAC, 1995 and AOAC, 2000). The 24 samples were analyzed in duplicate for crude protein, crude dietary fiber, moisture, ash and carbohydrate content. The average of two measurements was used.

3.5.5.1 Determination of moisture content

The moisture content of the samples provided was determined in duplicate samples. The crucible were weighed and recorded as weight 1 (W1). Samples were first weighed and recorded (W2), then dried at 105°C for 24 hours, cooled for 2 hours and then weighed to obtain constant weight (W3). (Mueller, 2000). The average moisture content was calculated using the following formula:

$$\text{Moisture Percent} = \frac{(W_2 - W_1) - (W_3 - W_1)}{(W_2 - W_1)} \text{ X } 100$$

Where:

W_1 = Weight of crucible

W_2 = Weight of sample in a crucible

W_3 = Weight of sample in a crucible

3.5.5.2 Crude protein determination

About 0.5g of samples were weighed in duplicate and digested. Total Nitrogen (N) and crude protein in the samples provided were worked out as follows:

$$\text{Percent } N = \frac{(14 x 0.1) x A}{W} x 100$$

Where:

A = the titre of acid used in millilitres

W = original weight of the digested sample

N = ***Total Nitrogen***

Percent crude protein = Percent N x Factor (6.25)

3.5.5.3 Crude fat determination (Ether Extract)

Crude fat of sorghum grain was determined by ether extraction method using the Soxtec System. Ten grams of grain sorghum sample was transferred into extraction thimble and covered with defatted cotton wool. Then thimble inserted into the extraction unit, then the extraction cup containing 70 ml of solvent (40- 60^0C petroleum ether). The extraction was about two hours, boiling (15 minutes), rinsing (45 minutes) and recovery (10 minutes). The cups containing extracted fat were dried in an oven at 105^0C for about 30 min, Cooled and lastly weighed. The percentage crude fat was calculated using the following formula:

$$\% \text{ Crude fat} = \frac{Weight\ of\ crude\ fat\,(g)}{Weight\ of\ dry\ samples\,(g)} \times 100$$

3.5.5.4 Ash content determination

About 1g of the test sample was weighed in pre-weighed crucibles. The samples were then ignited in carbolated muffle furnace (530 2RR, England) at 550^0 C for six hours, followed by cooling and weighed.

The ash content was calculated as bellow:

$$\text{Percent ash} = \frac{(W_3 - W_1)}{W_2} x100$$

Where:

W_1 = Weight of crucible

W_2 = Weight of sample before ashing

W_3 = Weight of sample in a crucible after ashing

3.5.5.5 Carbohydrate

The total carbohydrate content was determined by difference, that is, 100% - other proximate chemical compositions, using the following formula;

% Carbohydrate = 100 - (% moisture + % ash + % crude protein + % fat +% crude fiber).

3.5.6 Cost benefit analysis

Cost benefit analysis conducted to determine relative cost on sorghum smut management using suggested seed dressing fungicide and the selected sorghum varieties as described by Richard *et al*. (2014). The analysis based on the labour charge on sorghum production activities including: land preparation, planting, cost of fungicide, fertilizer application, bird scaring, weeding, harvesting, threshing, winnowing and bagging as well as transport cost. The profit was measured in terms of marketable grain yield which converted into money (Tanzania shillings) basing on the selling price at Dodoma market as reported by Ministry of Agriculture URT (2019).

Cos benefit ratio was calculated using the following formula;

$$\text{Cost benefit Ratio} = \frac{\textit{Net profit}}{\textit{Total cost of production}}$$

as used by Richard *et al*. (2014)

3.6 Statistical Analysis

Data gathered were organized in Microsoft Excel and subjected to the analysis of variance (ANOVA) using Genstat Software 15th Edition. For the homogeneity of variance, percentage disease incidence and severity, yield loss and carbohydrate data were Arcsine transformed, while protein, fat and fibre data were square root transformed, after analysis the means returned to the original form as before transformation. The factorial design was applied to evaluate the main and interaction effects of the treatments.

With statistical mode

$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + e_{ijk}$

Where: Y_{ijk} = outcome score for the i^{th} unit

μ = represents the overall mean effect

α_i = is the effect of the i^{th} level of factor A (i= 1, 2, 3, …….m)

B_j = is the effect of the j^{th} level of factor B (j = 1, 2, 3,……...m)

$(\alpha\beta)_{ij}$ =represents the interaction effect between A and B

e_{ijk} = represents the random error terms

the subscript *k* denotes the replicates (k =1, 2,3,4)

For Lab data one way Randomized Complete Block Design used to evaluate means effects with statistical model.

$$Y_{ij} = \mu + \alpha_i + B_j + €_{ij}$$

Where:

Y_{ij} = outcome score for the i^{th} unit

μ = represents the overall mean effect

α_i = is the effect of the treatment (i= 1, 2, 3, …….m)

B_j = is the block effect

$€_{ij}$ = represents the random error terms

For weather and cost benefit data, a descriptive statistics was used.

Where treatment means were significantly different, they were separated using Duncan Multiple Range Test at $P \leq 0.05$. Simple correlation coefficient (*r*) and coefficient of determinant were carried out using Pearson’s correlation by Microsoft Excel program as described by Gomez and Gomez (1984).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Growth Parameters

4.1.1 Sorghum varietal and fungicide effects on days to crop emergency seedling vigour and plan population at various growth stages

Results on the varietal effect on days to crop emergence, seedling vigour and plant population at various growth stages and that of fungicides applied show that there was no significant difference at p<0.05 for the two factors (varieties and fungicides) on the analyzed variables (Table 3 and 4).

Table 3: Sorghum varietal effect on days to crop emergence, seedling vigour and plant population at different growth stages

Sorghum Variety	Days to crop emergence (6 DAS)	Seedling vigour (score) at 5th leaf growth stage	Plant population at 5th leaf growth stage	Plant population at Dough stage	Plant population at harvest (maturity)
Wahi	6.25a*	1.13a	26.88a	26.38a	26.38a
Hakika	6.31a	1.25a	27.19a	26.75a	26.75a
Macia	6.06a	1.13a	26.62a	26.06a	26.06a
NACO	6.19a	1.06a	27.19a	27.19a	27.19a
Gombela1107	6.44a	1.19a	27.38a	26.88a	26.88a
Langalanga	6.56a	1.06a	26.56a	26.25a	26.25a
GM	6.3	1.14	26.97	26.58	26.58
S.E	0.17	0.12	0.74	0.79	0.79
CV (%)	2.70	10.57	2.74	2.97	2.97
p-Value	0.0	0.60	0.085	0.711	0.711

*All means in the same column followed by the same letters are statistically equal from each other at (p≤0.05) according to Duncan New Multiple Range test. DAS (Days after planting

It is well known that seed germination and crop growth are both affected by environmental conditions such as soil temp and moisture and seed characteristics (House, 1985). During the planting time and hence time of emergence there was a conducive environmental condition for germination and hence emergence as shown in Appendix 4, according to Sisay *et al.* (2012) sorghum germination favored by high temperature and enough moisture. The results on the seedling vigour at the initial stages of sorghum growth also is an evidence that the smut disease effect most of the time observed at the flowering stage of growth (Thakur *et al.,* 2007).

Table 4: Effect of fungicides on days to crop emergence, seedling vigour and plant population at different growth stages

Fungicide type	Days to crop emergence (6 DAS)	Seedling vigour at 5th leaf growth stage (score)	Plant population at 5th leaf growth stage	Plant population at Dough stage	Plant population at harvest (maturity)
Seed Watch	6.13 a*	1.21a	27.29a	26.62a	26.62a
Apron Star	6.38a	1.13a	26.04a	26.04a	26.04a
Snow Angel	6.38a	1.04a	27.42a	26.92a	26.92a
Control	6.33a	1.17a	27.12a	26.75a	26.75a
GM	6.30	1.14	26.97	26.58	26.58
SD	0.14	0.10	0.61	0.64	0.64
CV (%)	2.22	8.81	2.26	2.41	2.41
p-Value	0.220	0.380	0.560	0.711	0.711

*All means in the same column followed by the same letters are statistically equal from each other at ($p \leq 0.05$) according to Duncan New Multiple Range test. DAS (Days after planting

4.1.2 Sorghum varietal effect on the panicle length, days to 50% flowering and plant height

The results on the varietal effect on the panicle length, days to 50% flowering and plant height indicate a significant difference among sorghum varieties (p=0.001) on days to 50% flowering, plant height and panicle length. For days to 50% flowering Macia was the earliest (59 days) and the local variety Langalanga which took 84 days to attain 50% flowering was the latest. Again, sorghum varieties Wahi, Hakika and Macia were the shortest varieties with mean plant height 121.8cm, 126.1cm and 126.2 cm respectively, while the local variety Langalanga (230.3cm) was the tallest in the experiment. Two varieties of NACO Mtama 1 and Gombela were observed to be with a mean plant height of (160.4cm) and (170.5cm) respectively (Table 5).Having tall and vigour stalk may be one of the reasons why Langalanga is mostly preferred by most farmers since the stalk are used as firewood, fencing and building material as well as fodder for their animals (Obilana *et al.*, 1995; Richard *et al.*, 2017).

For the panicle length Wahi and Hakika were observed to be with the highest panicle lengths of 26.33 and 25.36cm respectively. The smallest panicle length (20.26) was observed on Gombela followed by NACO Mtama1 (22.53cm), Langalanga and Macia (23.45cm) (Table 5).

The variation on these parameters was due to the differences on genetic make-up among the varieties which may be inherited from the parents used on varieties development, this finding is in line with the study by (Mwamahonje and Maseta, 2018) who also noted. Again Fetene, 2018, reported that observed differences among the tested sorghum varieties could be attributed by the genetic variability of the tested sorghum genotypes, in which the gene they possessed characterizes their performance.

4.1.3 Effect of fungicides application and interaction of sorghum varieties and fungicides applied on panicle length, days to 50% flowering and plant height

There was no significant difference among fungicides applied and also the interaction between sorghum varieties and fungicides applied ($p<0.05$) on the days to 50% flowering, plant height and panicle length (Table 6 and 7).The low effect of smut diseases on the growth parameters may be due to the low incidence and severity of smut disease recorded in fungicide treated plots. According to Sajjan *et al*. (2011), the effect of smut disease on the growth parameters depends on the level of the incidence and severity of disease. In this study, two types of smut disease; covered smut and long smut disease were commonly observed. Long smut as airborne disease, most infection occurs at boot stage and the effects are only on the panicle (Prom *et al*., 2014).

In this study head smut disease which is the most destructive and with tendency of causing effects to the growth parameters such as plant height panicle length and days to flowering were not observed. Similar findings have been reported by different researchers (Craig *et al*., 1992; Thakur *et al*., 2007; Richard *et al*., 2014). In the study conducted by Prom *et al.* (2014), when assessing the resistance of sorghum lines and hybrids to sorghum grain mold and long smut in Senegal found less effect of smut disease to the growth parameters.

4.2 Smut Disease Assessment

4.2.1 Sorghum varietal effect on smut incidence and severity

Table 5: Sorghum Varietal effect on percentage disease incidence and severity, Panicle length (PL), days to 50% flowering and Plant Height

Variety	% smut Disease incidence (%)	% Disease Severity (%)	Panicle Length (cm)	Days to 50% Flowering (days)	Plant Height (cm)
Wahi	14.28b*	16.47b	26.33c	62.62b	121.80a
Hakika	14.51b	17.03bc	25.36c	63.50b	126.20a
Macia	14.87b	17.44bc	23.45b	59.50a	126.10a
NACO	4.57a	11.41a	22.53b	69.75c	160.40b
Gombela	19.20c	17.68bc	20.26a	72.12d	170.50b
Langalanga	22.18c	19.07c	23.45b	84.81e	230.30c
GM	14.94	16.52	23.56	68.72	155.89
CV (%)	10.51	5.42	3.31	0.97	4.62
SE	1.57	0.896	0.78	0.67	7.17
p-Value	0.001	0.001	<0.001	<.001	<.001

*All means in the same column followed by the same letters are not significantly different at p≤0.05 according to Duncan New Multiple Range Test.

Table 6: Fungicidal effect on percentage disease incidence and severity, Panicle length, days to 50% flowering and Plant Height

Fungicides applied	% smut Disease incidence (%)	% Disease Severity (%)	Panicle Length (cm)	Days to 50% Flowering (DAS)	Plant Height (cm)
Seed Watch	8.91b*	14.21b	23.33a	68.83a	157.20 a
Apron Star	3.71a	11.15a	24.08a	68.88a	157.30 a
Snow Angel	10.19b	14.03b	22.99a	68.88a	154.90 a
Control	36.93c	26.68c	23.85a	68.29a	154.20 a
GM	14.94	16.52	23.56	68.72	155.89
CV (%)	8.63	4.42	2.67	0.80	3.78
S.E	1.29	0.73	0.63	0.55	5.86
P Value	0.001	0.001	0.307	0.655	0.931

*All means in the same column followed by the same letters are not significantly different at p≤0.05 according to Duncan New Multiple Range Test

A very highly significant differences was observed in disease incidence and severity of smut diseases among sorghum varieties (p=0.001). From these results, Langalanga and Gombela had both the highest mean smut disease incidence 22.18% and 19.20% and severity 19.07 and 17.8% respectively. The lowest smut incidence and severity, 4.57 and 11.42% respectively were observed on NACO Mtama 1 (Table 5). In this study, different types of smut diseases were observed with varied incidences. Covered kernel smut had the highest incidence (75%) followed by long smut (25%), no head smut or loose kernel smut was observed. According to the smut resistance classification scale described by Kutama (2011), the level of resistance of all sorghum varieties tested in this study to smut disease were found to range between very resistant and very susceptible. By considering responses of sorghum varieties when not applied with fungicides NACO Mtama 1 was observed to be very resistant with incidence and severity of 6.35% and 12.22% while varieties such as Wahi, Hakika and Gombela were susceptible with smut disease incidence and severity ranging 33.97 to 49.04% and 23% to 30%, Langalanga variety was very susceptible with disease incidence and severity of 50% and 37% respectively (Table 7).

The variations obtained on disease incidence and severity within different sorghum varieties tested may be due to the differences in the individual inherent reaction to smut pathogen (Gwary *et al.*, 2007).These results agree with earlier reports by Kutama *et al.* (2011) and Prom *et al.* (2014) that resistance to smut disease the trait is controlled by single gene and being resistant or susceptible variety depends on the parent used to develop the variety. Again a study conducted by Merkuz *et al.* (2012), out of 12 sorghum varieties evaluated with covered kernel smut, 'Tetron' cultivar was found to be highly resistant where incidence and severity on the rest of the cultivars varied from 21 to 47% and 40 to 53% respectively. More experiments using artificial inoculation of specific smut pathogen and molecular characterization on the genetic makeup for the resistance of NACO Mtama1 smut diseases. This will make the variety to be used as potential in sorghum production and used in the future breeding programs as source of smut resistance. Other improved sorghum varieties which are commonly grown in central zone (Wahi, Hakikam Macia and Gombela) were observed to be highly susceptible to smut disease but had shown high grain yield when treated with fungicides (Table 9). Local variety Langalanga was the most susceptible among the varieties tested. This was also report by Njoroge *et al.* (2017) and Taferi *et al.* (2015) that NACO Mtama1 is less infected by sorghum diseases in Tanzania while local varieties like Langalanga is highly affected by different fungal and non fungal diseases such as smut disease.

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Plate 3: Plot of sorghum infected by Covered kernel smut disease at TARI Hombolo 2018/2019 cropping season

4.2.2 Effect of fungicides on smut disease incidences and severity

Again, a very highly significant difference (p=0.001) among the seed dressing fungicides on the smut disease incidence and severity. The highest smut disease incidence (36.93%) and severity (26.68%) respectively, were observed in plots where no fungicide was applied and the lowest smut disease incidence (3.72%) and severity (11.15%) respectively, were recorded on Apron Star (Table 6).

From the results obtained in this study, all the three fungicides tested were observed to be effective in management of smut diseases of sorghum under natural infection. The seed dressing fungicides applied in this study resulted into significant reduction of smut diseases incidence and severity when compared to the untreated sorghum plants. The results obtained agree with the previous studies such as by Mtis *et al*. (1996), Gwary *et al*. (2007), Sajjan *et al*. (2011) and Richard *et al*. (2014) that fungicides with Metalaxyl component can be used for effective management of smut pathogen.

For maximum management of sorghum smut disease, a combination of more than one method is required such as seed dressing fungicide, use of resistant variety and supplement of fungicide spray before the booting stage especially for seed production plots as suggested by Sisay *et al*. (2012). This will overcome the challenge of air borne pathogens (*Sporisorium ehrenbergii)* for long smut which its infection occurs during the booting stage through the flag leaf before panicle emerged (Prom *et al*., 2012). Study conducted by Richard *et al*. (2014) indicated that metalaxyl when used as seed dressing is effective on controlling loose and covered smut disease of sorghum. Furthermore, long smut disease as an air-borne disease may not significantly be lowered by seed treatment that result resulted into high long smut disease incidence at 95 days after sawing.

4.2.3 Effect of Interaction between fungicides and the sorghum varieties on smut disease incidence and severity

A very highly significant difference ($p<0.001$) was observed on the interaction between the fungicides used sorghum varieties. The best combination observed was Apron Star when applied on NACO Mtama1which resulted with smut disease incidence and severity of 2.79% and 11.02% respectively. The combination were when Langalanga and Gombela grown without application of fungicide, this was resulted with the highest smut disease incidences of 56.56 and 40.02% and smut disease severity of 19.7 and 17.68% respectively (Table 7).

Table 7: Interaction of Sorghum Varieties and applied Seed dressing fungicides on percentage Disease incidences and disease Severity, panicle length Days to 50% flowering and plant height

Treatments	Smut disease Incidence (%)	Smut Disease Severity (%)	Panicle length (cm)	Days to 50% Flowering (DAS)	Plant Height (cm)
SW*W	8.05abcd	15.64cde	26.50a	63.00a	121.10a
AP*W	3.75ab	9.93a	25.70a	63.00a	122.40a
SN*W	11.37cde	17.23e	25.95a	62.50a	120.70a
C*W	33.97f	23.06f	27.15a	62.00a	123.30a
SW*H	9.24abcde	16.29de	24.25a	64.50a	123.60a
AP*H	3.71ab	11.23ab	25.20a	63.00a	129.70a
SN*H	8.93abcde	13.99abcde	25.55a	63.00a	128.90a
C*H	36.16f	26.59fg	26.45a	63.50a	122.40a
SW*M	8.48abcd	14.32bcde	22.65a	60.00a	122.70a
AP*M	4.04abc	12.01abc	24.95a	60.00a	138.90a
SN*M	7.47abcd	13.63abcde	22.75a	59.50a	127.50a
C*M	39.51f	29.82gh	23.45a	58.50a	115.40a
SW*NC	4.46abc	10.91ab	22.45a	70.50a	169.10a
AP*NC	2.79a	11.02ab	23.25a	68.50a	162.00a
SN*NC	4.66abc	11.51abc	23.15a	70.50a	162.90a
C*NC	6.35abcd	12.22abcd	21.25a	69.50a	147.90a
SW*G	11.16bcde	14.38bcde	21.45a	71.50a	175.10a
AP*G	3.98abc	11.44abc	20.20a	73.50a	170.10a
SN*G	12.63de	13.93abcde	18.75a	72.50a	160.00a
C*G	49.04g	30.95h	20.65a	71.00a	177.10a
SW*L	12.08de	13.70abcde	22.65a	83.50a	231.80a
AP*L	4.02abc	11.24ab	25.20a	85.25a	220.80a
SN*L	16.07e	13.89abcde	21.80a	85.25a	229.30a
C*L	56.56h	37.43i	24.15a	85.25a	239.40a
GM	14.94	16.52	23.56	68.72	155.89
CV (%)	21.08	10.84	6.54	1.95	9.25
S.E	3.15	1.79	1.54	1.34	14.34
p Value	0.001	0.001	0.57	0.663	0.86

All means in the same column followed by the same letters are not significantly different at p≤0.05 according to Duncan New Multiple Range Test. *AP=Apron Star, SN, Snow Angel, SW= Seed Watch. W=Wahi, H=Hakika, M= Macia, NC=NACO Mtama1, G=Gombela and L= Langalanga. DAS=Days after Planting.

Therefore, for this study, the combination of NACO Mtama1 with Metalayl (20%) is the best on management of sorghum disease. The effectiveness of Metalaxyl on sorghum smut disease management it is due it’s mechanism of Penetrates the seed coat and is systemically trans-located to both shoots and roots during germination interfering the transcription of the pathogen which may results into protection to the seedling for about four weeks. The effectiveness of Apron Star has also been reported in other studies (Mtisi, 1996, Gwary *et al.*, 2007 and Richard *et al*., 2014).

4.3 Grain Yield and Yield Parameters

4.3.1 Effects of sorghum varieties on the grain yield and yield components

Again a very highly significant differences (p=0.001) observed among sorghum varieties on 1000 grain weight, dry panicle weight, seed weight per plant and grain yield (t/ha). The highest 1000 grain weight (3.48g), dry panicle weight (141.9g), seed weight per plant (36.12g) and grain yield (3.21 tha^{-1}) was observed on NACO Mtama while the lowest of 100 seed weight (3.03g), dry panicle weight (81.6g), grain weight per plant (26.8g) and grain yield (2.38 tha^{-1}) was observed on Langalanga landrace (Table 8).

Table 8: Sorghum varietal effect on the 1000 grain weight, Dry panicle weight, grain weight per plant, grain yield (t/ha) and grain yield loss

Treatments	1000 grain Weight (g)	Dry Panicle Weight (g)	Grain weight per Plant (g)	Grain Yield(t/ha)	% Grain yield losses
Wahi	32.12b*	90.75b	33.08b	2.95b	16.17ab
Hakika	32.56b	106.40b	31.46b	3.01bc	19.73abc
Macia	31.19ab	110.20b	33.86b	2.80b	20.86bc
NACO	34.69c	141.90c	36.12c	3.22c	11.82a
Gombela	31.19ab	128.30a	31.29b	2.78b	24.71c
Langalanga	29.38a	81.60a	26.80a	2.38a	25.17c
GM	31.85	113.20	32.10	2.86	19.70
CV(%)	2.89	4.80	4.20	4.20	19.24
S.E	0.92	5.43	1.36	0.12	3.79
p-Value	0.001	0.001	0.001	0.001	0.005

*All means in the same column followed by the same letters are not significantly different at p≤0.05 according to Duncan New Multiple Range Test

Variation in grain yield and yield components among the tested sorghum varieties, suggest variation on genetic composition of the varieties. The results approve that NACO Mtama 1 is rich in high yield traits gene. This has been reported in other studies such as by Mwamahonje and Mseta (2018). In the study conducted at Makutupora Agricultural Research Centre, NACO Mtama 1 reported to have highest yield compared to the other varieties tested. The late maturity local variety Langalanga observed with the lowest grain yield among all varieties. The low yield of Langalanga may be due to being poor in high yield trait gene, but also may be due to unfavorable condition during the flowering and grain formation. According to Awori *et al*. (2015), in sorghum, plants with very high plant height, the plants spend more energy in growth than grain filling, which may result in to low grain harvested. This the days to 50% flowering, the early maturity varieties said to be more capable of adapting extreme conditions like drought and water stress, and hence maintain high grain yield (Hussain *et al*., 2011). This also was reported by Fetene (2018), that local late maturing varieties experiences low yield compared to improved medium and early matured ones when grown under rain fed, with below recommended rainfall.

4.3.2 Effects of fungicides on the yield and yield components

In the protected plots with low disease pressure the grain yields were much higher as compared to the control plots. Again higher overall mean yield was for the protected plots as compared to the control plots by average of 26.32% grain yield difference. Therefore, application of fungicides raised the yield by average of 26.32% of the sorghum grain compared to the control plots where by the maximum grain yield increase 31.49% was observed when Apron Star used (Table 9).

The effects of smut disease can be associated with the effect of disease to the 100 seed weight, panicle weight and seed weight per plant as contributor to the final grain yield, the lowest weight on 1000 grain weight, panicle weight and seed weight per plant were observed in control plots with high disease incidences and severity (Table 9). This was also observed by Lilian *et al*. (2016) in pearl millet and Fetene (2017) when considering the effects of sorghum covered Kernel smut on yield components. Gwary *et al.* (2007) and Richard *et al.* (2014) also reported on the effect of smut disease on the grain yield and yield components in parts of Nigeria.

Table 9: Fungicidal effect on the 1000 grain weight, Dry panicle weight, grain weight per panicle and grain yield (t/ha)

Fungicides applied	1000 grain Weight (g)	Dry Panicle Weight (g)	Grain weight per Plant (g)	Grain Yield(t/ha)	Grain Yield loss reduction (%)
Seed Watch	31.96b*	116.70b	32.58b	2.94b	22.82a
Apron Star	34.92c	129.00c	37.04c	3.29c	31.49b
Snow Angel	32.46b	118.80b	33.55b	2.98b	24.66ab
Control	28.08a	88.30a	25.11a	2.24a	0.00a
GM	31.85	113.20	32.10	2.86	19.70
CV(%)	2.35	3.91	3.46	3.50	15.69
SD	0.75	4.43	1.11	0.10	3.09
p-Value	0.001	0.001	0.001	0.001	0.001

*All means in the same column followed by the same letters are not significantly different at p≤0.05 according to Duncan New Multiple Range Test.

4.3.3 Interaction effect of sorghum varieties and fungicides applied on the grain yield parameters

Results on the effect of interaction of sorghum varieties and fungicides applied on the grain parameters indicates that, there is a significant difference on the effect of interaction of the two factors on the dry panicle weight and the grain weight per plant as well as on the grain yield (t/ha) at p≤0.05. The highest dry panicle weight (160.70g), grain weight per plant (40.90g) and grain yield (3.64t/ha) observed when apron star applied on the NACO Mtama 1 while the lowest values of dry panicle weight and grain weight per plant of (76.00g) and (19.09g) respectively were observed on local variety Langalanga with no application of fungicide (Table 10).

Table 10: Interaction of Sorghum Varieties and applied Seed dressing fungicides on Dry panicle Weight (g), grain weight per plant (g), Grain yield (t/ha) and Grain yield loss reduction (%)

Treatments	Dry Panicle weight (g)	Grain weight per Plant (g)	Grain Yield (t/ha)	Grain yield loss reduction (%)
W*SW	114.00bcde	37.38ghij	3.32ghij	26.48a
W*AP	124.40cdefg	35.75ghij	3.18ghij	22.98a
W*SN	106.00bc	32.30defgh	2.87defgh	15.25a
W*C	98.50ab	26.90bcde	2.44bcde	0.00a
H*SW	110.10bc	37.54ghij	3.34ghij	27.73a
H*AP	116.10bcde	38.42hij	3.42hij	31.18a
H*SN	119.10bcdef	33.08efgh	2.94efgh	20.01a
H * C	80.40a	26.41bcd	2.35bcd	0.00a
M*SW	111.90bcd	26.13bcd	2.32bcd	13.06a
M*AP	135.80efgh	40.56ij	3.61ij	40.01a
M*SN	116.50cde	35.04fghij	3.12fghij	30.38a
M * C	76.50a	24.11abc	2.14abc	0.00a
NC*SW	148.60ghi	34.61fghij	3.08fghij	9.79a
NC*AP	160.70i	40.92j	3.64j	22.70a
NC*SN	142.20fghi	37.51ghij	3.33ghij	14.80a
NC*C	115.90bcde	31.43defg	2.79defg	0.00a
G*SW	137.70efghi	32.86efgh	2.92efgh	30.71a
G*AP	142.10fghi	35.39fghij	3.15fghij	4.98a
G*SN	151.00hi	34.19fghi	3.04fghi	33.19a
G * C	82.20a	22.73ab	2.02ab	0.00a
L * SW	77.80a	27.60bcde	2.45bcde	29.17a
L * AP	94.90ab	31.23defg	2.78defg	37.19a
L * SN	77.80a	29.20cdef	2.60cdef	34.34a
L * C	76.00a	19.09a	1.70a	0.00a
Grand mean	113.2	32.10	2.85	19.70
CV (%)	9.58	8.50	8.39	38.43
S.E	10.85	2.73	0.24	7.57
p Value	0.010	0.024	0.068	0.018

All means in the same column followed by the same letters are not significantly different at p≤0.05 according to Duncan New Multiple Range Test.
*AP=Apron Star, *SN, Snow Angel, *SW= Seed Watch. W=Wahi, H=Hakika, M=Macia, NC=NACO Mtama1, G=Gombela1107 and L=Langalanga.

For the effect of interaction of the sorghum varieties and the fungicides applied on the 100 grain weight (g), no significant difference was observed at p≤0.05, but the highest value for 100 grain weight was observed when Apron star applied to the NACO Mtama 1 variety. Macia which is one of the high grain yielding varieties, here shows high performance on grain yield (3.61t/ha) when Apron star is applied to control fungi diseases. The high gran yield of Macia when dressed with Apron star prove that grain yield is the results combination of different factors such as weather condition, pest and diseases soil fertility and type of variety grown. This also prove the results in part 4.6.1

and 4.6.2 Apron star have shown to be more effective for smut management which may results into highest grain yield.

4.3.4 Grain yield loss estimation (%)

A highly significant difference (p=0.003) observed among sorghum varieties on percent grain yield loss due to sorghum smut disease. The lowest grain yield loss (11.82%) was observed on NACO Mtama 1 and the highest 25.17% and 32.95 were recorded on Langalanga and Gombela sorghum varieties (Table 8).

Generally, in this study improved variety of sorghum (NACO Mtama1) had the lowest yield loss and this can be related to the lowest smut disease incidence and severity. In contrary, local late maturity variety (Langalanga) together with Gombela observed to be the most susceptible sorghum varieties with the highest smut disease incidence and severity as well as the highest yield loss. The results show that some of the grain yield loss contributed by presence of smut disease.

For the grain yield loss reduction the application of fungicides reduced the grain yield loss for the average of 26.29%, where the highest grain yield reduction was when Apron star applied to the Macia variety (40%) and Langalanga landrace (37%) (Table10). The high yield loss reduction indicate the effect of growing sorghum without fungicide application as well as the ability of Apron star as seed dressing fungicide to control fungal diseases (sorghum smut) where the percentage is the difference that lost if the variety grown without fungicide application. The sorghum grain yield losses reported in this study was closer to the findings reported in other parts of Africa such as in Ethiopia a yield loss ranging between 6.1% to 80.9% on local varieties (Merkuz *et al.,* 2012; Fetene, 2018) and in Nigeria 20 to 60% (Gwary *et al*.,2007).

4.4 Regression and Correlations between Smut Disease Parameters, Grain Yield and Grain Yield Losses in Sorghum

The results of this study showed a strong correlation between grain yield parameters and smut disease recorded at Hombolo. Sorghum smut disease incidence was significant ($p<0.05$) positively correlated to the disease severity with coefficient of determination and correlation coefficient $R^2 = 0.92$ and $r = 0.96$ respectively. Also, the sorghum smut disease severity and incidence were significantly correlated to the percentage grain yield loss with the coefficient of determination ($R^2 = 0.71$ and 0.92) and correlation coefficient ($r = 0.84$. and 0.96) respectively. These results indicate that the percentage of grain yield loss per hector may be due to smut disease incidence and severity. On the other hand, sorghum smut disease severity and incidence were significantly negatively correlated to the grain yield, seed weight per plant and 100 seed weight which are important yield components (Figure 5: (a), (b), (c), (d) and (e)). The smut disease severity directly related to grain yield losses basing on linear regression equations related to ($Y = 2.5673X - 16.3$). The findings implied that an increase in smut disease severity corresponded to the decrease of the yield component. The grain yield losses due to disease have also been reported by Lilian *et al*. (2016) in pearl millet and Chuwa (2016) in rice.

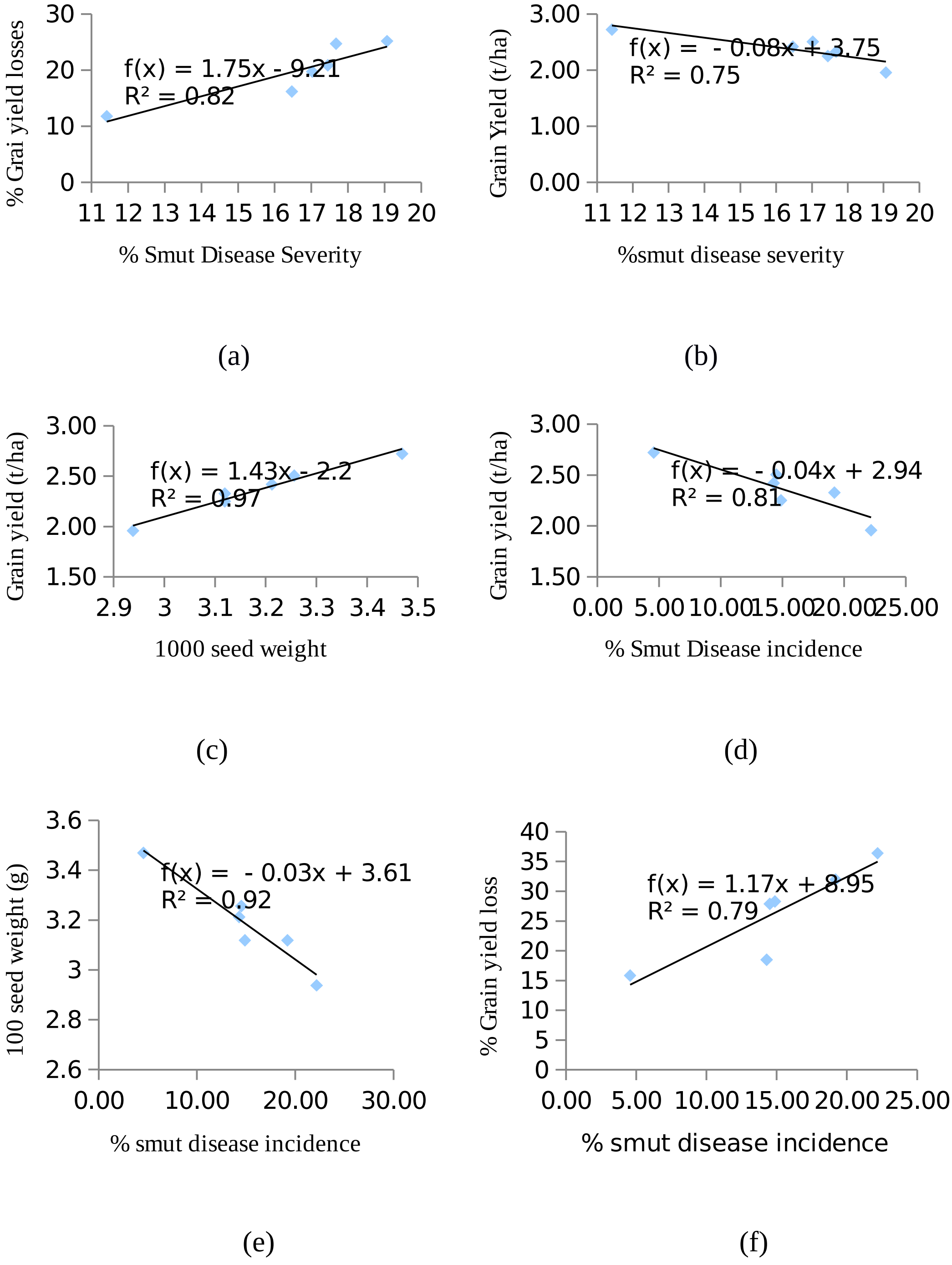

Figure 3: **Relationship between (a) Smut disease severity and grain yield loss on the tested sorghum varieties (b) Smut disease severity and grain yield (t/ha) (c) 1000 grain weight and grain yield (t/ha), (d) Smut disease incidence and grain yield (t/ha) (e) Smut disease incidences and grain Yield (t/ha) (f) Smut disease incidences and % grain yield losses**

4.5 Performance of Improved Sorghum Varieties over Local Landrace

From this study, the results showed clear difference on performance between improved and local landrace, this was in terms of grain yield as well as resistance to smut disease. All improved sorghum varieties performed well under application of fungicide for fungal disease control compared to local landraces (Langalanga and Gombela) which were found to be the most susceptible and lowest grain yield even when treated with fungicides. The performance of improved sorghum varieties over local landraces also revealed by different studies such as Mwamahonje and Maseta (2018), in Central Tanzania assessed four sorghum genotypes and among them improved (3 genotypes) observed to perform well over a landrace (Udo) in terms of grain yield. Again Fetene (2018) when assessing the reaction of sorghum genotypes to *Sphacelotheca sorghi* and efficacies of some botanicals against covered kernel smut, the results showed improved varieties to perform better than local landraces although one local landrace found to be resistant to the pathogen.

4.6 Sorghum Nutritional Value Analyses

A very highly significant difference ($p<0.001$) was observed among sorghum varieties on the percentage fat, fibre and crude protein. Also, results had showed a significant difference ($p=0.005$) among varieties on total carbohydrate contents. Fibre content was ranged from 1.119 – 2.028% g/100g edible portion and it was higher in NACO Mtama1 and lowest in Langalanga sorghum varieties, whereas, total carbohydrate was ranged from 74.89 to 78.15g/100g edible portions, where highest value was recorded in Macia Wahi and Gombela, the lowest value was in NACO Mtama 1. The crude protein was ranged from 7.14 – 10.155 g/100g edible portions and it was highest in NACO Mtama 1 and lowest in Wahi, whereas, fat content ranged from 3.34 – 5.34 g/100g edible portions with highest content in Langalanga and lowest in Macia (Table 11).

Table 11: Comparison of percentage crude fat, fibre, protein and carbohydrate components among the tested sorghum varieties

Sorghum Varieties	%Fat	%Fibre	% Crude Protein	Total Carbohydrate (g/100g)
Wahi	3.34a*	1.62b	7.15a	78.15b
Hakika	3.91b	2.46d	7.86ab	76.53b
Macia	3.70b	2.18c	8.25bc	78.03b
Naco	3.99b	2.03c	10.16d	74.89a
Gombela	4.52c	1.27a	7.48ab	78.15b
Langalanga	5.35d	1.12a	8.91c	75.23a
GM	4.19	1.79	8.30	76.85
Cv (%)	5.01	6.15	4.58	1.21
S.E	0.21	0.11	0.38	0.93
PValue	0.001	0.001	0.001	0.005

*All means in the same column followed by the same letters are not significantly different at p≤0.05 according to Duncan New Multiple Range Test. Values reported were average of duplicate analysis RV=Recommended values as indicated by Abdulrahman and Omoniyi (2016).

Protein as an important component for body building especially for growing children was highest on NACO Mtama1 among the tested sorghum varieties. Other varieties were within the recommended range as used by Abdurrahman *et al*. (2016). The variety NACO Mtama 1 has also reported being with highest content of protein by Mwenda *et al*. (2018) in determination of physical chemical properties and selection of elite sorghum genotypes in Tanzania. The results are also close to what reported by Jimoh and Abdullahi (2017) in which they reported the crude protein of sorghum to range from .56 to 8.02 and Abdulrahman *et al*. (201) who reported percentage of crude protein in sorghum to be 10.13 in Nigeria. Kaijage *et al*. (2014) also reported percent crude protein for three white sorghum varieties in Tanzania to be 10.4 and 12.7 which is slightly higher than what obtained from present study. According to Bryden *et al*. (2009), variation in nutritional components among sorghum varieties is the function of type of variety, soil type, growing condition and time of Harvest.

In Table 11, percentage crude fat also was in the recommended range (1 – 7%) where the highest (5%) observed on the local variety Langalanga. The low fat content of the grain sorghum suggest the long life storage without peroxidation of polyunsaturated fatty acid if not properly stored (Abdulrahman *et al*., 2016). The results obtained are similar to that reported by Afify *et al.* (2012) in Egypt that reported fat in raw white sorghum to range between 3.58 and 3.91, also Kaijage *et al*. (2014) and Mutayoba *et al*. (2011) in Tanzania who reported percentage crude fat to range between 2.66 and 4.05 and 3.1 and 3.16 and 3.72 respectively.

Dietary fibre which is one of the most important components in whole grain foods, vegetables and fruits is very important for human health. It helps on normalizing bowls movement, regulates blood sugarand lowers cholesterol levels as well as in promoting normal laxation for children (Mayo, 2019; Williams, 1995). In the results the highest fibre content was observed in NACO mtama1 and the lowest was in langalanga. According to Abdulrahman *et al.* (2016), the range obtained is falling to the recommended rate for infants and also in the recommended range for sorghum grain. The results obtained are similar to that reported by (Mustafa *et al.*, 2003; Afify *et al*., 2012; Kaijage *et al.*, 2014; Abdulrahman *et al.*, 2016).

Carbohydrate content of the sorghum grain was determined by subtraction of the moisture, ash, protein, dietary fibre and fat content. So the carbohydrate was considered to be the amount of material left after the subtraction. The results therefore observed to be highest on Macia variety and lowest on the NACO mtama1. The percentage of carbohydrates for the sorghum varieties grown at Hombolo tested in this experiment observed to be in the recommended values and close to what reported by Jimoh and

Abdullahi (2017) who reported range of 65 and 76, Mwenda *et al.* (2018) in Tanzania reported carbohydrate to be 79g/100g.

4.7 Cost Benefit Analysis on Sorghum Smut Management for Sorghum Production at Hombolo

The main sorghum production activities and their costs used in this study based on the lobour charge in Central Zone specific at Hombolo area. The selling price of sorghum based on the information on cost of sorghum at Dodoma market as obtained from the Ministry of Agriculture, released through National Food Security Bulletin Tanzania in August 2019 (Appendix 5 and 6).

Table 12: Cost benefit analysis of sorghum production for each of the three fungicides and Untreated seeds at TARI-Hombolo on 2018/2019 the cropping season

Income	**SEED WATCH**	**APRON STAR**	**SNOW ANGEL**	**UNTREATED**
Yield of marketable grain kg/ha	2400	2680	2490	1880
Yield increase over undressed (%)	21.67	29.86	24.50	-
Production cost (TZS/ha)	566 000	575 000	56 000	555 000
Selling price (TZS/kg)	470	470	470	470.00
Total income	1 128 000	1 259 600	1 170 300	883 600
Profit	553 000	693 600	607 300	328 600
Cost benefit ratio	1	1.2	1.1	0.6

The results show an increase of the grain yield on the treated plots over untreated plots that resulted to net profit ranging from 553 000 and 693 600 TZS compared to that of untreated plot of 328 600TZS. The highest net profit (693 600TZS) which is equivalent to 315USD obtained when Apron star was applied. The cost-benefit ratios among the treated and control plots ranged from 0.6 to 1.2 where the highest (1.2) obtained on application of Apron Star (Table 12).

Table 13: Cost benefit analysis comparing production of each of the Six sorghum varieties when treated and not treated by Seed dressing Fungicide (ha^{-1}) in 2018/2019

Income	WAHI		HAKIKA		MACIA		NACO MTAMA1		GOMBELA		LANGALANGA	
	Treated	Control	Treated	Control	Treated	Control	Treated	Control	Treated	Control	Treated	Control
Yield of marketable grain kg/ha	2650	2071	2888	1992	2785	1736	3077	2385	2490	1717	2198	1356
Production cost (TZS)	565 000	545 000	565 000	545 000	565 000	545 000	565 000	545 000	565 000	545 000	565 000	545 000
Selling price (kg)	470	470	470	470	470	470	470	470	470	470	470	470
Total income (TZS)	1 245 500	973 370	135 7360	936 240	1 308 950	815 920	1 446 190	1 120 950	1 170 300	806 990	1 033 060	637 320
Profit (TZS)	670 500	418 370	782 360	381 240	733 950	260 920	871 190	565 950	595 300	251 990	458 060	82 320
Cost-benefit ratio	1.2	0.8	1.4	0.7	1.3	0.5	1.5	1.1	1.1	0.5	0.8	0.2

The cost benefit ratio based on the TAS 470/= the cost of sorghum at Dodoma Market in 2019, as indicated by Ministry of Agriculture (National Food Security Bulletin Tanzania August, 2019)

The highest net profit (871100 TZS) which is equivalent to 396USD obtained when apron star applied on NACO Mtama1 while the smallest profit (82 320TZS) which is equivalent to 37USD was observed when local variety Langalanga grown without fungicide application. The highest cost-benefit ratios (1.5) and lowest (0.2) were obtained on the combination of NACO Mtama1 variety with the application of Apron star fungicide and on the control of Langalanga variety respectively (Table 13).

From the cost-benefit ratio result, it clearly shown that higher profit can be obtained when sorghum seeds are treated with fungicides compared to the untreated seeds. But among the seed dressing chemicals used in this experiment, Apron Star observed to be the best option due to the lowest disease incidence and disease severity as well as highest profit gain in sorghum production with smut management consideration.

The performance of treated seeds with Apron star over untreated seeds in sorghum production on smut management has reported by different researchers such as Gwary *et al*. (2007) in Nigeria, Mtis (1996) in Zimbabwe and Fetene (2018) in Ethiopia. Also NACO mtama1 observed to perform well compared to most of sorghum varieties grown in central part of Tanzania (Mwamahonje and Mseta, 2018).

CHAPTER FIVE

5.0 CONCLUSION AND RECOMANDATIONS

5.1 Conclusion

Generally, this study indicated that, most of the sorghum varieties grown in central part of Tanzania are susceptible to smut disease with exception of NACO Mtama 1 which was observed with lowest level of smut disease severity and incidence. When sorghum seeds are sown without fungicide application it leads to higher smut disease incidence and disease severity which may results into reduction of quantity and quality of the grain harvested and hence low profit in sorghum production. All seed dressing fungicides used in this study showed effectiveness on sorghum smut disease management where by smut disease incidence and severity were reduced by 32% and 15% respectively and grain yield increased by about 29% percent compared to the untreated seeds. But for maximum management of sorghum smut disease, a combination of seed dressing fungicide, use of resistant variety and supplement of fungicide spray before the booting stage especially for seed production plots. This will overcome the challenge of air borne pathogens (*Sporisorium ehrenbergii)* for long smut which its infection occurs during the booting stage.

The study again revealed grain yield loss due to smut disease to ranging from 11.17 to 25.17 percent, among the sorghum varieties tested at TARI Hombolo Centre. From this study the combination of NACO Mtama1 and seed dressing with Apron star (Metalaxy + thiamethoxa + difenoconazole) was found to be more effective with low sorghum smut disease incidence and severity and hence high grain yield and profit at Hombolo, Dodoma, Tanzania. Also, the study indicated that sorghum grown in central part of

Tanzania can be used as source of protein, fibre, fat and carbohydrate in different uses such as stiff porridge, porridge for children and other foods such as cakes breads as well as raw materials for feed and beer industries since the contents are in the recommended range, although further characterization on the nutrient elements such as Zinc, Iron and others is important.

5.2 Recommendations

i. Further experiments should be done using specific isolates of smut disease to confirm it’s resistance to smut disease as well as molecular characterization the variety is required so as to identify the genetic makeup that made it to be resistant.

ii. Further studies should be conducted on pathological genetic characterization of NACO Mtama1 so as to be used as potential in sorghum production as well as source of resistance to sorghum smut in future breeding programs.

iii. For this study Apron star, Seed Watch and Snow Angel 30%DS (all contained metalaxyl with different ratios) observed to perform well in smut management and can be labeled for smut management in Central part of Tanzania as well as in other semi-arid areas.

iv. Further studies should be conducted to verify the results obtained in this study especially on the percentage of grain yield loss due to smut disease and the real effects of smut diseases on the macronutrients on sorghum grain yield.

v. All six varieties tested can be used as source of protein, carbohydrates, fats and fibres since they ranged on the recommended values.

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APPENDICES

Appendix 1: Some physical and chemical properties of the soil in the study area (TARI-Hombolo)

Soil properties	**Value**	**Rating**
Particle size distribution		
(%) Sand	66	
(%) Clay	30	
(%) Silt	4	
Textural class	Sandy clay	
Chemical properties	**Value**	**Rating**
Soil pH	6.04	Medium
C (%)	0.459	Very low
Total N (%)	0.09	Very low
C:N	5.04	Very low
Ext P (mg/kg)	15.1	Medium
CEC (cmol/kg)	9.00	Low
Ca^{++} (Cmol/kg)	2.46	Low
Mg^{++} (cmol/kg)	0.85	Medium
Na+ (cmol/kg)	0.14	Low
K^{+} (cmol/kg)	0.83	High
Base saturation (%)	47.6	Low

*****the rating of the soil parameters was according to landon (1991).

***** c= organic carbon, n= nitrogen, p= phosphorus, cec= cation exchange capacity, ca^{++}= calcium, mg^{++}= magnesium, na^{+}= sodium and k^{+}= potassium.

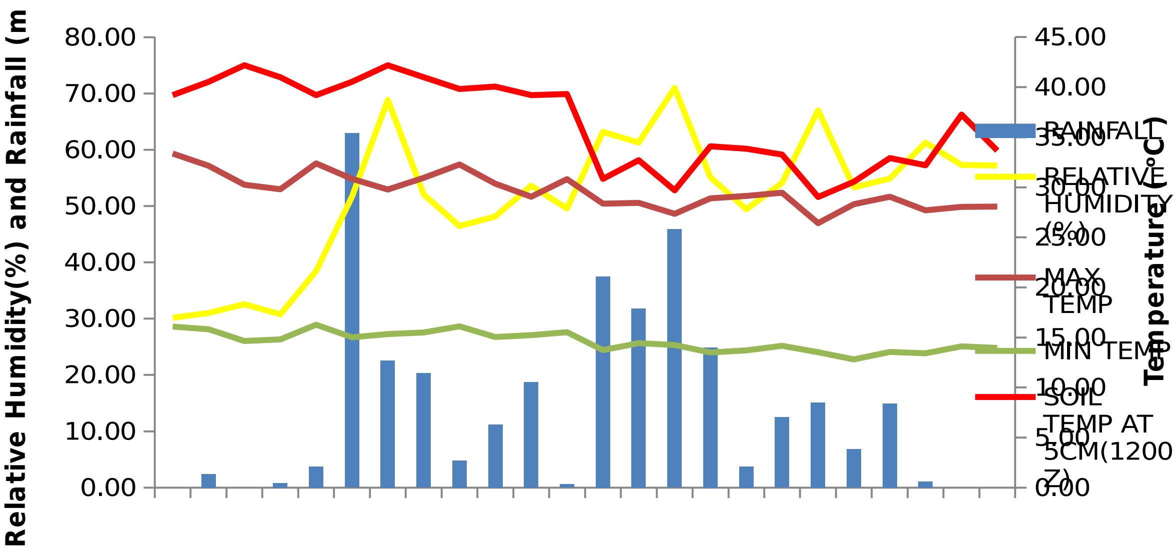
Appendix 2: General descriptions of sorghum genotypes that were used in the field experiment at Hombolo during 2018/2019 cropping season

Species: Sorghum (*Sorghum bicolor* (L.,) Moench						
Variety	**Year of release**	**Owner(s)/Maintainer and seed source**	**Optimal production altitude range (Masl)**	**Places recommended**	**Grain yield (t/ha)**	**Special attributes/Disease reaction**
1. Macia	1998	ARI Ilonga	600-1500	Morogoro Dodoma Shinyanga Kilimanjaro Singida, Pwani	2.5-3.0	Moderately resistant to *Striga hermonthica* and *S.asiatica* and S. *Forbesii*
2. Wahi	2002	ARI Ilonga	600-1500	Morogoro Dodoma Shinyanga Kilimanjaro Singida, Pwani	3.5	Highly tolerant to *Striga hermonthica,* S. *asiatica* and *S. Forbesii.* Resistant to leaf blight and sooty stripe. Susceptible to long smut.
3. Hakika	2002	ARI Ilonga	600-1500	Morogoro Dodoma Shinyanga Kilimanjaro Singida, Pwani	3.5	Resistant to *Strigahermonthica* and *S. asiatica* and S. *forbesii.* Resistant to leaf blight.
4. NACO MTAMA1	2012	Namburi Agricultural Company	0 – 1200		4.5 –5.5	It has big seed size compared to other sorghum varieties
5 .LANGALANGA	-	Local landrace	-	Dodoma Singida	-	-
6.GOMBELA	-	Local landrace	-	Dodoma Singida	-	-

Appendix 3: Fungicide seed treatments used in the field trial and their rates for the control of Sorghum smuts at Hombolo, Dodoma Tanzania

Fungicides	Active ingredients	Formulation	Recommended rate
Seed Watch 20%WS	10% Imidacropid 5% Metalaxyl 5% Cabendazzim	Dust	10g / 4kg of sorghum
Apron Star	20% Metalaxyl-m 20% Thiamethoxa 2% Difenoconazole	Dust	10g / 4kg of sorghum
Snow Angel W30% DS	10% Imidaclopid 10% Metalaxyl 10% Thiram	Dust	10g / 4kg of sorghum
Control	None	None	None

Appendix 4: Mean weekly weather characteristics during experiment period for the cropping season 2018-2019 at TARI-Hombolo Centre



Appendix 5: Sorghum production activities and cost when the seeds treated by the three fungicides and when not treated in 2018/2019 cropping season at TARI-Hombolo

	SEED WATCH	APRON STAR	SNOW ANGEL	UNTREATED

Land preparation	87500	87 500	87 500	87 500
Cost of seed purchasing 10kg (TZS)	5000	5000	5000	5000
Cost of Fungicide (TAS per 30g)	6 000	15 000	3000	0
Seed dressing labour (TZS)	5000	5000	5000	0
				37500
				140000
				20000
				00 000
				20 000
				50 000
				30 000
				30 000
				15 000
				20 000
				50 000

					MACIA				GOMBELA		LANGALANGA	
	Treated	control	Treated	control	Treated	control	Treated	Control	Treated	Control	Treated	control
Land preparation	87500	87500	87 500	87 500	87 500	87500	87500	87500	87500	87500	87500	87500
Seed purchasing (10kg)	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Fungicide (TZS) 30g		0	15 000	0	15 000	0	15 000	0	15 000	0	15 000	0
Seed dressing labour	5000	0	5000	0	5000	0	5000	0	5000	0	5000	0
Cost of planting	37500	37500	37 500	37 500	37 500	37500	37 500	37 500	37 500	37 500	37 500	37 500
Fertilizer (DAP) 2 sachets	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000	140 000
Application cost	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000
Urea application 2 sachets	100 000	100 000	100 000	100 000	100 000	100 000	100 000	100 000	100 000	100 000	100 000	100 000
Application cost	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000
2 Weeding	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000
Harvesting	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000
Threshing/winnowing/bagging	15 000	15 000	15 000	15 000	15 000	15 000	15 000	15 000	15 000	15 000	15 000	15 000
Transportation	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000	20 000
Total cost of production	**575 000**	**555 000**	**575 000**	**555 000**	**575 000**	**555 000**	**575 000**	**555 000**	**575 000**	**555 000**	**575 000**	**555 000**

Appendix 6: Production activities and cost (ha^{-1}) for each of the Six sorghum varieties when treated and not treated by Seed dressing Fungicide(ha^{-1}) in 2018/2019 cropping season

Appendix 7: (a) and (b) effect of covered smut on sorghum varieties (c) long smut of sorghum and (d) field activities at TARI Hombolo centre on establishment of trial


(a) (b)


(c) **(d)**