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Influence of selected grass mulches on soil physical properties under sprinkler irrigation system

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Abstract

Mulching is a vital agricultural practice that affects soil moisture retention, temperature regulation, and overall soil health. Three grass mulching materials (Gamba (*Andropogon Gayanus*), Jema (*Chrysopogan Zizanioides*) and Kachala (*Typha Angustifolia*)) at four mulching depths (0, 5, 10 and 15 cm) were examined to assess their effects on soil moisture content, temperature, bulk density and porosity. The study was conducted on onion plots irrigated with sprinkler system at a constant operating pressure (100 kPa). The study was carried out at the irrigation field laboratory of the Yelwa campus of Abubakar Tafawa Balewa University, Bauchi. Data were analysed using SPSS software version 23. The results indicated a significant combined impact of mulch type and depth on all studied parameters, except for bulk density. Results showed that Kachala grass, particularly at 15 cm depth, demonstrated superior moisture retention capabilities with 16.8% moisture content, leading to optimal soil moisture levels for plant growth. While the lowest soil moisture (8.81%) was conserved under the control (Un-mulched plot). Soil temperature recorded beneath the mulch was lowest (19.1^{o}C) under 10 cm Kachala grass, while the highest (28.0 ^{o}C) was recorded under 15 cm Gamba grass. Highest soil bulk density (1.78 g/cm^3) was recorded under the control, while 15 cm depth of Kachala grass gave the lowest (1.5 g/cm^3) value of bulk density. The highest value of soil porosity (46.8%) was observed under 15 cm Kachala grass and the lowest (34.2%) was observed under the control. In conclusion, grass mulching has a positive effect on soil physical properties under sprinkler irrigation system in the fadama areas of Bauchi, Nigeria.

Keywords: Mulching; Sprinkler system; Soil physical properties; Bauchi

1. Introduction

The adoption of soil and moisture conservation practices have the potential to play a key role in increasing agricultural productivity and enhancing food security in developing countries as well as in stimulating sustainable economic growth. Land degradation in the form of soil erosion and nutrient depletion presents a threat to the food security and sustainability of agricultural production in Africa [1]. Excessive sunlight on uncovered soil makes it dry faster, kill microorganisms and remove the essential air pockets in the soil. Similarly, when sprinkler irrigation systems are operated under high pressure, the water droplets possess high kinetic energy that cumulatively cause soil compaction.

The practice of mulching, an age-old agricultural technique, has gained renewed attention in modern sustainable farming systems. Mulching involves the application of organic or inorganic materials to the soil surface, providing a protective layer that offers a myriad of benefits to both soil health and crop production [2]. As global agriculture faces the challenges of water scarcity, soil degradation, and the need for enhanced resource efficiency, the role of mulching in optimizing soil physical properties and improving irrigation practices has become increasingly significant [3].

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In NIGERIA, some farmers use plastics, synthetic materials and rice straw as mulching materials. The low adoption of the plastic and rice straw mulching is mainly due to high cost of plastic and the straw as a result of the need for the demand of plastic in other areas. In Bauchi state, Gamba (*Andropogon Gayanus*), Jema (*Chrysopogan Zizanioides*), and Kachala (*Typha Angustifolia*) grasses are potential mulching materials because they are easily obtained and grow on fallowed land and have similar morphology with rice straw, which maybe good mulching material for irrigation farmers in Bauchi state and Nigeria.

It has been observed that high pressure operated sprinkler irrigation have higher impact over the soil surface causing increased soil detachment, compaction and crust formation with resultant reduced water infiltration [4]. The farmers in the savannah vegetation zones like Bauchi state Nigeria require more options for soil and moisture conservation techniques especially on the dry season irrigated fields. Therefore, this study aimed to investigate the dynamic interplay between mulch type and mulch depth on some selected physical properties under a high pressure operated sprinkler irrigation system.

2. Research methodology

2.1. Study Site Description

This research was conducted at the irrigation research farm of Abubakar Tafawa Balewa University (ATBU), Bauchi, Nigeria. It is situated in Bauchi local government area which falls within the Northern Guinea Savannah ecological zone. This area lies within latitude 10^{o} 17'N and longitude 09^{o} 49'E with a mean altitude of about 650 m above the see level.

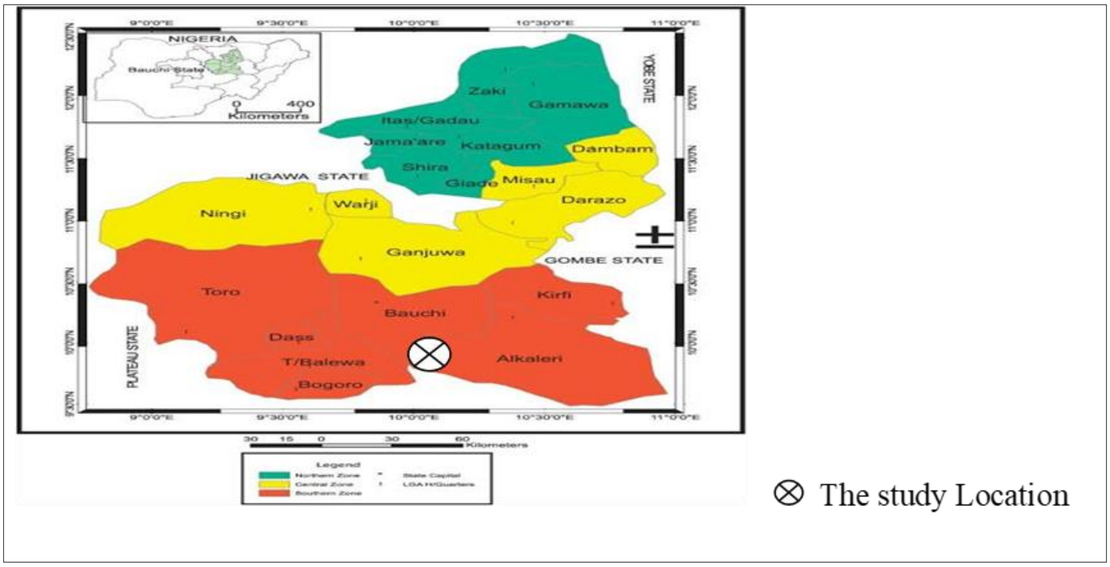

Figure 1 Map of Bauchi State showing the study location

Source: [5].

2.2. Sprinkler Description

During this study, a sprinkler irrigation system was used. The system consists of 50 mm diameter lateral pipelines and main pipeline. The spacing between one lateral and another was 6 m. So also, between one sprinkler riser head and another. Riser heights were 0.9 m each.

2.3. Mulch materials

2.3.1. Gamba grass (Andropogon Gayanus)

Gamba grass (*Andropogon Gayanus*) is a perennial leafy grass which is commonly found in Bauchi state and other parts Nigeria. It can reach up to about 2.5 m in height. It is shown in plate 1.

Plate 1 Gamba grass

Plate 2 Jema grass

Plate 3 Kachala grass

2.3.2. Jema grass (Chrysopogan Zizanioides)

Jema grass (*Chrysopogan Zizanioides*) Commonly grows in tropical and semi-arid areas and thrives majorly under the sun. It is used in soil and water conservation, protection of farm infrastructure and in pest control. It is shown in plate II.

2.3.3. Kachala grass (Typha Angustifolia)

Kachala grass (*Typha Angustifolia*) is usually found in the northern hemisphere. It has flat leaves and can grow up to 6 inches tall when fully matured as shown in plate III.

2.4. Field layout and Data Collection

The experiment was conducted on a 10.20×19.2 m plot divided into 36 sub-plots. Each plot was 3×1.5 m with a buffer zone of 0.2 m between each plot. Onions were transplanted on each plot at seedling stage (14 days after germination). Mulches were applied at various depths by randomisation into the 36 onion plots in three replicates. Irrigation water requirement and interval were determined as described by [9]. The plot was irrigated at a constant operating pressure of 100 kPa.

2.5. Data Analysis

The recorded data was sorted and subjected to statistical analysis. Analysis of variance were determined and reported using IBM SPSS software version 23.

3. Results and Discussion

3.1. Effect of mulching regimes on soil moisture content

The results of the effect of mulch type and depth on soil moisture content on the plots before next irrigation at 11 WAT is presented in Figure 2.

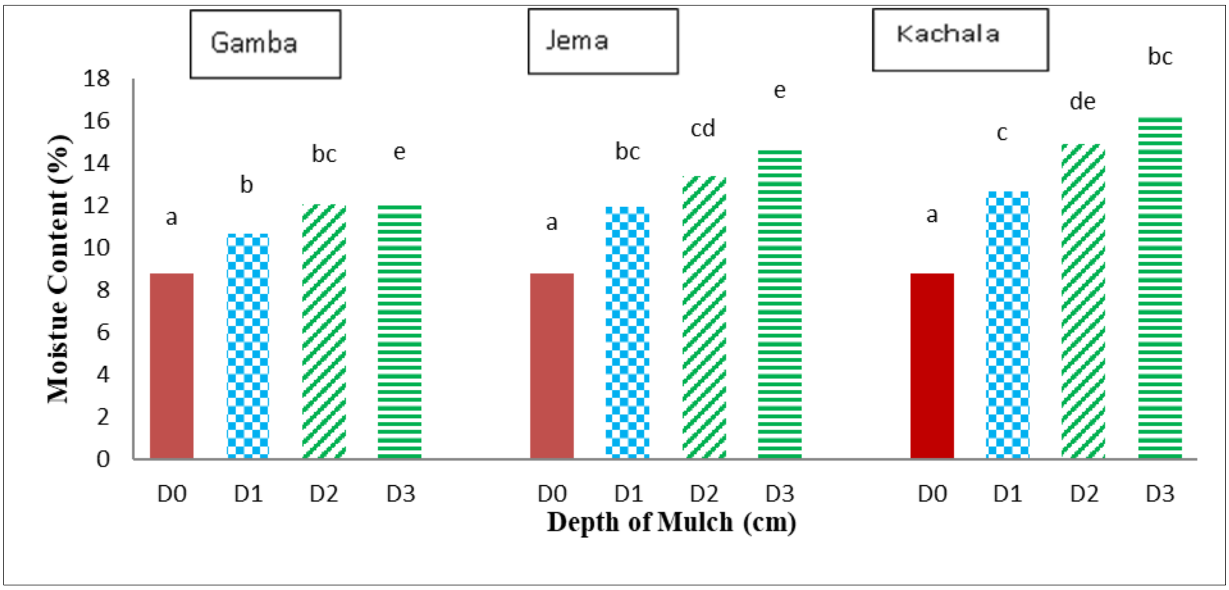

Figure 2 Moisture Content versus Depth of Mulch by Type at 11 WAT

The highest soil moisture (16.8%) was conserved in the treatment with 15 cm Kachala grass, followed by 15 cm Jema grass mulch (14.59%). On the other hand, the lowest moisture content was obtained in the control treatment (8.81%) followed by 5 cm Gamba grass (10.68%). Gamba grass, while not as efficient as Jema and Kachala grass in soil moisture retention, still exhibited notable soil moisture conservation compared to the un-mulched (control) plots. This result showed that mulching with 15 cm depth of Kachala grass performed comparatively better than the other treatments. In general, there was a statistically significant difference between the combined effects of mulch type and mulching level on soil moisture retention ($p < 0.05$).

The observed variations in soil moisture content can be attributed to several factors, including mulch characteristics, water retention properties, and decomposition rates. Earlier studies such as [10, 11] have also suggested that mulches, including plastic, gravel, barks, wood chips, and grass can retain the moisture content of soil by reducing the rate of evaporation. This effect was evident across all mulch types. Deeper mulch depths provide better soil coverage and insulation, leading to reduced evaporation and improved moisture retention. This corroborates earlier findings by [12], who observed higher soil moisture retention with deeper mulches.

Therefore, grass mulches, especially Kachala grass when applied at higher depths, enhance soil moisture retention compared to bare soil. Additionally, mulching with at least 15 cm Kachala grass would provide the best option in terms of soil moisture retention compared to the other treatments.

3.2. Effects of mulching regimes on soil temperature

The results of the combined effect of mulch type and depth on soil temperature recorded at 11 WAT are shown in Figure 3.

The highest soil temperature (28.0°C) was observed from the plot treated with 15 cm Gamba grass, while the lowest (19.1°C) was observed from the plots treated with 10 cm Kachala grass as shown in figure 3. The analysis of variance showed that there was a significant difference between the combined effects of mulching types and levels ($p<0.05$) on soil temperature.

Mulching can influence soil temperature by providing insulation against temperature fluctuations. However, deeper mulch layers may lead to more stable soil temperatures, reducing the impact of extreme heat or cold [13]. Nevertheless, higher heat conductance might also have occurred due to higher soil moisture content in the treatments with deeper mulches, as evident in the higher soil temperature recorded from the 15 cm mulching depth of all the grasses. This is in line with few studies such as [14] who also reported that compared to un-mulched soil, mulched soil showed higher soil temperature during cold weather and lower soil temperature during warmer weather.

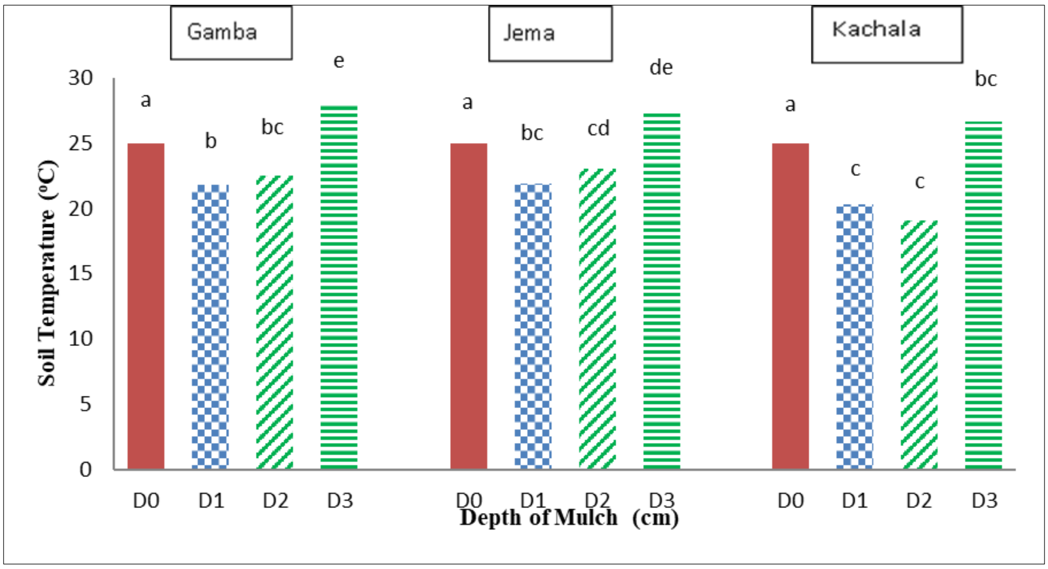

Figure 3 Soil temperature versus depth of mulch at 11 WAT

3.3. Effects of mulching regimes on soil bulk density

The results of the combined effect of mulch type and depth on soil bulk density recorded at 14 WAT is shown in Figure 4.

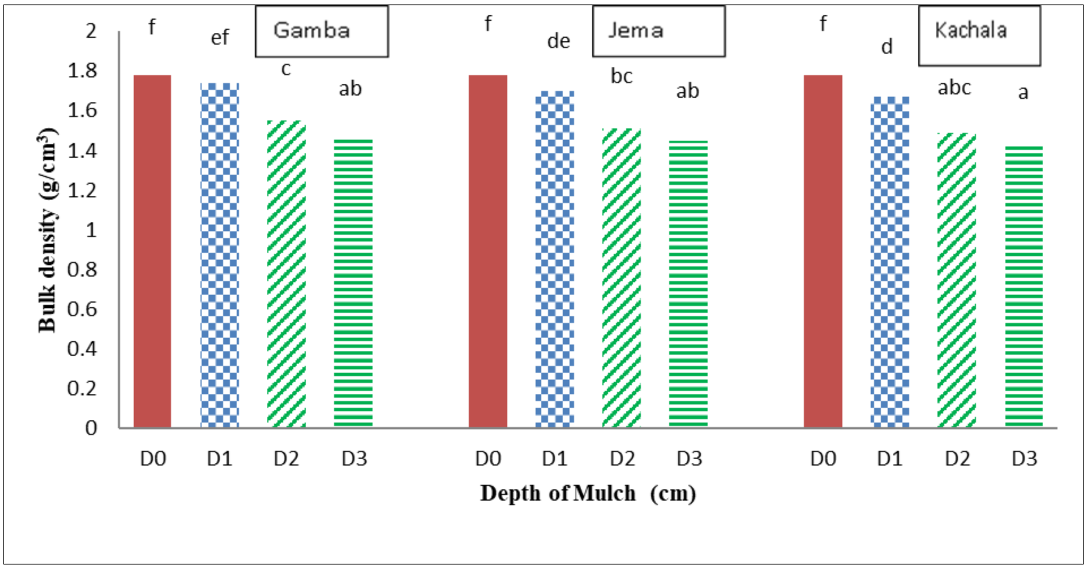

Figure 4 Soil bulk density versus depth of mulch by type at 14 WAT.

The highest soil bulk density (1.78 g/cm^3) was recorded at the control (un-mulched) plot, while the lowest bulk density (1.43 g/cm^3) was recorded in the plots treated with 15 cm Kachala grass (Figure 5). The analysis of variance showed that there was no statistically significant difference between the combined effects of mulch type and mulching levels on soil bulk density ($p > 0.05$).

From the results, mulching with 15 cm Kachala grass performed better than the other treatments in improving the soil bulk density, which could be as a result of a better ground coverage by the Kachala grass coupled with higher mulching depth, which reduces the effect of compaction, caused by the impact of sprinkler water droplets. This is consistent with some studies such as [15,16,17] who have also shown that mulches can insignificantly improve the bulk density of soil. This indicates that using the mulches, especially Kachala grass with 15 cm depth as mulching material tends to improve the soil bulk density.

The results indicate that mulch type and depth play vital roles in influencing soil bulk density under a sprinkler irrigation system. Kachala grass mulch, most likely due to its decomposition process, had the most positive impact on bulk density reduction. Gamba and Jema mulches, particularly when placed at moderate to deeper depths, also might have contributed to improved water retention and decreased compaction caused by the sprinkler irrigation water droplets. The control treatment might have exhibited the highest bulk density due to inadequate moisture retention and higher evaporation rates. This corroborates earlier findings by [18,19,20] who also observed a higher bulk density under bare soil treatment compared to mulched soil.

The findings suggest that proper selection of mulch type and depth can help maintain optimal soil bulk density levels, which in turn affects soil porosity, aeration, and water movement. Farmers and land managers can use this information to make informed decisions about mulch application practices to enhance soil health and agricultural productivity under sprinkler irrigation systems.

3.4. Effects of mulching regimes on soil porosity

The combined effects of three different mulch types; Gamba, Jema, and Kachala grasses at three different depths (5, 10, and 15 cm) on soil porosity prior to harvest (at 14 WAT) is shown in (Figure 5).

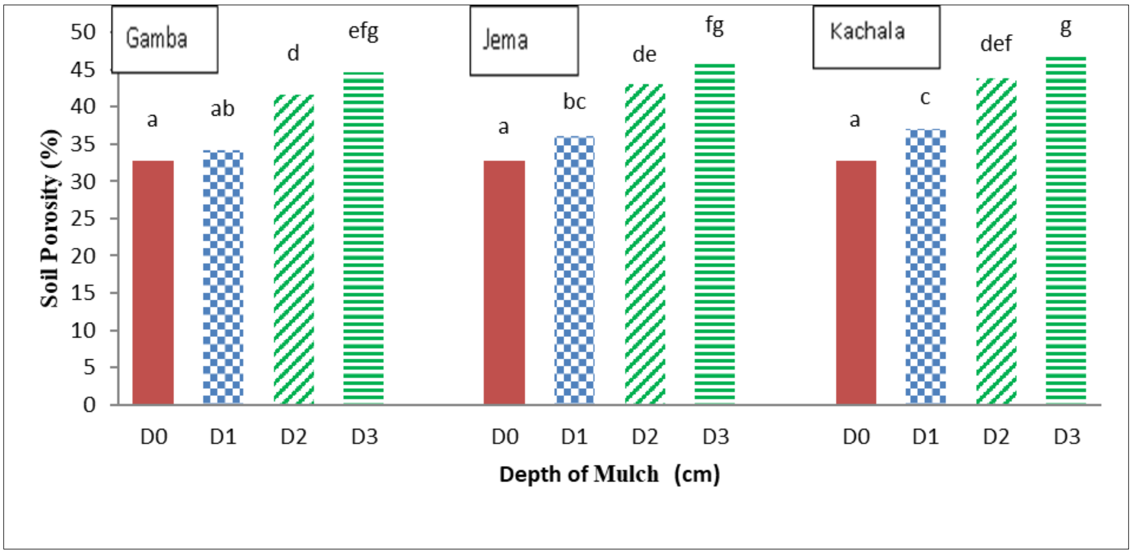

Figure 5 Soil porosity versus depth of mulch by type at 14 WAT

Soil porosity was highest in the treatment with 15 cm depth of Kachala mulch (46.8%), and the lowest was recorded at the control (32.7%) followed by 5 cm Gamba grass (34.2%). This result could be attributed to decrease in soil bulk density in all the plots treated with 15 cm mulches. There was no statistically significant difference between the effect of mulching type and levels on soil porosity. (p >0.05). The result conforms with [21,22,23] who reported that soil porosity is improved with the application of mulch. 15 cm Kachala grass tends to do better in terms of soil porosity improvement amongst all the mulch types studied.

The results of this study indicate that both mulch type and depth have a significant impact on soil porosity under a sprinkler irrigation system. The results also indicated that mulches, even at shallow depths, might improve soil porosity by enhancing moisture retention, reducing compaction, and promoting aeration. However, influence of mulch depth on soil porosity was almost similar under the various mulching types. For instance, in Gamba mulch treatments, the increase in porosity with increasing depth was similar to that of Jema and Kachala grasses.

4. Conclusion

In conclusion, the study underscores the significance of proper mulch management as a sustainable strategy for improving soil physical properties under a sprinkler irrigated onion field. By properly optimizing mulch type and depth, farmers can enhance soil health, increase water use efficiency, mitigate erosion, and promote overall agricultural sustainability. The outcomes of this research contribute to the growing body of knowledge on soil and water management and have practical implications for practitioners aiming to enhance crop productivity and environmental stewardship. Overall, the research encourages the adoption of mulching as a viable strategy to improve agricultural productivity under sprinkler irrigation systems. It would also be worthwhile to study the influence of such grass mulches on irrigation management.

Compliance with ethical standards

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Disclosure of conflict interest

The authors (Abubakar Bidawa Mahmood, Ahmed Usman Ibrahim, Sunusi Amin Abubakar, and Shuaibu Muhammad Musa) declared that there is no conflict of interest.

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