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Effects of Tillage Practices on the Growth and Yield of Maize, in the Guinea Savannah Ecological Zone of Ghana

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Abstract: A field study was conducted to investigate the influence of conventional tillage (CVT) and conservation tillage (CST) on various aspects of maize yield parameters and grain yield, using the Wagdaata maize variety. The study was conducted at the experimental farm of Tamale Technical University, located at Northern region, Tamale, Sagnarigu municipality in the Guinea savannah ecological zone of Ghana in 2023 cropping season. A randomised complete block design was used with three replicates. The treatments consisted of two tillage practices: conventional tillage (CVT) and conservation tillage (CST) and a control. The CVT involved plowing the soil to a depth of 15cm using a tractor plough with disk to plow. The CST involved use of hoe to make ridges and the control was direct seeding without loosen the soil. Plant height was evaluated every two weeks by measuring the height of maize to the base of the apex leaf. Other data collected were: maize leaf area. Cob characteristics including ear height, cob weight with husk, fresh cob weight, and dry cob weight, number of cobs per hectare and number of kernels per cob, 1000 seed weight and grain yields. The present study revealed that plant height, maize leaf area and shoot dry weight increased in the ridges than the other tillage practices. Cob characteristics such as ear height, cob weight with husk, fresh cob weight, and dry cob weight, number of cobs per hectare and number of kernels per cob, 1000 seed weight and grain yields was also optimum with the ridges as a against the other tillage practices. The study showed increased grain yield by 66% in the ridge tillage (2,389 kg/ha) over the plough tillage (1,436 kg/ha). The study provides comprehensive insights into the impact of tillage practices on various aspects of maize growth and yield, with ridge tillage emerging as a favorable practice for optimizing maize plant development and overall productivity in the Guinea savannah ecological zone of Ghana.
Keywords: Maize, conventional tillage, conservation tillage

I. INTRODUCTION

Maize (*Zea mays* L) is an important crop grown worldwide in a broad range of agroecological environment and all above ground part of the crops can be used for food, feed for livestock, fuel and industrial product [1]. It is a major food and cash crop for smallholder farmers in Ghana and is gown on about 83% of the cropped area every year [2]. Tillage system is considered the most effective farm activity, which improves the physical condition of the soil, and leads to increased nutrient uptake and efficiency yield of crops [3]. The proper use of tillage system can improve soil related constrains while improper tillage may cause a range of undesirable processes, such as destruction of soil structure, accelerated soil erosion, depletion of organic matter and fertility, and disruption in cycle of water and organic carbon and plant nutrient [4]. Use of excessive tillage is often harmful to soil. Therefore, currently there is a significance interest and emphasis on the shift to the conservation agriculture methods for the purpose of controlling erosion process [5]. Approximately 65% of agricultural land in Sub-Saharan Africa (SSA) is degraded [6]. A major cause is intensive soil tilling and removal of crop residues [6]. Arable agriculture across sub-Saharan Africa exposed to climate stress and climate change is predicted to further increase risks of both extreme temperatures and drought [7]. Negative impacts on crop yields are therefore expected ([8];[9]). According to [10], tillage practice plays an important role in the manipulation of nutrient storage and release from soil organic matter (SOM). Conventional tillage (CVT) induces rapid mineralization of SOM and potential loss of soil carbon (C) and soil nitrogen (N). Several agricultural systems have been established to be climate-smart, and this includes conservation tillage (CST), ([11];[12]). The benefits of CST include increased water infiltration, reduction in soil moisture evaporation and reduced soil erosion [12].

Despite the yield benefits accruing from the CST practices in Sub-Saharan Africa [13], the majority of smallholder farmers' fields are still under conventional tillage methods.

Furthermore, in SSA, the gaps in *Zea mays* L. yields are high with yields having trends of stagnation or decline ([14];[15]). This low productivity is associated with frequent dry spells and soil fertility depletion ([16]; [17]). According to [18], closing these yield gaps and reversing this yield decline is a priority. Improved soil and crop yields increase are reported elsewhere in the world as a result of CST practices ([19];[12]).

However, the physiological basis of the observed yield increases as a result of CST practices has not yet been reported. By investigation the effect of different tillage systems on maize growth and yield, we can determine the approach that optimizes crop productivity. This knowledge will aid farmers in making informed decisions and adopting practices that enhances their yield potential. Ensuring high maize yield through sustainable tillage practices will contribute to food security and economic stability in maize dependent regions. While research exist on the impact of different tillage systems on various crops, there is a lack of specifics knowledge regarding maize production. Given maize's unique growth requirements and it' widespread cultivation, conducting research on the effect of conventional and conservation tillage on maize growth and yield is essential. This research will fill knowledge gap, providing valuable insights for farmers, agronomists, and policymakers involved in maize cultivation and contribute to the development of Sustainable agricultural practices. Conducting research on the effect of conventional and conservation tillage on maize growth and yield is justified to promote environmental sustainability and ensuring food security. Hence, the objective of this research is to evaluate the effect of conventional tillage (CVT) and conservation tillage (CSA) on the growth and yield of maize in the Guinea savannah ecological zone of Ghana.

II. MATERIALS AND METHODS

A. Study Area

The study was conducted at the experimental farm of Tamale Technical University, located at Northern region, Tamale, Sagnarigu municipality, the Guinea savannah ecological zone of Ghana. The altitude of the area is approximately about 150 meters (500 feet) above sea level, with a mean annual rainfall average range from 600mm to 1100nm. The mean day temperature ranges from 28°C (December -mid- April) to about 38°C (April- June) while the mean night temperature range from 18°C (December) to 25°C (February-March). The soil type of the area is sandy loam, with a pH ranging from 6.0 to 7.0.

B. Experimental Design and treatment

The experiment was conducted using a randomized complete block design (RCBD) with three replications. The treatments consisted of two tillage practices: conventional tillage (CVT) and conservation tillage (CST). The CVT involved plowing the soil to a depth of 15cm using a tractor plough with disk to plow. The CST involved the use of hoe to make ridges and the control (zero tillage) which was direct seeding without loosen the soil. The maize variety used was Wang data.

C. Agronomic practices and Data collection

Inorganic compound fertilizer (15-15-15, NPK) was applied at 250kg/ha two weeks after planting and sulphate of ammonia fertilizer was applied at 50kg/ha six weeks after planting as side-dressing. The experimental plot size was 4m × 3m sizes. The soil was plowed to the depth of 15cm in CVT plots. The CVT plots were plowed using a plough disk and the CST plots were tilled using hoe and control was done as direct sowing after slashing and the application of glyphosate without losing the soil surfaces. The maize seeds were planted manually on the same day in all the plots using 75cm × 40cm plant spacing with 1malleys between plots and 2m between replications at a depth of 4cm. Inorganic compound fertilizer (15-15-15, NPK) was applied at 250 kg/ha 2 weeks after planting (WAP) and sulphate of ammonia fertilizer was applied at 125 kg/ha 6 WAP as side-dressing [20]. Data collected on the maize included plant height, maize leaf area, shoot dry weight. Cob characteristics such as ear height, cob weight with husk, fresh cob weight, dry cob weight, number of cobs per hectare, number of kernels per cob, 1000 seed weight and grain yields.

D. Data Analysis

The data was individually subjected to analysis of variance (ANOVA) technique using GENSTAT statistical package version 12 and the means compared and separated using LSD test at 5% probability level (GenStat, 2008).

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III. RESULTS

A. Plant Height

Figure 1 shows maize plant height at two weeks and six weeks after planting. The height of plant was significantly affected ($P < 0.05$) by the effects of the tillage treatment. Ridges recorded significantly ($P < 0.05$) the maximum plant height at both the timings, while the ploughed supported lower values. Generally, there were significantly higher plat height at 6WAP compared with 2WAP.

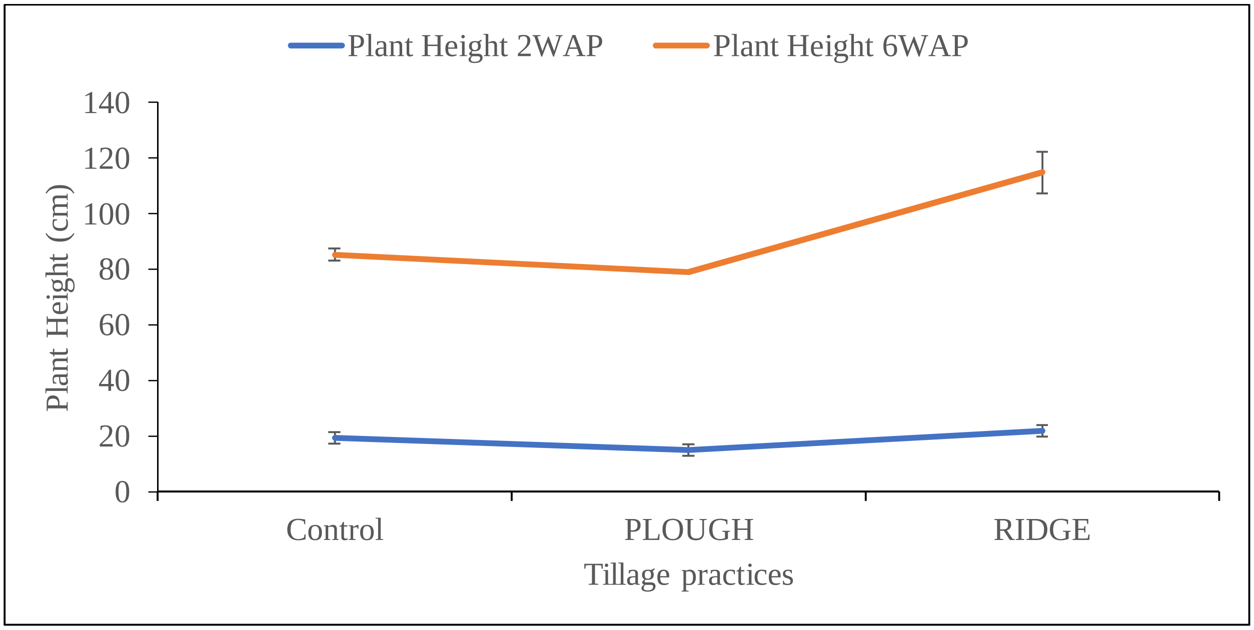

Figure 1. Variation in Plant Height at 2 and 6 weeks after planting due to the effect of tillage treatments. Error bars represent LSD at 5% probability level.

B. Leaf Area

LAI was significantly ($P < 0.01$) affected by the application of the tillage practices at 2, 4 and 6 WAP. Ridges recorded significantly ($P < 0.01$) higher LAI at all the timings (Figure 2). There were no significant ($P > 0.05$) difference between the control and the plough however, the two were significantly ($P < 0.05$) different from the ridged. Also, there were significant ($P < 0.05$) difference among all the treatments at 4 ad 6 WAP.

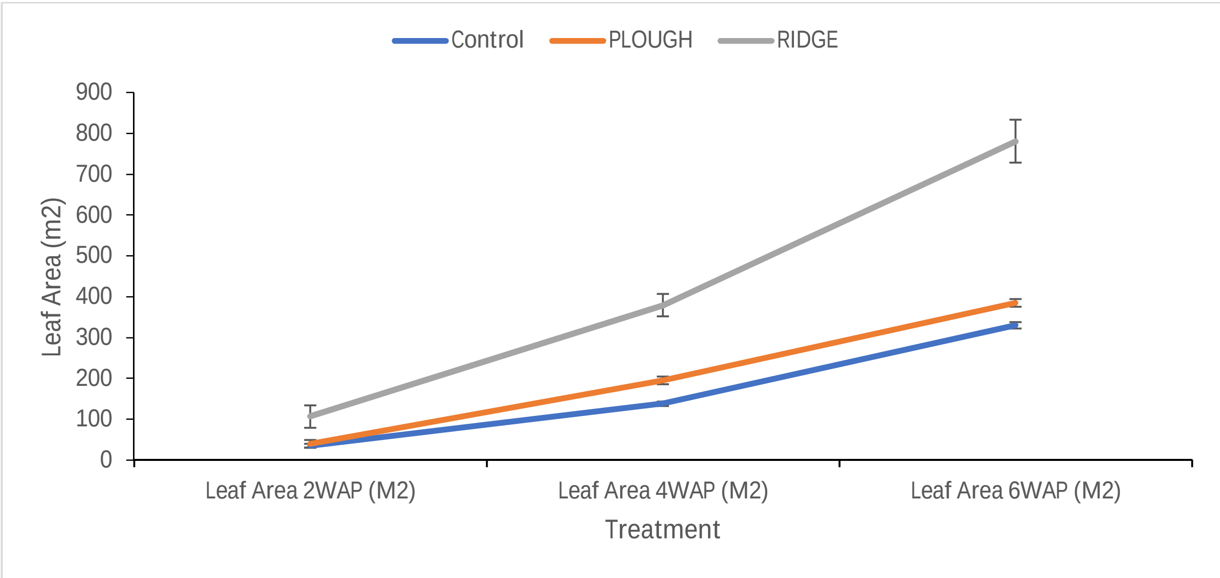

Figure 2. Variation in Leaf Area at 2, 3 and 6 weeks after planting due to the effect of the treatments. Error bars represent LSD at 5% probability level.

C. Ear Height

Ear height was significantly affected ($P < 0.01$) by tillage practices. At maturity, Ridged Plots recorded significantly ($P < 0.01$) the highest ear height followed by plough whilst the control recorded the lowest (Figure 3).

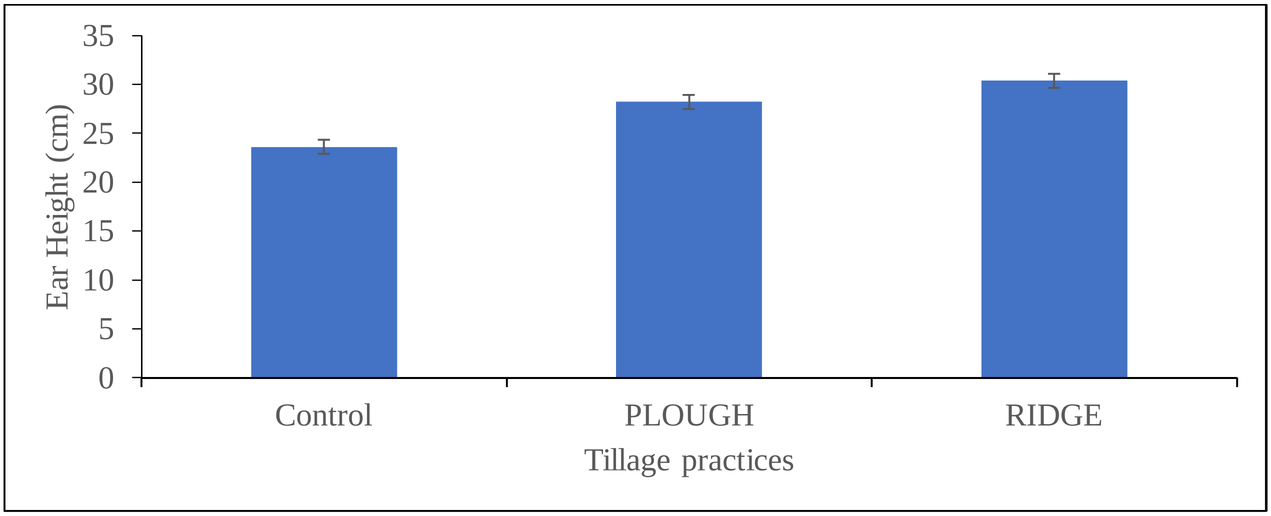

Figure 3. Effects of tillage treatments on Maize Ear Height. Error bars represent LSD at 5% probability level

D. Above-Ground Biomass

Above-ground biomass was significantly affected ($P < 0.05$) by tillage practices. Ridges yielded maximum dry weight of 1033 kg/ha, while the least shoot biomass of 5100 kg/ha was obtained from the ploughs (Table 1).

E. Cob weight with Husk

Results in Table 1 showed that cob weight with husk was significantly ($P<0.05$) affected by the tillage practices. The highest cob weight with husk was observed with ridges whilst the control recorded the lowest values of 102.2 kg/ha (Table 1)

F. Fresh Cob weight

The examination of the fresh cob weight resulted in a significant ($P < 0.05$) effects between ridges and control. The ridges had the maximum weight of 129.4 kg/ha, followed by plough with 113.1 kg/ha fresh cob weight. Control produced the lowest with 79.2 kg/ha (Table 1).

G. Dry Cob weight

The dry cob weight was significantly affected ($P < 0.05$) by the tillage practices. Ridge treatments had the maximum weight of 122.89 kg/ha, followed by plough treatments with a dry cob weight of 104.00 kg/ha. The fresh cob weight in the control was 72.67 kg/ha (Table 1).

H. Number of Cobs per ha

Results on number of cobs per hectare of maize showed significant ($p < 0.05$) variations among the treatments applied. Ridges yielded maximum number of cobs per hectare of 42,222 while the least cobs were recorded in the control with a total of 25,833 (Table 1). According to the analysis, the ridge and the plough did not exhibit significant differences when compared to each other,

I. Number of Kernels per cob

The Number of Kernels per cob showed significant differences ($P<0.01$) among the treatments. Ridges recorded the highest number of kennels of 312 per cob whilst the plough supported the lower values of 261.3 (Table 1).

J. 1000 Seed Weight

The tillage practices recorded significant ($P < 0.01$) differences in 1000 seed-weight. The ridges yielded the maximum 1000 seed weight of 236.7 g and the plough recorded the minimum weight of 197.7 g (Table 1).

K. Stover yield

Stover yield was significantly affected ($P < 0.05$) by the tillage practices. Ridges produced the highest stover yield of 7,175.83 kg/ha whilst the plough recorded the lowest stover yield of 3,541.67 kg/ha (Table 1).

L. Grain Yield

Table 1 showed tillage practices were significantly ($P < 0.05$) influenced by the grain yield of maize. Ridge treatments gave the highest grain yield of 2,389 kg/ha, followed by a control treatment which yielded 2,025kg/ha and lowest yield of 1,436 kg/ha was recorded by the plough.

Table 1: Effects of Treatments on yield and yield-related parameters

Treatment	Cob weight with Husk (kg/ha)	Fresh Cob weight (kg/ha)	Dry Cob weight (kg/ha)	No. of Cob/ha	No of Kernels per cob	1000 Seed Weight (g)	Stover yield (kg/ha)	Grain Yield per plot	Grain Yield (kg/ha)
CONTROL	102.2c	79.2c	72.7c	25,833c	261.3b	206.7b	6713.3b	2.43b	2025b
PLOUGH	127.8b	113.1b	104b	36,111b	200.1c	197.7c	3541.7c	1.72c	1436c
RIDGE	151a	129.4a	122.9a	42,222a	311.9a	236.7a	7175.8a	2.87a	2389a
Mean	127	107.23	99.87	34722	257.77	213.7	69.73	2.34	1950
SEM	4.14	8.26	10.44	1469.9	12.56	4.63	3.41	0.29	243.6

SEM: Standard error of means

IV. DISCUSSION

A. Effects Of Treatment On Growth And Growth-Related Parameters

The findings show that tillage practices significantly ($P < 0.05$) influenced maize plant height, both in the early and late stages of growth. These observed differences could be due to the ability of the ridges to conserve more moisture and nutrients for use by the plants which enhanced root growth and development and produce the tallest plant. This aligns with studies by [21], which demonstrated that ridge tillage promotes superior plant height compared to conventional plowing. [22] Liu *et al.* (2020) also found in China that reduced tillage practices boosted maize plant height. Similarly, [23] discovered that reduced tillage techniques boosted maize plant height when compared to conventional tillage in South Africa. Conventional tillage practices such as the plowing on the other hand, have the potential to diminish maize height by degrading soil, restricting nutrient and water availability, and increasing soil compaction. For example, research in Zambia by [24] found that traditional tillage techniques of constant plowing lowered maize plant height compared to reduced tillage practices, owing to soil deterioration and pest infestation. The observed differences in plant height at six weeks after planting further emphasize the enduring impact of tillage practices. Ridge tillage produced tallest plants, indicating sustained benefits throughout the growth period. These findings support the idea that tillage practices can positively influence plant height at various stages of maize development, aligning with above cited literature on the subject.

The data illustrate a significant impact of tillage practices on maize leaf area at different stages of development. Ridges again exhibited larger leaf areas than control and plough tillage (Figure 2). The enduring effect of tillage on leaf area is evident in the substantial differences observed six weeks after planting. Ridge tillage maintained a significantly larger leaf area compared to control and plough tillage. This finding could be due to the load of nutrient, water and proper aeration availed by the ridges as compared to the other tillage practices. This aligns with studies by [25] and [21], which both reported increased leaf areas under ridge tillage. [22] also found in China that reduced tillage practices boosted maize plant leaf area. Conversely, [26] discovered that conventional tillage practices lowered maize leaf area output in Ethiopia when compared to no-till practices.

The highly significant ($p < 0.05$) variations in maize ear height among tillage practices indicate that tillage has a lasting effect on this crucial parameter. Ridges consistently displayed the tallest ears, emphasizing the positive impact of ridge tillage on ear development (Figure 3). The observed differences in ear height at maturity suggest that the benefits of ridge tillage persist throughout the growth period. This could be due to improved soil organic matter, water penetration and nutrient conservation in ridges compared to plough tillage. This finding is consistent with studies by [21], which reported increased ear height under ridge tillage compared to conventional plowing.

Conservation tillage strategies such as ridges have been found in studies to improve soil organic matter, water penetration, soil structure and microbial activity, resulting in increased crop yields and decreased soil erosion [27]. In contrast, conventional tillage can deplete soil organic matter, diminish soil moisture, and increase soil erosion and greenhouse gas emissions [28].

B. Effects of Treatment on yield and yield-related parameters

The data indicates highly significant ($p < 0.05$) differences in above-ground biomass among different tillage practices. While ridge and control practices showed statistically similar values, the plough treatment exhibits significantly ($p < 0.05$) reduced above-ground biomass. This could be attributed to increased soil nutrient and water availability in the ridges than plowing. This aligns with the study by [29], highlighting the importance of conservation tillage, such as ridging, in maintaining higher biomass levels compared to conventional plowing. Conversely, according to [30] conventional tillage practices resulted in large losses of nutrients such as nitrogen and phosphorus through soil erosion, resulting in lower maize yields. Similarly, [31] discovered that plowing and harrowing reduced soil nutrient availability and uptake by maize plants when compared to no-till practices.

Significant ($p <0.05$) variations are observed in the number of cobs per hectare and number of kernels per cob. Ridge produced significantly higher number of cobs and kernels than both control and plough treatments (Table 1). This is probably due to the soil, water and nutrient conservation ability of the ridges. Ridge treatments consistently exhibit higher values compared to Plough and Control treatments. This is consistent with research by [32] and [29]), suggesting that ridge tillage positively influences cob development and weight.

Results presented in Table 1 showed significant ($p <0.05$) effect of the different tillage practices on 1000 seed weight. Ridge treatments consistently produced greater 1000 seed weight compared to control and plough treatments. The observed differences in seed weight were as a result of more nutrients and water conserved by the ridges than the other tillage practices. This aligns with studies by [33], highlighting the positive impact of ridge tillage on seed weight, which is a crucial indicator of seed quality and potential yield. Similarly, [27] found that no-till and ridging practices increased soil available nutrients and consequently seed yield. Conversely, [28] demonstrated plough tillage practices can reduce nutrient availability and uptake by maize plants, by facilitating nutrient leaching, volatilization, and soil erosion.

Both stover yield and grain yield exhibit substantial differences among the tillage practices. The differences observed in grain yield implies that ridge tillage maintains comparable higher stover and grain yields due to more available nutrients, water and aeration compared to conventional plowing. This finding is consistent with studies by [21], which reported increased stover and grain yield under ridge tillage compared to conventional plowing. [22] found in China that, reduced tillage practices boosted maize plant height, leaf area, and biomass when compared to conventional tillage. As was reported by [27] that no-till and tied-ridging practices boosted maize dry weight, and grain yield by up to 49% in Zimbabwe compared to conventional tillage. In contrast, conventional tillage practices can impair maize growth by producing soil compaction, reducing nutrient and water availability, and boosting weed competition [28].

V. CONCLUSION

Ridge tillage emerged as a favorable practice, promoting superior plant development, increased leaf area, taller ears, enhanced biomass, cob characteristics, seed weight, and overall yield compared to conventional plowing. We have established that the use of ridge tillage in the Guinea savanna agroecological zone of Ghana in maize production has the potential to increase grain yield by 66% in the ridge tillage (2,389 kg/ha) over the plough tillage (1,436 kg/ha). In addition, ridges had increased maize stover yield by 7,175.83 kg/ha compared to 3,541 kg/ha. Finally, ridges are essential in conserving soil nutrients, water and it helps control soil erosion by blocking the flow of water across the field.

Conflict of interest:
The authors state no conflict of interest.
Data availability statement:
The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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