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Impact of zero tillage and rice straw mulch on the growth and productivity of garlic (*Allium sativum*)

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Abstract
This study investigates the impact of zero tillage and rice straw mulch on the growth and productivity of garlic (*Allium sativum*). The experiment was conducted to evaluate the effects of these sustainable agricultural practices on garlic yield, soil health, and weed suppression. Results indicated that zero tillage combined with rice straw mulch significantly enhanced garlic growth, increased yield, improved soil moisture retention, and reduced weed density. These findings suggest that integrating zero tillage with rice straw mulch can be a viable strategy for sustainable garlic production.

Keywords: Zero tillage, Rice straw mulch, Garlic, Sustainable agriculture, Soil health, Weed suppression

Introduction
Garlic (*Allium sativum*) is a valuable crop with significant culinary and medicinal uses. Traditional tillage practices, while effective, can lead to soil degradation and increased labor costs. Zero tillage and the use of organic mulches, such as rice straw, have been proposed as sustainable alternatives that improve soil structure, conserve moisture, and reduce weed pressure. This study aims to evaluate the impact of zero tillage and rice straw mulch on the growth and productivity of garlic.

Objective of the paper
To evaluate the impact of zero tillage and rice straw mulch on the growth, productivity, and soil health in garlic (*Allium sativum*) cultivation.

Materials and Methods
The experiment was conducted at the Institute of Agricultural Research and Training (IAR&T), Ibadan, Oyo State, Nigeria, located at 7.3775° N latitude and 3.9470° E longitude. The region experiences a tropical wet and dry climate with an average annual rainfall of 1300 mm, predominantly during the rainy season from April to October. The study was carried out during the 2020 growing season. A randomized complete block design (RCBD) was used with four treatments and three replications: conventional tillage without mulch (CT), conventional tillage with rice straw mulch (CT+M), zero tillage without mulch (ZT), and zero tillage with rice straw mulch (ZT+M). Garlic cloves (cv. Purple Stripe) were planted on November 10, 2020, at a spacing of 15 cm x 10 cm. Rice straw mulch was applied at a thickness of 5 cm immediately after planting. Standard agronomic practices were followed for fertilization and irrigation, including 100 kg/ha of nitrogen, 50 kg/ha of phosphorus, and 50 kg/ha of potassium. Soil samples were collected before planting and after harvest from a depth of 0-15 cm using a soil auger. Soil moisture content was determined using the gravimetric method, and organic matter content was analyzed using the Walkley-Black method. Plant height and the number of leaves per plant were measured at 30, 60, and 90 days after planting (DAP). Bulb diameter was measured at harvest using a Vernier caliper. Total yield per plot and average bulb weight were recorded at harvest. Bulb yield was determined by weighing the harvested bulbs from each plot and converting it to yield per hectare. Weed density was assessed at 30, 60, and 90 DAP by counting the number of weeds within a 1 m^2 quadrat placed randomly in each plot. Data were analyzed using analysis of variance (ANOVA) with the help of Statistical Package for the Social Sciences (SPSS) software version 25.0. Means were compared using the least significant difference (LSD) test at a 5% significance level.

Results

Table 1: Soil health

Treatment	Initial Soil Moisture (%)	Post-Harvest Soil Moisture (%)	Initial Organic Matter (%)	Post-Harvest Organic Matter (%)
CT	12	14	1.2	1.6
CT+M	12	18	1.2	2.4
ZT	12	16	1.2	1.8
ZT+M	12	22	1.2	2.8

The results from Table 1 indicate that zero tillage combined with rice straw mulch (ZT+M) significantly improved soil moisture content and organic matter compared to other treatments. Post-harvest soil moisture content was highest in ZT+M (22%), followed by CT+M (18%), ZT (16%), and CT (14%). The higher moisture retention in ZT+M can be attributed to the mulch acting as a barrier, reducing evaporation and maintaining soil moisture. These findings are consistent with previous studies that have shown similar improvements in soil moisture retention with mulching and conservation tillage practices (Kim *et al*., 2019; Smith *et al*., 2020) [3, 1]. Similarly, organic matter content increased significantly in ZT+M (2.8%) compared to CT (1.6%), indicating enhanced soil fertility. The decomposition of rice straw mulch likely contributed to the increased organic matter, supporting findings from previous research (Patel *et al*., 2018) [4].

Table 2: Plant growth parameters

Treatment	Plant Height (cm) at 90 DAP	Number of Leaves at 90 DAP	Bulb Diameter (cm) at Harvest
CT	45.2	5	3.9
CT+M	50.3	7	4.5
ZT	55.1	6	4.8
ZT+M	60.5	8	5.6

Table 2 shows that plants in the ZT+M treatment exhibited significantly better growth parameters. At 90 DAP, plant height in ZT+M (60.5 cm) was substantially greater than in CT (45.2 cm), indicating robust growth under zero tillage and mulching. The number of leaves per plant was also highest in ZT+M (8 leaves), suggesting enhanced vegetative growth. Bulb diameter, a crucial yield determinant, was largest in ZT+M (5.6 cm), reflecting the favorable growing conditions provided by zero tillage and mulching. These results align with earlier studies where conservation tillage and mulching improved plant growth and development (Kim *et al*., 2019; Smith *et al*., 2020) [3, 1].

Table 3: Yield parameters

Treatment	Total yield (kg/m²)	Average bulb weight (g)
CT	1.9	25
CT+M	2.8	35
ZT	2.3	40
ZT+M	3.5	45

According to Table 3, the ZT+M treatment yielded the highest total garlic yield (3.5 kg/m²) and average bulb weight (45 g). These results demonstrate that zero tillage combined with rice straw mulch enhances garlic productivity, likely due to improved soil moisture and organic matter. This increase in yield is in agreement with previous research indicating that conservation tillage and organic mulches can significantly boost crop yields by improving soil health and reducing stress factors (Patel *et al*., 2018; Smith *et al*., 2020) [4, 1].

Table 4: Weed density

Treatment	Weed Density (weeds/m²)
CT	25
CT+M	15
ZT	12
ZT+M	8

Table 4 reveals that weed density was significantly lower in the ZT+M treatment (8 weeds/m²) compared to CT (25 weeds/m²). The reduction in weed density can be attributed to the rice straw mulch effectively suppressing weed germination and growth by blocking sunlight and providing a physical barrier. These findings are supported by earlier studies that have shown mulching as an effective weed management strategy (Kim *et al*., 2019) [3].

Discussion

The findings of this study provide significant insights into the impact of zero tillage and rice straw mulch on the growth and productivity of garlic (*Allium sativum*). The results demonstrated that the combination of zero tillage and rice straw mulch (ZT+M) considerably enhanced soil health, plant growth, yield parameters, and weed suppression compared to conventional tillage without mulch (CT). The soil health improvements observed in the ZT+M treatment are noteworthy. Post-harvest soil moisture content was significantly higher in ZT+M (22%) compared to CT (14%), indicating that the mulch effectively reduced soil evaporation and conserved moisture. This finding is consistent with previous studies, such as those by Kim *et al*. (2019) [3] and Smith *et al*. (2020) [1], which highlighted the role of mulching in improving soil moisture retention. Moreover, the organic matter content in the ZT+M treatment increased to 2.8% from an initial 1.2%, a significant enhancement compared to the 1.6% observed in CT. The decomposition of the rice straw mulch likely contributed to the increased organic matter, which in turn improved soil structure and fertility. These improvements in soil health are crucial for sustainable agricultural practices as they enhance soil resilience and productivity over the long term. In terms of plant growth, the ZT+M treatment resulted in significantly better outcomes. At 90 days after planting (DAP), garlic plants in the ZT+M treatment were taller (60.5 cm) and had more leaves (8 leaves per plant) compared to those in the CT treatment (45.2 cm and 5 leaves per plant, respectively). The larger bulb diameter observed in the ZT+M treatment (5.6 cm) further underscores the positive impact of zero tillage and mulching on garlic growth. These enhancements in plant growth parameters can be attributed to the improved soil moisture

and organic matter, which provide a conducive environment for root development and nutrient uptake. The findings align with those of Patel *et al*. (2018) [4], who reported similar benefits of conservation tillage and organic mulches on crop growth. Yield parameters were also significantly influenced by the treatments. The total yield and average bulb weight were highest in the ZT+M treatment, with values of 3.5 kg/m² and 45 g, respectively, compared to 1.9 kg/m² and 25 g in the CT treatment. These results indicate that zero tillage combined with rice straw mulch not only enhances the growth of garlic plants but also translates into higher productivity. The yield increase can be attributed to the improved soil conditions and reduced competition from weeds, as evidenced by the lower weed density in the ZT+M treatment (8 weeds/m²) compared to CT (25 weeds/m²). Mulching effectively suppresses weed growth by blocking sunlight and providing a physical barrier, reducing the need for herbicides and manual weeding. This finding is in line with previous studies by Kim *et al*. (2019) [3] and others, which have documented the weed-suppressing benefits of organic mulches. Comparing these results with previous studies, the consistency in findings underscores the reliability of zero tillage and rice straw mulch as effective agronomic practices. For instance, Smith *et al*. (2020) [1] highlighted that conservation agriculture practices, including zero tillage and mulching, significantly enhance soil health and crop productivity. Similarly, Kim *et al*. (2019) [3] demonstrated that rice straw mulch improves soil moisture retention and reduces weed pressure, leading to better crop performance. Patel *et al*. (2018) [4] also reported that zero tillage practices improve soil organic matter and moisture content, which are critical for sustainable crop production. The study's results highlight the potential of integrating zero tillage with rice straw mulch to achieve sustainable garlic production. The improved soil health, enhanced plant growth, increased yield, and effective weed suppression observed in the ZT+M treatment suggest that these practices can be adopted by farmers to improve garlic productivity while maintaining soil quality. Furthermore, the reduced need for chemical inputs such as herbicides aligns with sustainable agriculture principles, promoting environmental health and reducing production costs. Overall, this study contributes to the growing body of evidence supporting conservation agriculture practices. The positive impacts of zero tillage and rice straw mulch on garlic cultivation observed in this study reinforce the need for further research to explore their long-term effects across different soil types and climatic conditions. Adopting these practices on a broader scale could significantly enhance the sustainability and productivity of garlic and other crops, contributing to food security and environmental conservation.

Conclusion

This study demonstrates that zero tillage combined with rice straw mulch significantly enhances the growth, productivity, and sustainability of garlic (*Allium sativum*) cultivation. The results indicate substantial improvements in soil moisture retention and organic matter content, which contribute to better plant growth and higher yields. The ZT+M treatment notably increased plant height, leaf number, bulb diameter, total yield, and average bulb weight while effectively reducing weed density. These findings align with previous research, underscoring the benefits of integrating zero tillage and organic mulches in agricultural practices. Adopting these sustainable practices can lead to improved garlic productivity, reduced input costs, and enhanced soil health, supporting long-term agricultural sustainability. Further research should explore the long-term impacts of these practices across various soil types and climatic conditions to validate and expand upon these promising results.

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