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EFFECTS OF DIFFERENT CROP RESIDUE TYPE ON SOIL CHARACTERISTICS IN SEMI-ARID REGION CASE OF MARANGE.

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SUPERVISOR: MR MUTSENGI

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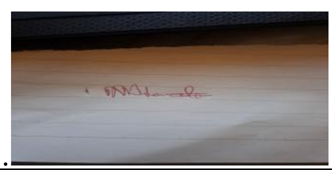
Student's Signature: …………………………. Date 17/09/2025

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DEDICATION

I first dedicate this work to the Almighty God, whose boundless grace, unwavering strength, and profound wisdom that illuminated my path and enabled the successful completion of this academic endeavor.

I secondly give dedication to my cherished family, whose enduring love, unwavering support, and countless sacrifices provided the bedrock of my motivation and the comfort in every challenge.

Thirdly I also give dedication to my esteemed supervisor, Mr. Mutsengi, whose patient guidance, insightful mentorship, and diligent effort were truly instrumental in shaping this research project from its beginning to its end.

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ABSTRACT

The study focused on examining how different crop residues (cereal and legume) influence soil characteristics. Its specific objectives were to evaluate their impact on soil physical properties (e.g., bulk density, porosity, infiltration), determine their influence on soil moisture retention, assess their effects on plant growth, and examine their overall impact on crop yield, all within the context of sustainable agriculture in semi-arid regions. This investigation was conducted in Marange, a semi-arid area characterized by sandy soils, the experimentation utilized a Randomized Complete Block Design (RCBD). Four treatments were replicated four times: maize residue, soybean residue, wheat residue, and a control (no residue). Maize variety (ZAP 43) was selected as the test crop. The results demonstrated significant differences among the treatments ($P<0.05$), with soybean residue consistently showing superior outcomes. It led to the highest plant heights, lowest bulk density, highest infiltration rates, optimal soil moisture retention, and significantly higher crop yields (8.125 t/ha). In contrast, maize and wheat residues offered intermediate improvements, while the control treatment consistently resulted in the least favorable soil conditions and lowest yields (2.375 t/ha). These findings highlight that the effectiveness of crop residues is influenced by their type, particularly the more rapid decomposition and nutrient release associated with legume residues. Based on the empirical evidence and scientific interpretations derived from this study, the farmers, agricultural extension services, and policymakers in semi-arid regions like Marange should prioritize the retention and incorporation of legume residues (e.g. soybean residue) in their cropping systems. These residues are highly effective in improving soil physical properties (infiltration, bulk density, and porosity), soil moisture retention, and enhancing high plant height, leading to significant increases in crop yield.

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CHAPTER 1
INTRODUCTION AND BACKGROUND OF STUDY

1.1 Introduction

Semi-arid regions, such as the Marange region in Zimbabwe, face significant challenges of soil degradation and limited agricultural productivity, which can have far-reaching consequences for food security and sustainable development. Applying crop residues to improve soil health and advance maintainable agriculture is one imaginable way to address these issues. Conversely, depending on the kind of residue used, crop residues can differ greatly in their ability to provide these benefits, highlighting the need for more investigation in this area. The drive of this study is to determine how several crop residue kinds affect the physical, chemical, and biological characteristics of the soil in the Marange area. Through an investigation of the relationships between crop residue types and soil properties, this research will present insights into the best crop residue managing practices for improving soil health and progressing sustainable agriculture in semi-arid areas.

1.2 Background of study

Worldwide, crop residue significantly influences soil features, particularly in semi-arid regions. In the USA, Britain, and China, studies demonstrate that crop residue retention increases soil health. " For instance, crop residue preservation improved soil biota by 15–25% (Hallett et al., 2022), reduced erosion by 40–50% (Karlen et al., 2020), and improved soil organic matter by 20–30% (Blanco-Canqui & Lal, 2022). Crop residue improved nutrient cycling by 12–18% and soil structure by 10–20% in the UK (Smith et al., 2021). The best methods to manage crop residues, still, differ depending on the area; some investigation advocates burning (Karlen et al., 2020), whereas others clash with it because of the detrimental effects it has on soil biota and soil organic matter (Liu et al., 2022). Based on the research of Wang et al. (2021), the majority of research (70–80%) agrees that crop residue controlling is vital for soil conservation and carbon sequestration.

In Africa, particularly in Botswana, Egypt, and Nigeria, the effects of different crop residue types on soil properties in semi-arid regions have been thoroughly examined. Conserving crop residue has been shown to increase soil organic carbon by 20–30% and increase soil water-holding capacity, as well as increase soil productiveness and structure (Blanco-Canqui & Lal, 2022). Crop residue preservation is crucial for carbon sequestration and soil conservation in Egypt. It also lessens soil erosion and increases soil organic matter stocks by 15–25%. Crop residue organization is essential in Nigeria to lift soil productivity, decrease soil degradation, and increase crop produces by 10–20% (Liu et al., 2022). On the best amount of residue to retain, however, different researchers have dissimilar opinions; some promote 50%, while others advocate 100%. In general, addition of crop residues might enhance soil's capability to hold water by 15–25% (Wang et al., 2021).

Investigation conducted in Zimbabwe's Marange region highlights how important it is to preserve crop residues in order to improve the properties of the soil in semi-arid regions. Harvest residues retention escalates soil organic carbon by 20–30% and improves soil fertility and structure (Blanco-Canqui & Lal, 2022). Better crop productivity and less water stress are the outcomes of a 10–20% increase in crop produces and a 15–25% improvement in soil water-holding capacity (Liu et al., 2022). The significance of this practice for soil preservation and fertility was further emphasized by a recent study conducted in Zimbabwe that initiate that adding of crop residues increased soil organic carbon stocks and reduced soil degradation (Mupangwa et al., 2022). Retaining crop residue has benefits beyond soil health; it also increases water quality, boosts biodiversity, and expands ecosystem services. All things reflected, keeping crop residues is an essential way for advancing sustainable farming and improving soil properties in semi-arid areas like Marange, Zimbabwe.

1.3 Problem statement

Crop residue retention is helpful for conserving soil fertility and structure in semi-arid areas like Marange. The improvement of sustainable agricultural practices and soil preservation strategies in these areas is disadvantaged by the lack of research on the specific effects of several crop residue types on soil properties like organic carbon, fertility, and water-holding capacity.

1.4 Justification of the study

1.4.1 Importance to Stakeholders

Understanding the best effective crop residue types can assist farmers implement sustainable agricultural practices that enhance productivity, encourage conservation, and decrease soil degradation threat. The outcomes of this study will notify farmers, agricultural policymakers, and environmental conservationists about the greatest practice for handling crop residues, contributing to sustainable agricultural practices that address soil degradation and limited productivity, improving food security, livings, and environmental sustainability. This study is key for farmers, agricultural policymakers, and environmentalists in semi-arid regions like Marange.

In order to deliver evidence-based agricultural practices and policies, this study investigates how various types of crop residues affect soil properties in semi-arid regions. The results provide context-specific recommendations for related regions with a focus on Marange, Zimbabwe. By directing ways and means for achieving sustainable agricultural development and environmental sustainability in semi-arid regions, the study moreover adds to the body of knowledge at present on soil conservation, sustainable agriculture, and climate change mitigation.

1.5 Research objectives

1.5.1 Primary Objective

To comprehend the effects of different crop residue types on soil characteristics in semi-arid regions, precisely in Marange.

Specific Objectives

a. To assess the impact of different crop residues on soil physical properties.

b. To assess the effects of different crop residues on plant growth.

c. To examine the effects of crop residue types on crop yield.

1.6 Hypotheses

1. Crop residue types has got an effect on soil physical properties.

2. Crop residue types has got an effect on plant growth.

3. Crop residue types has got an effect on crop yields.

CHAPTER 2
LITERATURE REVIEW

2.1 Crop residues

Crop residues, including materials like stalks, leaves, and roots, play a vibrant role in increasing soil fertility, structure, and overall health. Blanco-Canqui and Lal (2007), who stress the significance of crop residues in improving soil quality, lend support to this idea. Crop residues are essential for conserving soil moisture and lessening erosion in semi-arid areas like Marange (Bhattacharyya et al., 2015). The type and quantity of crop residue applied can have a big influence on the bulk density, porosity, and infiltration rate of the soil (Sharma et al., 2016). They achieve this by reducing the bulk density of the soil, which increases the porosity of the soil. Water enters the soil more rapidly as a result of improved water soil pore spaces and infiltration. Crop residues also encourage the improvement of soil aggregates, which are important for enhancing soil structure and enabling water infiltration even more. These effects together reduce runoff, erosion, and evaporation, making more water accessible for plant use.

Latest studies have underlined the benefits of crop residues in improving soil health. As they break down, they release vital nutrients like potassium, phosphorus, and nitrogen, which reduces the need for synthetic fertilizers. They work as mulch, keeping soil moisture and pull down evaporation, particularly in arid environments. Additionally, they offer a shielding layer that stops wind and water from eroding the soil (Singh et al., 2022). By blocking sunlight, they inhibit the growing of weeds and promote the aeration and nutrient cycling of useful soil microorganisms. Crop residues have the capability to raise soil organic carbon by as much as 30%, which is necessary for steadying soil structure and forming soil aggregates. Giving reference to Sharma et al. (2016), this increases soil fertility, water-holding capacity, resistance to environmental stressors, nutrient availability, weed control, and pathogen protection.

2.2 Legume Residues

Legume residues, rich in nitrogen and other nutrients, are appreciated resource for improving soil fertility and structure. They have been constantly shown to increase soil fertility and improve its structure (Giller et al., 2013; Kumar et al., 2022), increasing soil organic carbon by up to 25% (Kumar et al., 2022). A review by Zhang et al. (2023) pinpoint the importance of legume residues in icreasing soil fertility and improving its structure structure, while a study by Li et al. (2023) agreed that legume residues can improve soil fertility and structure, increasing crop yields by up to 30%. The main mechanism for their effect on soil fertility is nitrogen improvement. In their root nodules, leguminous plants have a cooperative connection with rhizobia, which are nitrogen-fixing bacteria. Through a process well-known as biological nitrogen fixation (BNF), atmospheric nitrogen gas (N_2) is converted into forms that plants can use, such as ammonia. After harvest, the nitrogen-rich stems, roots, and leaves of legume plants are left to decay in the field. Compared to wheat residues, legumes naturally have a low Carbon-to-Nitrogen ratio, often less than 20:1. This low carbon to nitrogen ratio may speed up the breakdown of materials by soil bacteria. The excess nitrogen is then mineralized (released) into the soil solution, where it is readily accessible for use by subsequent crops. Soil fertility is significantly increased by directly adding nitrogen that plants can access, which decreases the need for artificial nitrogen fertilizers and increases agricultural yields.

In terms of improving soil structure, legume residues, like those from other crops, help in the accumulation of soil organic matter as they break down. By encouraging the accumulation of soil particles into stable structures, this soil organic matter assists as an essential binding agent. In addition to generating microbial byproducts like polysaccharides and glomalin, the increased microbial activity associated to the breakdown of nitrogen-rich legume residues also produces fungal hyphae, which further stabilize soil aggregates. Well aeration, water infiltration, and water retention follow from better-quality soil structure, and these factors are crucial for strong root growth and general soil health. The unique capacity of legume residues for biological nitrogen fixation directly influences soil fertility and provides a different mechanism compared to other residue types, making them a keystone of sustainable nutrient management.

2.3 Cereal Residues

Cereal residues, explained as plant materials left over after harvesting cereal crops, have been found to have an undesirable impact on soil fertility due to their low nitrogen content (Singh et al., 2015). Cereal residues, such as maize Stover and wheat straw, typically have a high Carbon-to-

Nitrogen (C: N) ratio, higher than 30:1. This high ratio shows a large amount of carbon relative to nitrogen. When these residues are combined with the soil, soil microorganisms rapidly begin to decompose the carbon-rich material. However, these microbes need nitrogen for their own metabolic processes and growth. The bacteria will hunt the available inorganic nitrogen (nitrate and ammonium) from the nearby soil environment because the residue itself doesn't supply enough nitrogen. This process is known as nitrogen immobilization. During nitrogen immobilization, nitrogen becomes momentarily unavailable for plant uptake, potentially leading to a "nitrogen penalty" for the subsequent crop. This can manifest as nitrogen insufficiency symptoms in plants and reduced crop yields if supplementary nitrogen fertilizer is not applied to pay compensation. The immobilized nitrogen is ultimately released back into the soil through a process well-known as mineralization, which may happen too late to help the present crop, as the remains continue to break down and the microbial population declines. The quantity of crop residue sprayed has a direct relationship with the degree of immobilization.

However, agreeing to some research, the type of cereal crop and the quantity of residue left on the soil can affect how cereal residues affect soil fertility (Bhattacharyya et al., 2020). Cereal residues have been presented in some studies to reduce soil fertility by as much as 20% (Giller et al., 2022), while in other studies they have been publicized to increase soil water retention by as much as 10% (Singh et al., 2022) or decline soil organic carbon by as much as 15% (Kumar et al., 2022). The type of cereal crop, the quantity of residue left on the soil, and the type of soil are some of the variables that can affect the complex relationship among cereal residues and soil fertility.

Furthermore, other cereal residues, especially those from maize and sorghum, have been found to have neutral effects on soil characteristics (Bhattacharyya et al., 2015). However, new research specifies that these residues may have positive effects, such as increased soil organic carbon and better soil water retention (Liu et al., 2022; Zhang et al., 2023; Kumar et al., 2022). Agreeing to a study by Zhang et al. (2023), maize residues can improve soil structure and increase soil water retention by up to 25%, though another study by Liu et al. (2022) found that they can improve soil water retention by up to 30%. These outcomes were supported by a review by Kumar et al. (2022), which established that maize residues can improve soil properties like soil organic carbon and water retention. In order to control erosion and save moisture, maize residues, for example, are commonly heavy and, because of their higher lignin content, can remain on the soil surface for longer periods of time (Liu et al., 2022). Maize residues could seriously increase soil water retention by up to 30%, as according to research by Liu et al. (2022). Through their slow breakdown, residues from both sorghum and maize help to increase the amount of soil organic carbon; some studies have found that the amount of soil organic carbon in maize residues can rise by as much as 20% (Liu et al., 2022). Even though maize and sorghum residues are cereals, their unique biomass traits and degrees of decomposition can cause alterations in how they specifically affect soil properties when matched to other cereal residues. Even when nitrogen dynamics require careful management, these exact effects—such as improved long-term soil protection and moisture conservation abilities—often contribute to overall positive results on soil characteristics.

2.4 Soil characteristics

The properties of agricultural soils, which are greatly impacted by management practices like crop residue retention, are what essentially decide their health and productivity. The amount of organic matter, bulk density, porosity, aggregation, nutrient accessibility, and water retention capacity are essential soil properties.

Certain soil properties have been confirmed to benefit from crop residue retention. Crop residue incorporation and surface retention greatly increase soil organic matter and consequently soil organic carbon (SOC) (Kumar et al., 2022). This increase in organic matter is directly linked with improved soil structure, revealed as increased porosity, reduced bulk density, and improved aggregation. These physical enhancements are crucial for increasing soil aeration, encouraging root development, and quickening water infiltration into the soil, all of which increase the soil's water-retention capacity.

To add more, a protecting layer of residues on the soil surface seriously diminishes soil erosion brought on by water and wind (Zhang et al., 2023). This helps to preserve the land's long-term productivity in addition to stopping the loss of essential nutrients and topsoil. In addition to providing a buffer against sharp temperature fluctuates, residues also foster a more active and varied soil microbial community, both of which are critical for nutrient cycling and overall soil health.

2.5 Crop Residue Management in Semi-Arid Regions

Attaining agricultural sustainability in semi-arid regions needs effective crop residue management, mainly because it conserves vital soil and water resources and increases crop productivity (Lal, 2004). One significant management system that is commonly incorporated into conservation agriculture systems is the use of remains to improve and preserve the soil. One of the major methods is mulching, which keeps agricultural waste on the soil's surface. The practice of conservation agriculture practices, such as mulching and cover crops, can lead to improved soil fertility and structure (Blanco-Canqui and Lal, 2007). Additionally, applying crop wastes as a soil supplement may improve soil moisture retention and reduce erosion (Sharma et al., 2016).Mulch acts as a physical barrier, significantly reducing soil water evaporation by shielding the soil surface from direct solar radiation and wind. This is critical in water-scarce semi-arid environments. It also helps maintain a more stable soil temperature. Additionally, surface residues intercept the energy of raindrops, minimizing the detachment of soil particles (splash erosion) and reducing the velocity of surface water runoff, which curtails sheet and rill erosion. This protective layer helps maintain soil structure at the surface since erosion has been managed. Furthermore, crop residues lead to Soil Health Improvement. As residues decompose, they contribute directly to soil organic matter. This addition of organic material improves soil structure by promoting the creation of stable soil aggregates, enhances water infiltration rates, and increases the soil's water-holding capacity. Furthermore, decomposition releases nutrients gradually, supporting plant growth. However, a critical aspect of residue management is determining the optimal amount of residue to retain. While benefits are clear, some research suggests that excessive crop residue accumulation could potentially lead to issues such as the immobilization of nutrients like nitrogen (if residues have a high C: N ratio), or create unfavorable conditions for seed germination for certain crops if not managed properly. Thus, depending on certain local factors such as climate, soil type, cropping system, and the type of crop residue itself, the optimal amount and approach of residue management will differ.

2.6 Challenges in Crop Residue Management

Regardless of the benefits of crop residue management, a number of challenges are associated with its implementation in semi-arid regions. One main challenge is the inadequate availability of crop residues, particularly in areas with low crop yields (Bhattacharyya *et al.,* 2015). The use of crop residues as a soil amendment can be labor-intensive and costly (Sharma *et al.,* 2016). Recent research by Kumar *et al.* (2022) found that the high charge of crop residue collection and transportation can be a significant obstacle to its adoption. A review by Zhang *et al.* (2023) highlighted the significance of addressing labor and cost constraints related with crop residue management. Adoption may also be disadvantaged by a lack of technical knowledge regarding suitable skills or a lack of understanding of the long-term advantages of residue management. It's possible that farmers don't totally understand how different residue types impact their particular soils or how to incorporate residue management into their modern farming practices. Also, termites can quickly eat crop residues that have been surface-applied in some semi-arid tropical regions, which reduces their persistence and the time that they add to soil cover and organic matter. Strategies that either safeguard residues or take this quick decomposition pathway into reflection are therefore required. The chance of disease and pest carryover is the other trouble. Crop residues can sometimes contain pests or diseases from the previous crop if they are not appropriately managed, which could have an impact on the next crop. In certain circumstances, this necessitates giving crop rotation and residue treatment considerable thought.

Yet, some studies disagree on the magnitude of these challenges, proposing that the benefits of crop residue management can outweigh the costs (Li *et al.,* 2023). Recent research by Liu *et al.* (2022) found that crop residues can diminish soil erosion by up to 50%. Key statistics include inadequate availability of crop residues in areas with low crop yields (Bhattacharyya *et al.,* 2015), high costs of crop residue collection and transference (Kumar *et al.,* 2022), and using agricultural wastes as a soil amendment, which is costly and timewasting (Sharma et al., 2016).

CHAPTER 3
MATERIALS AND METHOD

3.1 Study Site

The field experiment was conducted in the Marange area, found in Mutare district of Manicaland Province, Zimbabwe. It is positioned at about 100 km south-west of Mutare city. The coordinates of the area are 18º26`18.45228S latitude and 30º29`54.88902E longitude. This area is classified under agro-ecological region IV, which is characterized by a semi-arid climate with naturally low and unpredictable rainfall. The area generally receives an average annual rainfall of less than 650 mm with a unimodal pattern from November to February, and experiences mean annual temperature of 27°C. Sandy soils were the predominant soil type at the experimental location where the trial was carried out.

3.2 Experimental Design

Four treatments, each replicated four times, were employed in a Randomized Complete Block Design (RCBD). The land's slope was used as the blocking factor. Maize residue, soybean residue, wheat residue, and a control treatment devoid of crop residue were the treatments.

3.3 Agronomic and management practices

3.3.1 Land preparation and Plot Layout

The experimental field was meticulously prepared through the use of a disk harrow and tractor, achieving a consistent ploughing depth of 30 cm to create an optimal seedbed. Following this, planting stations were precisely marked out using hoes. Each individual experimental plot measured 5 meters in length by 4.5 meters in width. To minimize interference between plots, a 1-meter space was maintained between adjacent plots. The experimental design involved 16 plots (derived from 4 treatments replicated 4 times), which were arranged in a layout that encompassed all plots and their immediate inter-plot pathways. This 'net plot area' measured approximately 23 meters in length by 21 meters in width, resulting in a calculated area of 483 m^2. Furthermore, a 2-meter space was maintained between experimental blocks to ensure isolation and minimize interference. Based on this arrangement of 4 blocks, the total experimental area, including these inter-block spaces and plots, measured approximately 23 meters in length by 24 meters in width, covering a total area of 552 m^2.

3.3.2 Crop Residue Collection and Application

Three types of crop residues were used: cereal residues (wheat straw and maize Stover), and legume residues (soybean residue) sourced from previous harvest from a nearby farm, research station fields. The residues were air-dried, chopped into lengths of approximately 30-35 cm to facilitate handling and uniform spreading. The required quantities of residues for each treatment plot were weighed and uniformly broadcast by hand onto the surface of the respective plots after land preparation but before planting, as per the treatment allocations. Prior to this residue application, the land was cleared of debris such as rocks and weeds to ensure a smooth and even surface for uniform residue application. The specified crop residues for each treatment were applied at the designated rate (5 tons/ha for individual components in treatments). These residues were then incorporated into the soil using a shovel to a depth of several centimetres to ensure even distribution.

3.3.3 Planting and Crop Management

ZAP 43 variety was the kind of maize used as the test crop. Two maize seeds were manually sown at each designated point, to maintain a consistent plant population and reduce competition, seedlings were thinned to one maize plant per station after emergence. A goal plant population of around 53,333 plants per hectare was achieved by spacing the maize plants 0.25 meters inside a row and 0.75 meters between rows.

3.3.4 Fertilizer Application

A basal fertilizer, Compound D (N: P: K, 7:14:7), was applied to all plots at a rate of 500 kg/ha at the time of planting. This was applied in the planting furrow. Top dressing with Ammonium

Nitrate (AN, 34.5% N) was carried out six weeks after maize emergence at a rate of 80 kg N/ha. This translated to an application of approximately 232 kg AN/ha (80 kg N / 0.345 N content).

3.3.5 Weed Management

Manual weed control was implemented. The first weeding was conducted two weeks after maize emergence, and a second weeding was performed before the maize crop reached the reproductive stage. Weeds were removed using hand hoes and by hand pulling to ensure that they did not interfere with the assessment of residue effects. Subsequent weeding operations were carried out as deemed necessary to keep the plots reasonably weed-free, particularly before the maize crop reached the reproductive stage, to minimize weed competition for water and nutrients.

3.3.6 Disease and Insect Pest Control

The maize crop experienced an attack by fall armyworm (Spodoptera *frugiperda*), which was controlled using Lambda-cyhalothrin. With a backpack sprayer, 100 millilitres of pesticide were applied for every 15 liters of water. Current commercial preparations based on cythalothrin have two active ingredients: gamma-cyhalothrin and lambda-crhalothrin. Both are cis-3-[(Z)-2-chloro-3,3,3-trifuoropropenyl] cyanohydrin esters. Carboxylic acid of -2,2-demethylcyclopropane. Thirty-five days after maize emerged, applications began. Some maize plants were also observed to be affected by Maize Streak Virus during the study. Routine spraying for pest and disease management was conducted using a knapsack sprayer at 7-day intervals, starting at week three after maize emergence until maturity. To prevent spray drift to adjacent plots, plastic spray-shields were used during application. The sprayer was cleaned with liquid soap and rinsed with water after applying each treatment to ensure no cross-contamination.

3.4 Data Collection

Multiple types of data were collected to assess the effects of different crop residues on soil characteristics and crop performance.

3.4.1 Soil Moisture Content

Soil moisture content was measured at varying depths using a Theta Probe ML3 soil moisture meter. Prior to use, the meter was calibrated according to the manufacturer's instructions to ensure measurement accuracy. Measurements involved inserting the Theta Probe sensor into the soil at predetermined depths, and readings were recorded at reproductive stage to monitor soil moisture levels.

3.4.2 Infiltration Rate

Soil infiltration rate was determined at before planting, at emergency, after planting, mid and late season of the experimental period in all plots, using the double-ring infiltrometer method. To minimize soil disturbance, an inner ring (20 cm diameter) and an outer ring (30 cm diameter), both around 25 cm high, were gently pushed into the ground to a depth of 5–10 cm. To keep the water level about equal, water was pumped into the inner ring as well as the annular area between the rings. Until a nearly constant pace was reached, the water level decrease in the inner ring was measured with a ruler at regular intervals of 10, 15, and 30 minutes, followed by longer intervals. The amount of water infiltrating per unit area of the inner ring over time was used to compute the infiltration rate (mm/hr.).

3.4.3 Bulk Density

Bulk density of the soil was measured in each plot 10–20 cm before, after planting, mid and late season. A core sampler of known volume (a 100 cm^3 metal cylinder) was used to gather undisturbed soil cores. To make sure the soil volume matched the sampler volume, the core sampler was carefully pushed into the ground, dug up, and trimmed. After being gathered, the soil samples were put in labelled bags, brought to the lab, and oven-dried at 105°C for a consistent weight, usually 24 to 48 hours. Bulk density (g/cm^3) was then achived by dividing the dry weight of the soil by the volume of the core sampler.

3.4.4 Porosity

The bulk density (ρb) and particle density (ρd) values were used to calculate the total porosity of the soil. 2.65 g/cm^3 was taken as the particle density, which is a typical value for mineral soils.

Porosity (%) = [1 – (Bulk Density / Particle Density)] × 100 was the formula that was applied. It was ascertained concurrently with the determination of bulk density.

3.4.5 Plant height

Plant height was measured using a measuring tape at three-week intervals to ascertain the effect of crop residue types on maize plant growth in terms of stem height. From the plant's base to the tip of the tallest leaf or tassel, measurements were made. To guarantee accuracy, at least ten plants per plot were chosen at random and measured. For every treatment, the average plant height was determined. Over the course of 14 weeks, measurements were taken to document the maize variety's full growth cycle. The effects of various crop residues on plant growth and development were then examined using the data that had been gathered.

3.4.6. Crop Yield Measurement

Grain yield was calculated at the end of the season so that I could observe the connection between crop residue type and crop yield. Each plot's net plot area was used to harvest maize cobs. A scale was used to weigh the grain after the cobs were manually shelled and put in 50 kg bags. The moisture content was ascertained using a subsample of grain. After that, the grain yield was converted to tons per hectare (t/ha) and adjusted to a standard moisture content of 12.5%.

3.5 Data Analysis

GENSTAT 14th Edition was used to statistically analyse the gathered data. Treatment significance was evaluated using analysis of variance (ANOVA). The Least Significant Difference (LSD) test will be used to distinct significant differences between treatment means at a significance level of 5%.

3.6 Data Model

$Y_{ijk} = \mu + Blk_i + T_j + Ei_{jk}$

Where: Y_{ijk} = Observed yield

μ= Overall mean

B_i = Effect of block

T_j = Effect of treatment

E_{ij} = Error term

CHAPTER 4

RESULTS

4.1: The impact of different crop residues on soil porosity

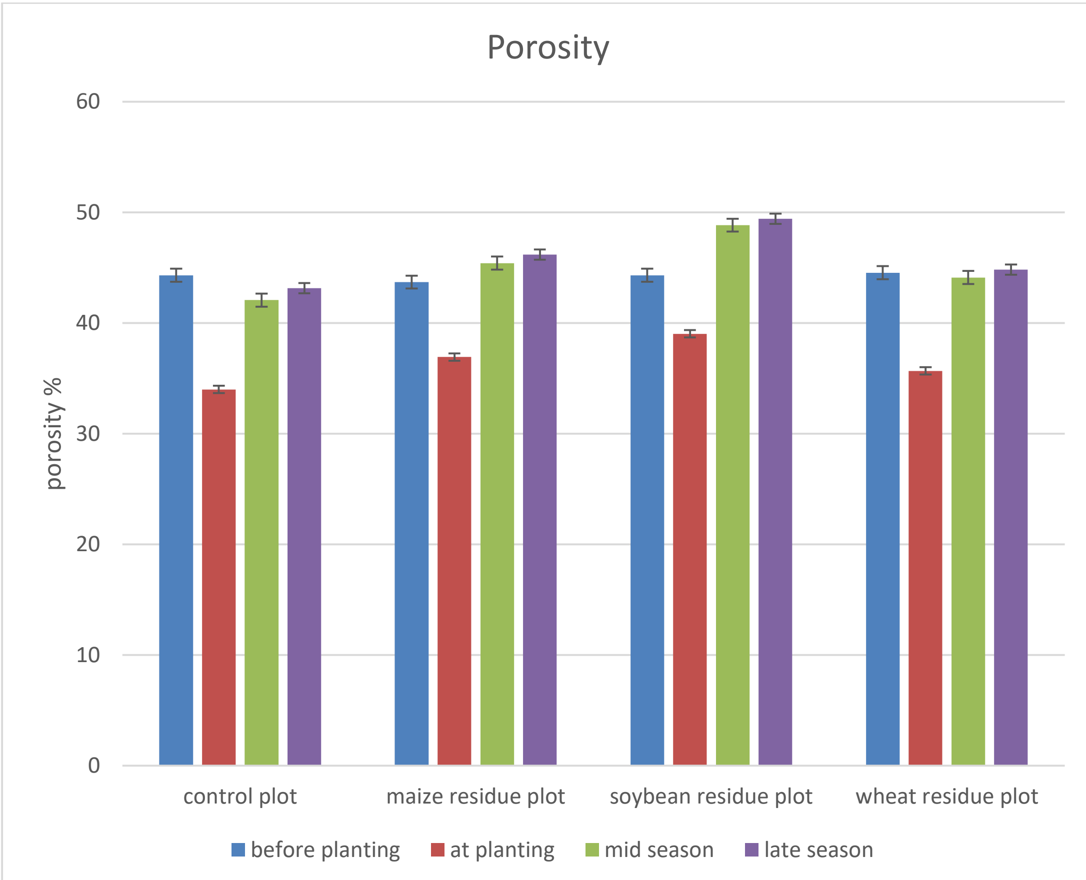

Figure 4.1: Impact of different crop residues on for soil porosity.

Crop residue type had a significant impact on soil porosity, according to the graph's porosity data analysis ($p < 0.001$). In particular, the control treatment exhibited the lowest porosity (43.15%) at late season stage, whereas soybean residue consistently displayed the highest porosity values (49.43%) at late season stage. The porosity of maize and wheat residues was frequently noticeably higher than that of the control. Prior to planting, there was no statistically significant variation in porosity amongst the treatments ($p = 0.532$).

4.2: The impact of different crop residue for bulk density

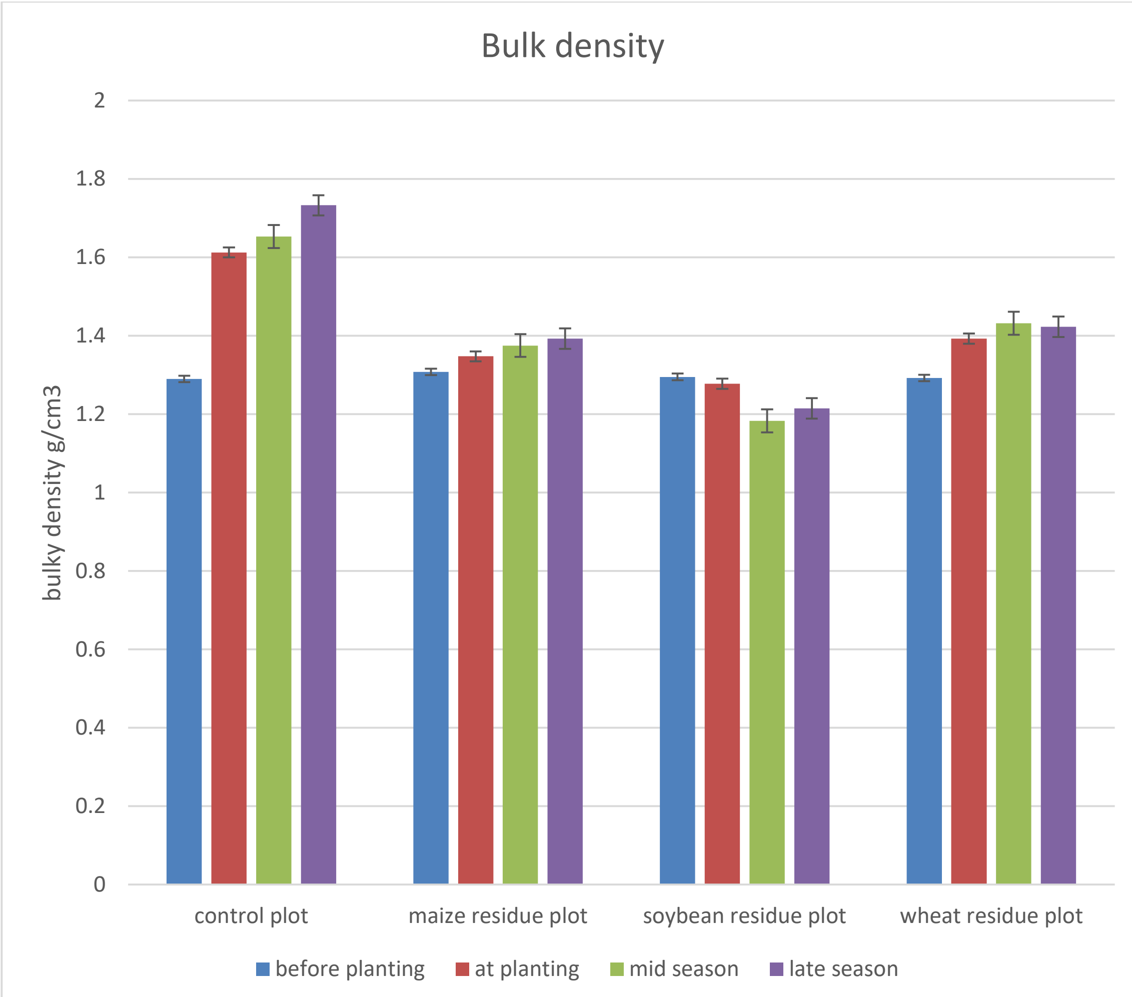

Figure 4.2: Impact of different crop residues for bulk density

Crop residue type significantly influenced soil bulk density ($p < 0.001$) across all measured stages. Specifically, the control treatment consistently showed the highest bulk density values (1.7325g/cm^3) at late season, while soybean residue demonstrated the lowest bulk density (1.215g/cm^3) at late season stage. Maize and wheat residues exhibited intermediate, yet distinct and statistically significant, effects compared to the control and soybean treatments as shown in fig4.2.

4.3: The impact of different crop residues for infiltration rate.

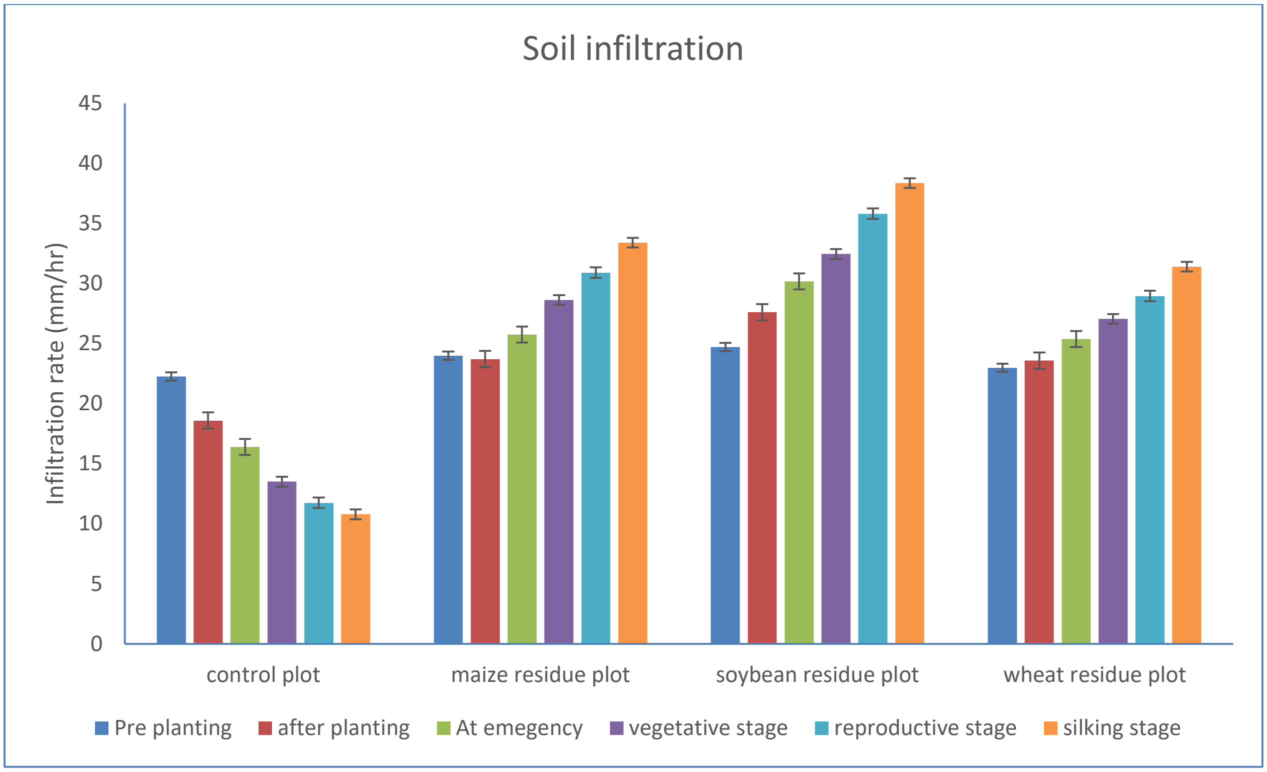

Figure 4.3: Impact of different crop residues for infiltration rate.

The analysis of infiltration rate data indicates that crop residue type significantly influenced soil infiltration rates across various crop growth stages ($P<0.001$). Specifically, soybean residue consistently led to the highest infiltration rates (38.35mm/hr) at silking stage. In contrast, the control treatment consistently resulted in the least favorable soil conditions(10.78mm/hr) at silking stage, which implies it exhibited the lowest infiltration rates. Maize and wheat residues offered intermediate improvements as shown on fig 4.3.

4.4: The impact of different crop residues on soil moisture retention.

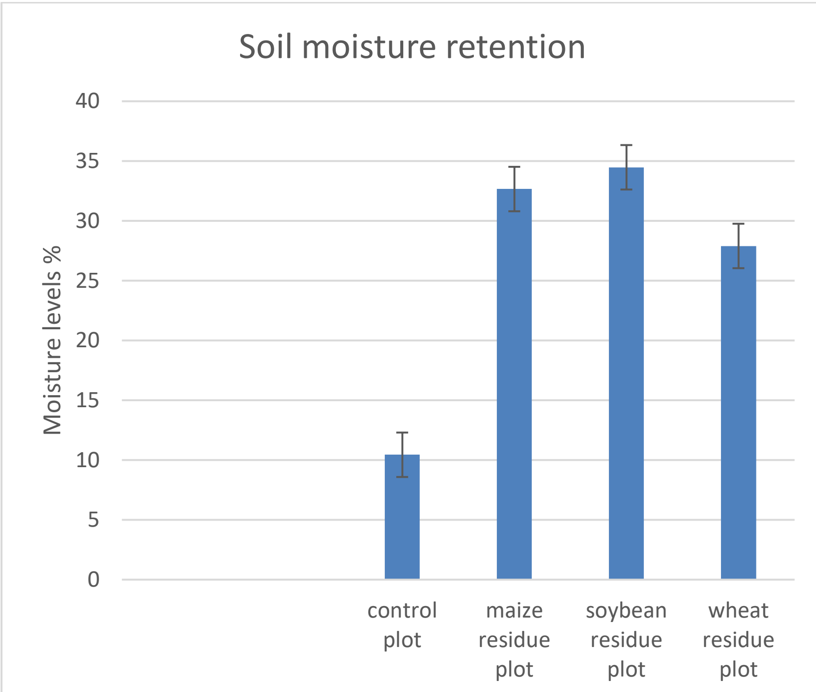

Figure 4.4: Impact of different crop residues on soil moisture retention.

The analysis of soil moisture retention data indicates that crop residue type significantly influenced soil moisture retention at reproductive growth stage ($p < 0.001$). Specifically, soybean residue consistently demonstrated the highest soil moisture retention (34.48%), while the control treatment invariably led to the lowest moisture retention (10.45%). Maize residue and wheat residues showed intermediate, yet distinct, effects compared to the control and soybean treatments as shown on fig 4.4.

4.5: The impact of different crop residues on plant growth.

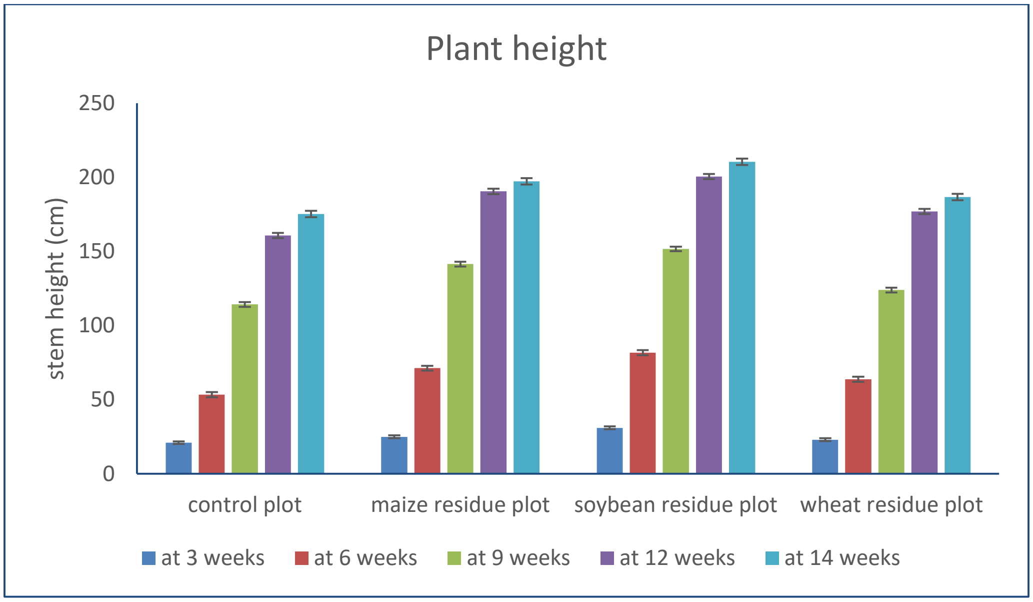

Figure 4.5: Impact of different crop residues on plant growth.

The analysis of plant growth (plant height) data from the graph indicates that crop residue type significantly influenced plant growth across all measured stages ($p < 0.001$). Specifically, soybean residue consistently demonstrated the highest plant height (210.5cm) at 14 weeks, while the control treatment showed the lowest plant height of (175.25cm) at 14 weeks. Maize and wheat residues often exhibited significantly higher plant height than the control, showing intermediate, yet distinct and statistically significant, effects.

4.6: The impact of different crop residue types on crop yield.

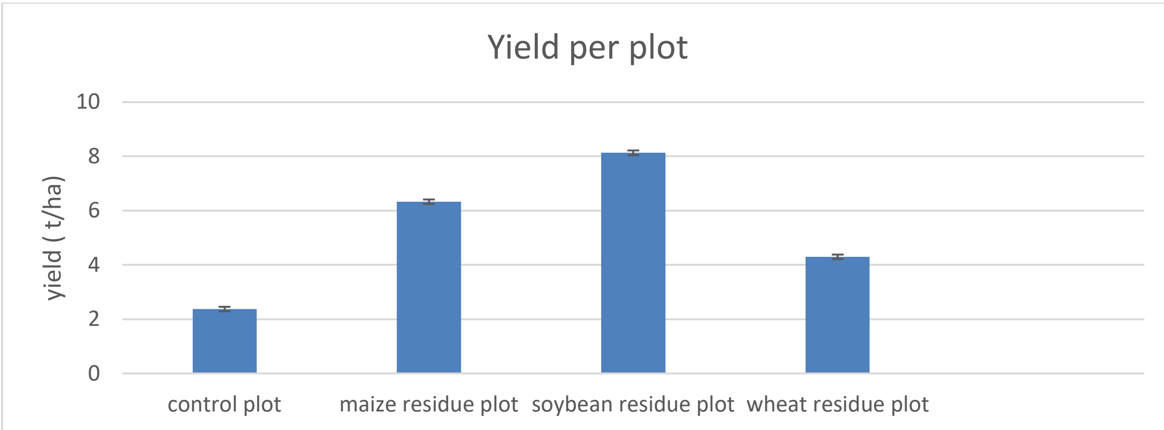

Figure 4.6: Impact of different crop residue types on crop yield.

The analysis of yield data from the graph indicates that crop residue type significantly influenced crop yield ($p < 0.001$). Specifically, soybean residue consistently demonstrated the highest yield, with a mean of 8.125. Conversely, the control treatment showed the lowest yield, with a mean of 2.375. Maize and wheat residues produced intermediate yields, with means of 6.325 and 4.300 respectively, and all treatment yields were significantly different from each other.

CHAPTER 5

DISCUSSION

5.1 Effects of crop residues on soil physical properties (porosity, bulk density, infiltration rate and moisture retention).

The consistently significant impact of different crop residue types on soil physical properties, including porosity, bulk density, and infiltration rate, is strongly supported by scientific principles observed in this study. Soybean residue ('s') consistently demonstrated superior outcomes, yielding the highest soil porosity and lowest bulk density. Its lower carbon-to-nitrogen (C: N) ratio is thought to have this positive effect because it promotes quicker decomposition and a larger and quicker buildup of stable soil organic matter (SOM) (Tian et al., 1999; Lal, 2009). By increasing macro-pore volume and generating more pore space, the elevated SOM lowers bulk density by boosting microbial activity, which is essential for tying soil particles into stable aggregates (Tisdall and Oades, 1982). Water infiltration is subsequently improved by this improved soil structure.

In contrast, maize ('m') and wheat ('w') residues exhibited intermediate improvements in porosity and bulk density compared to the control. Their higher C: N ratios result in slower decomposition rates (Reicosky and Forcella, 1998), meaning their initial contribution to stable SOM and immediate structural improvements are more gradual than soybean residue. Nevertheless, over the long term, these residues significantly contribute to SOM accumulation, which can still improve soil structure and reduce bulk density (Bauer and Black, 1994). The control treatment ('c'), lacking any residue inputs, consistently resulted in the least favorable soil conditions, marked by the lowest porosity and highest bulk density. This underscores the critical role of residue inputs in mitigating soil compaction and developing and maintaining a favorable soil structure (Blanco-Canqui and Lal, 2008). Observed dynamic changes in porosity throughout the growing season, such as initial reduction post-planting due to compaction from machinery (Plaza-Bonilla et al., 2010) followed by increases, are attributable to root proliferation and continued residue decomposition, which further contribute to SOM and aggregate stabilization (Westermann et al., 2011), ultimately improving aeration and water infiltration.

Soybean residue consistently demonstrated superior soil moisture retention. This is scientifically explained by its lower carbon-to-nitrogen ratio, which facilitates rapid decomposition and a quick increase in soil organic matter. This accumulated soil organic matter acts like a sponge, significantly boosting the soil's capacity to absorb and retain water (Jabro et al., 2010; Gupta et al., 2011). Moreover, more unchanging macro- and micro-pores are produced by the improved soil aggregation that derives from higher soil organic matter levels, permitting for more effective water retention against evaporation and gravitational pull (Six et al., 2004).

The moisture retention performance of maize and wheat residues was average. This is for the reason that their higher carbon to nitrogen ratios cause soil organic matter to accumulate more gradually and decompose at slower rates. This slower process has a less immediate effect on soil water dynamics, but it is still beneficial when related to the control (Liu et al., 2014).

On the other hand, since there was no residue involvement, the control treatment continuously showed the lowest soil moisture retention. This proves how important residue cover is for lowering direct evaporation from the soil's surface and improving the soil's natural capability to retain water (Krupinsky et al., 2007). The control plot's consistently low moisture retention highlights how significant residue inputs are for conserving soil water, particularly in semi-arid conditions. The foreseeable advantages of specific residue management practices on soil water dynamics are highlighted by this agreement with earlier studies.

5.2 The effects of different crop residues on plant growth.

Greater plant growth, including the tallest plant heights, was consistently recognized to soybean residue. Its lower carbon-to-nitrogen ratio is the main cause of this, as it encourages quick mineralization and decomposition, discharging easily accessible nitrogen into the soil solution. Soil fertility is greatly increased by this direct nutrient input. Furthermore, the fast decomposition helps soil organic matter build up, which improves soil structure by encouraging the creation of stable aggregates (Six et al., 2000; Bronick and Lal, 2005; Lal, 2009). These enhancements result in better water infiltration, aeration, and soil water retention (Krupinsky et al., 2007; Mutegi et al., 2012), all of which are crucial for strong root growth and general plant health.

Plant development was improved to an intermediate degree by maize and wheat residues. Due to their higher carbon to nitrogen ratio, these cereal residues decay more slowly and accumulate soil organic matter more slowly. First, nitrogen may become temporarily immobile due to this slower breakdown, reducing its accessibility to plants. However, in the long run, these residues can improve soil water retention and increase soil organic carbon (Liu et al., 2022; Zhang et al., 2023; Kumar et al., 2022), making a more stable and moisture-retentive environment that encourages plant growth.

Plant growth was constantly low in the control treatment, which had no crop residue. Poorer soil fertility and decreased water availability—both important for plant growth in semi-arid regions—are the results of the lack of helpful residue inputs on soil organic matter accumulation, nutrient cycling, and enhancements in soil physical properties (Blanco-Canqui and Lal, 2008). Better growth is also a result of the overall improved soil structure brought about by root proliferation and residue decomposition (Westermann et al., 2011).

5.3 Effects of crop residue types on crop yield.

The highest crop yields (8.125 t/ha) were consistently obtained from soybean residue. Its lower carbon-to-nitrogen ratio, which promotes quick mineralization and breakdown, is largely responsible for this better performance. This procedure greatly increases soil fertility by effectively releasing nitrogen and other nutrients that are available to plants into the soil. Moreover, stable soil organic matter, which improves soil structure by encouraging the creation of stable aggregates, is significantly accumulated as a result of the rapid breakdown of soybean residue (Six et al., 2000; Bronick and Lal, 2005; Lal, 2009). Increased porosity, decreased bulk density, and—most importantly—better water infiltration and increased soil moisture retention are the outcomes of these structural enhancements (Jabro et al., 2010; Gupta et al., 2011; Krupinsky et al., 2007; Mutegi et al., 2012; Six et al., 2004). Strong plant growth and increased yields are directly supported by the combination of improved nutrient availability and ideal soil physical and hydrological conditions.

Maize and wheat residues offered intermediate improvements in crop yield (maize: 6.325 t/ha, wheat: 4.300 t/ha). Their higher carbon to nitrogen ratios result in slower decomposition rates (Reicosky and Forcella, 1998), leading to a more gradual release of nutrients and slower soil organic matter accumulation compared to soybean. While initially, nitrogen immobilization can occur, potentially limiting nutrient availability, over the long term, these residues significantly contribute to soil organic matter and can improve soil water retention (Liu et al., 2014; Liu et al., 2022; Zhang et al., 2023; Kumar et al., 2022), thereby supporting moderate yield benefits.

The control treatment, lacking any residue input, consistently resulted in the lowest yields (2.375 t/ha). This is due to the absence of benefits conferred by residue incorporation, such as soil organic matter accumulation, improved soil structure (Blanco-Canqui and Lal, 2008), enhanced nutrient cycling, and reduced water loss through evaporation (Krupinsky et al., 2007). The less favorable soil conditions in the control plots directly translate to suboptimal plant growth and consequently, lower crop yields.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Crop residue type has got an effect on soil physical properties, moisture retention, plant growth, and ultimately, crop yield in semi-arid regions. Specifically, soybean residue proved to be a highly effective intervention for improving soil health and maize productivity in the Marange area.

6.2 Recommendations

Based on the empirical evidence and scientific interpretations derived from this study, the farmers, agricultural extension services, and policymakers in semi-arid regions like Marange should prioritize the retention and incorporation of legume residues (e.g. soybean residue) in their cropping systems. These residues are highly effective in improving soil physical properties (infiltration, bulk density, and porosity), soil moisture retention, and enhancing high plant height, leading to significant increases in crop yield.

For further research, it is recommended to investigate optimal application rates for different crop residue types under varying environmental conditions. This will help maximize their benefits without causing adverse effects such as nitrogen immobilization or hindering crop emergence.

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APPENDICES

GenStat 64-bit Release 17.1 (PC/Windows 8) 18 June 2010 12:28:32

GenStat Seventeenth Edition
GenStat Procedure Library Release PL25.1

POROSITY

Analysis of variance

Variate: At_plantin

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	1.9819	0.6606	3.03	
Block_number.*Units* stratum					
treatments	3	53.8069	17.9356	82.33	<.001
Residual	9	1.9606	0.2178		
Total	15	57.7494			

Analysis of variance

Variate: Before_planting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	0.8450	0.2817	0.41	
Block_number.*Units* stratum					
treatments	3	1.6050	0.5350	0.78	0.532
Residual	9	6.1400	0.6822		
Total	15	8.5900			

Analysis of variance

Variate: Late_season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	5.4819	1.8273	4.34	
Block_number.*Units* stratum					

treatments	3	84.8769	28.2923	67.17	<.001
Residual	9	3.7906	0.4212		
Total	15	94.1494			

Analysis of variance

Variate: at_Mid_season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	4.3369	1.4456	2.15	
Block_number.*Units* stratum					
treatments	3	97.0719	32.3573	48.09	<.001
Residual	9	6.0556	0.6728		
Total	15	107.4644			

Bulk density

Analysis of variance

Variate: At_plantin

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	0.0027500	0.0009167	2.80	
Block_number.*Units* stratum					
treatments	3	0.2510000	0.0836667	255.25	<.001
Residual	9	0.0029500	0.0003278		
Total	15	0.2567000			

Analysis of variance

Variate: Before_planting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	0.0002250	0.0000750	0.55	
Block_number.*Units* stratum					
treatments	3	0.0007250	0.0002417	1.78	0.222
Residual	9	0.0012250	0.0001361		
Total	15	0.0021750			

Analysis of variance

Variate: Late_season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	0.003669	0.001223	0.90	
Block_number.*Units* stratum					
treatments	3	0.554969	0.184990	135.84	<.001
Residual	9	0.012256	0.001362		
Total	15	0.570894			

Analysis of variance

Variate: at_Mid_season

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	0.007869	0.002623	1.53	
Block_number.*Units* stratum					
treatments	3	0.449169	0.149723	87.18	<.001
Residual	9	0.015456	0.001717		
Total	15	0.472494			

INFILTRATION RATE

Analysis of variance

Variate: After_Planting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	1.7675	0.5892	0.64	
Block_number.*Units* stratum					
treatments	3	164.1425	54.7142	59.28	<.001
Residual	9	8.3075	0.9231		
Total	15	174.2175			

Analysis of variance

Variate: At_emergency

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	6.0219	2.0073	2.26	
Block_number.*Units* stratum					
treatments	3	402.0919	134.0306	150.96	<.001
Residual	9	7.9906	0.8878		

Total	15	416.1044

Analysis of variance

Variate: Pre_Planting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	1.2350	0.4117	1.77	
Block_number.*Units* stratum					
treatments	3	14.0050	4.6683	20.10	<.001
Residual	9	2.0900	0.2322		
Total	15	17.3300			

Analysis of variance

Variate: Reproductive_stage

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	3.8269	1.2756	3.29	
Block_number.*Units* stratum					
treatments	3	1318.7219	439.5740	1133.37	<.001
Residual	9	3.4906	0.3878		
Total	15	1326.0394			

Analysis of variance

Variate: Vegetative_stage

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	2.4819	0.8273	2.46	
Block_number.*Units* stratum					
treatments	3	817.7419	272.5806	810.82	<.001
Residual	9	3.0256	0.3362		
Total	15	823.2494			

Analysis of variance

Variate: silking_stage

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	4.5319	1.5106	4.62	
Block_number.*Units* stratum					
treatments	3	1774.4669	591.4890	1807.22	<.001
Residual	9	2.9456	0.3273		

Total	15	1781.9444

Soil moisture retension

Analysis of variance

Variate: After_Planting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	1.7675	0.5892	0.64	
Block_number.*Units* stratum					
treatments	3	164.1425	54.7142	59.28	<.001
Residual	9	8.3075	0.9231		
Total	15	174.2175			

Analysis of variance

Variate: At_emergency

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	6.0219	2.0073	2.26	
Block_number.*Units* stratum					
treatments	3	402.0919	134.0306	150.96	<.001
Residual	9	7.9906	0.8878		
Total	15	416.1044			

Analysis of variance

Variate: Pre_Planting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	1.2350	0.4117	1.77	
Block_number.*Units* stratum					
treatments	3	14.0050	4.6683	20.10	<.001
Residual	9	2.0900	0.2322		
Total	15	17.3300			

Analysis of variance

Variate: Reproductive_stage

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	3.8269	1.2756	3.29	

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number.*Units* stratum					
treatments	3	1318.7219	439.5740	1133.37	<.001
Residual	9	3.4906	0.3878		
Total	15	1326.0394			

Variate: Vegetative_stage

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	2.4819	0.8273	2.46	
Block_number.*Units* stratum					
treatments	3	817.7419	272.5806	810.82	<.001
Residual	9	3.0256	0.3362		
Total	15	823.2494			

Analysis of variance

Variate: silking_stage

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block_number stratum	3	4.5319	1.5106	4.62	
Block_number.*Units* stratum					
treatments	3	1774.4669	591.4890	1807.22	<.001
Residual	9	2.9456	0.3273		
Total	15	1781.9444			

PLANT HEIGHT AND YIELD

Analysis of variance

Variate: %12_weeks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	86.188	28.729	4.57	
block.*Units* stratum					
treatments	3	3563.688	1187.896	189.01	<.001
Residual	9	56.562	6.285		
Total	15	3706.438			

Analysis of variance

Variate: %14_weeks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	95.688	31.896	3.44	
block.*Units* stratum					
treatments	3	2708.688	902.896	97.25	<.001
Residual	9	83.562	9.285		
Total	15	2887.938			

Analysis of variance

Variate: %6_weeks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	32.547	10.849	1.90	
block.*Units* stratum					
treatments	3	1722.797	574.266	100.57	<.001
Residual	9	51.391	5.710		
Total	15	1806.734			

Analysis of variance

Variate: %9_weeks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	52.250	17.417	3.54	
block.*Units* stratum					
treatments	3	3425.250	1141.750	232.22	<.001
Residual	9	44.250	4.917		
Total	15	3521.750			

Analysis of variance

Variate: AT_3_weeks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	3	9.230	3.077	1.72	
block.*Units* stratum					
treatments	3	224.030	74.677	41.77	<.001
Residual	9	16.090	1.788		
Total	15	249.350			

Analysis of variance

Variate: yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.

block stratum	3	0.87688	0.29229	20.94	
block.*Units* stratum					
treatments	3	74.34188	24.78063	1775.33	<.001
Residual	9	0.12563	0.01396		
Total	15	75.34437			