



Harnessing Zero-Tillage: Enhancing Garlic Growth and Yield via Rice Stubble Planting and Mulch Optimization in Far-Western Nepal

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ABSTRACT

Garlic planted in Nepal suffers from low yield due to inadequate soil moisture, delayed planting leading to high temperature exposure, and soil degradation from conventional tillage methods, especially in the areas where it is cultivated as a short winter crop after harvesting the rice. Field research was conducted to evaluate the effect of various tillage and mulching practices in local garlic variety grown after harvesting of rice in Kailali district of Nepal. The field study was conducted at Godawari, Kailali, from November 2021 to April 2022, and evaluated the effects of tillage and mulching on garlic growth and yield using a split-plot design with four replications. The main plot comprised two tillage methods, viz., zero tillage and conventional tillage, whereas the subplot consisted of five mulching practices, i.e., rice straw, rice husk, sawdust, sugarcane trash, and dried leaves. Zero tillage showed significantly higher ($p < 0.05$) plant height (71.1 cm), leaf number (7.51), leaf area (54.79 cm²), clove number (23.46), and yield (17.56 mt/ha). Among mulches, dried leaves and rice straw performed best, with dried leaves yielding 24.83 cloves and 17.57 mt/ha. The highest yield (19.82 mt/ha) came from zero tillage with dried leaves. This combination also improved organic matter, while zero tillage with rice straw improved bulk density and recorded the highest B: C ratio (11.77). Thus, zero tillage with rice straw mulch is recommended for better growth, yield, and profitability in the plains of the far western region of Nepal and areas with similar soil conditions.

Keywords: Bulb, Garlic, Mulching, Soil quality, Stubble, Weed

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INTRODUCTION

Garlic (*Allium sativum* L.; $2n=16$), a member of Alliaceae family, originated from the progenitor *Allium longicuspis* (Mc Collum, 1976). Native to South Asia, Central Asia, and northeastern Iran, it has been cultivated for centuries for its culinary, medicinal, and economic value (Block 2010, Bodner et al 1997). According to the Food and Agriculture Organization's (FAO) most recent figures for 2023, global garlic production reached over 28.67 million tonnes as of 2025, a significant rise from about 4.3 million tons in 1961 (FAO 2026). Being thermo-photo-sensitive, garlic's growth and bulb development are highly influenced by environmental conditions (Jones and Mann 1963, Rahim and Fordham 1988). Garlic is grown during the dry winter season when rainfall is scarce and irrigation for minor crops is limited, leading to low yields (Atif et al 2020, Haque et al 2003). According to the most recent figures, 9558 hectares of garlic were grown in Nepal in 2023–2024, with a total production of 72359 mt (AITC 2025). In Nepal, about 290,000 ha of land remains fallow after rice due to excess moisture or low returns (NARC 2011). Garlic, which thrives in cool weather from September to February (AITC 2023), can be a suitable option if planted timely. Garlic is widely recognized for its culinary and medicinal properties, making it a highly sought-after commodity. However, to achieve justifiable production, adopting effective practices of tillage and mulching is essential. Tillage affects soil structure, compaction, and nutrient availability (Derpsch et al 2010, Karuma et al 2014, Rodríguez et al 2022), while mulching aids in moisture retention, weed suppression, organic matter buildup, and temperature regulation (Kabir et al 2016, Yimer 2020, Zaman et al 2012).

Understanding the individual and combined effects of tillage and mulching on garlic production has been the subject of considerable research and debate. Though conventional tillage is common in garlic (Pokhrel and Soni 2018), it can lead to erosion and soil degradation (Derpsch et al 2010), and excessive tillage with heavy machinery can damage soil structure, deplete moisture, and harm beneficial microorganisms (ICIMOD 2013, Kabir et al

2016, Koirala and Chaudhary 2021). The local initiative, "No till garlic," which was started about 20 years ago in garlic, is yet to be recognized (Koirala and Chaudhary 2021). It effectively utilizes residual moisture and nutrients after rice harvest (ICIMOD 2013). Garlic, needing minimal land preparation, fits well after rice harvest during fallow periods. The shift of technique from fallowing to Garlic cultivation after rice has high technological suitability (FAO 2013). However, depending on a number of variables, including soil type, climate, garlic variety, and farming system, the best tillage and mulching techniques for garlic cultivation may differ (Liu et al 2021).

This research investigates the impact of various tillage and mulching practices on garlic production by assessing yield, bulb size, clove number, weed count, and soil properties. It also explores interactions between these practices to identify synergies or trade-offs. The findings aim to guide growers and researchers toward more sustainable and productive garlic cultivation.

MATERIALS AND METHODS

Study site

The study was conducted at ward number 2 of Godawari municipality, Kailali, Nepal, starting from November 2021 to April 2022. Geographically, the field lies at latitude 28° 54'36" N and longitude 80° 35'24" E with an altitude of about 178 m above sea level. The research site is plain land with clay to sandy loam type of soil. Temperatures range from 6–10 °C in winter to 37–42 °C in summer. The rainy season extends from June to September, with maximum rainfall in June and July.

Experimental design and treatment

The experiment used a split-plot design with two tillage methods: Zero tillage and Conventional tillage as main plots and five mulches: Rice straw, Rice husk, saw dust, Sugarcane trash, and Dried leaves as subplots, replicated four times in four blocks. A local garlic landrace maturing in 120–150 days was used, planting only outer ring cloves from healthy bulbs. The experiment included total 40 units each with the dimension of 1.05 m × 0.6m. The total area was 89.1 m², with 0.5 m between plots and 1 m between replications. Each plot had 8 rows with 5 plants per row, totaling 40 plants. Ten inner plants were randomly selected as sample plants.

Field preparation and analysis

In conventional tillage, soil was tilled four times with FYM mixed during the third ploughing, while zero tillage involved no disturbance, leaving a 5 cm rice residue layer and broadcasting FYM before planting. Cloves were treated with *Trichoderma viride* (2.5 ml/L) two hours before planting. FYM (0.98-1.18 mt/ha) and NPK fertilizer (151:109:47 kg/ha) were applied in all plots; mixed in conventional tillage and broadcast in zero tillage (AITC 2023). Conventional plots had 10 cm raised beds; zero tillage cloves were dibbled into rice stubble. 3–5 cm thick mulch was applied immediately after sowing as recommended from the good practice tested in the project "Enhanced climate change adaptation capacity of communities in contiguous fragile ecosystems in the Cordilleras" (2009 – 2011) in the Philippines (FAO 2012). Harvesting was done manually with spades when the tops of the garlic became partly yellow or brownish and exhibited signs of drying up and bending over after 141 days after planting of garlic cloves. Economic yield in ton per hectare was calculated on the basis bulb weight from 10 observational plants in each plot.

Statistical Analysis

Microsoft Excel (2010) and RSTAT (R v3.5.3) were used for data entry and analysis. Data were analyzed using split-plot analysis of variance (ANOVA), with replications (blocks) treated as random effects, to determine the significance of treatment effects. Treatment means were compared using Duncan's Multiple Range Test (DMRT) at the 5% level of significance.

RESULTS AND DISCUSSION

Growth parameters

Plant emergence and days to maturity

Days to first, 50%, and 100% garlic emergence differed significantly by tillage and mulching ($p < 0.05$) (Table 1). Zero tillage showed earlier emergence (3.75, 8.10, 14.20 days) than conventional tillage. Maturity took longer under zero tillage (136.7 days) versus conventional (134.95 days). This aligns with the findings by (Halim 2000) and (Kabir et al 2016), who reported higher emergence rates of garlic in zero tillage. Earlier emergence may be due to residual moisture and improved soil conditions (Koirala and Chaudhary 2021, Silva et al 2004).

Table 1. Plant emergence and days to maturity of garlic influenced by tillage and mulching practices at Godawari, Kailali, 2021/22

Treatments	Days to plant emergence			Days to maturity
	1 st emergence	50% emergence	100% emergence	
Tillage methods (Main plot)				
Zero tillage	3.75 ^b	8.10 ^b	14.20 ^b	136.7 ^a
Conventional tillage	4.40 ^a	8.55 ^a	15.75 ^a	134.95 ^b
SEm (±)	0.015	0.015	0.027	0.062
LSD _{0.05}	0.40*	0.40*	0.54**	1.25*
CV, %	9.8	4.8	3.6	0.9
Mulching practices (Sub-plot)				
Rice straw	3.63 ^c	7.76 ^b	14.13 ^b	137.00 ^a
Rice husk	4.00 ^{bc}	8.88 ^a	15.50 ^a	135.38 ^b
Saw dust	4.25 ^b	8.50 ^{ab}	15.13 ^{ab}	134.88 ^b
Sugarcane trashes	4.88 ^a	8.63 ^{ab}	16.00 ^a	134.75 ^b
Dried leaves	3.63 ^c	7.88 ^b	14.13 ^b	137.13 ^a
SEm (±)	0.068	0.102	0.127	0.10
LSD _{0.05}	0.56***	0.84*	1.06**	0.88***
CV, %	13.3	9.8	6.8	0.6

Means followed by the same letter (s) within a column are not significantly different from each other at 5% level of significance by DMRT; ***= significant at p<0.001, **= significant at p<0.01 and *= significant at p<0.05 and. SEM = Standard error of mean, LSD = Least significant difference, CV = Coefficient of variation

Among mulches, rice straw and dried leaves led to the fastest emergence (around 3.6 days), followed by rice husk, sawdust, and sugarcane trash. Days to 50% and 100% emergence were shortest with rice straw and dried leaves, and longest with sugarcane trash. Rice straw mulch showed the earliest and highest emergence (95.17%), similar to dried leaves and water hyacinth, likely due to their fibrous structure reducing evaporation (Saothongnoi et al 2014). Maturity varied from 134.75 days (sugarcane trash) to 137.13 days (dried leaves). Tillage and mulch interaction had no significant effect on emergence or maturity.

Plant height

Garlic plant height differed significantly by tillage at 30, 50, and 70 DAP (p<0.05) (Table 2), with zero tillage producing the tallest plants with the tallest overall (71.1 cm) at 90 DAP, and thereafter it declined due to senescence. These results align with (Hossain et al 2020) and (Kabir et al 2016), likely due to better soil structure and root growth in zero tillage (Hou et al 2012). Mulching also significantly affected plant height at all stages (p<0.05). Rice straw led at 30 DAP (34.11 cm), dried leaves at 50 DAP (43.39 cm), and dried leaves had the tallest plants at 70, 90, and 110 DAP (up to 73.55 cm), which was statistically similar to rice straw. This may be due to better moisture retention and temperature regulation. Sugarcane trash showed the lowest height, possibly due to more weeds, consistent with (Islam et al 2015).

Table 2. Plant height of garlic influenced by tillage and mulching practices at Godawari, Kailali, 2021/22

Treatments	Plant height (cm)				
	30 DAP	50 DAP	70 DAP	90 DAP	110 DAP
Tillage methods (Main plot)					
Zero tillage	31.56 ^a	39.96 ^a	56.59 ^a	71.1	70.10
Conventional tillage	30.21 ^b	38.84 ^b	50.6 ^b	64.7	64.00
SEm (±)	0.061	0.047	0.16	0.32	0.39
LSD _{0.05}	1.23*	0.95*	3.34*	ns	ns
CV, %	4	2.4	6.2	9.5	11.6
Mulching practices (Sub-plot)					
Rice straw	34.11 ^a	43.12 ^a	57.72 ^a	72.65 ^a	70.12 ^{ab}
Rice husk	29.75 ^c	37.52 ^b	50.8 ^b	66.63 ^b	66.86 ^{bc}
Saw dust	30.04 ^c	37.78 ^b	51.7 ^b	63.59 ^c	63.70 ^c
Sugarcane trashes	27.97 ^c	35.21 ^c	48.98 ^b	63.1 ^c	64.43 ^c
Dried leaves	32.54 ^b	43.39 ^a	58.79 ^a	73.55 ^a	71.91 ^a
SEm (±)	0.15	0.24	0.46	0.33	0.42
LSD _{0.05}	1.23***	2.01***	3.82***	2.78***	3.5***
CV, %	3.9	4.9	6.9	4	5

Means followed by the same letter (s) within a column are not significantly different from each other at 5% level of significance by DMRT; ***= significant at p<0.001, **= significant at p<0.01 and *= significant at p<0.05 and ns: not significantly different at 5% (p>0.05). SEM = Standard error of mean, LSD = Least significant difference, CV = Coefficient of variation and DAP = Days after planting

Tillage and mulching interaction significantly affected plant height at 30 and 90 DAP (p<0.05). At 30 DAP, the tallest plants (35.75 cm) were in zero tillage with rice straw mulch, statistically at par with zero tillage and dried

leaves, while at 90 DAP, zero tillage with dried leaves had the significantly tallest plants (77.99 cm), statistically similar with zero tillage and rice straw (77.81 cm).

Leaves per plant

Leaf number per plant was significantly higher in zero tillage at 50, 70, and 90 DAP (5.94, 6.03, 7.51) (Table 3). This aligns with (Hossain et al 2020). Fewer leaves in conventional tillage may result from soil disturbance and compaction limiting root (Blanco-Canqui and Ruis 2018). Mulching significantly influenced leaf number at all stages. Rice straw had the most leaves at 30 and 90 DAP (4.71, 7.73), while dried leaves led at 50, 70, and 110 DAP (5.99, 6.08, 7.24), both outperforming sugarcane trash. Similar results were reported by (Kabir et al 2016, Koirala and Chaudhary 2021). This may be due to the lower C/N ratio and better temperature stability in rice straw and dried leaves mulches.

Table 3. Number of leaves per plant of garlic influenced by tillage and mulching practices at Godawari, Kailali, 2021/22

Treatments	Number of leaves per plant				
	30 DAP	50 DAP	70 DAP	90 DAP	110 DAP
Tillage methods (Main plot)					
Zero tillage	4.48	5.94 ^a	6.03 ^a	7.51 ^a	6.99
Conventional tillage	4.420	5.55 ^b	5.66 ^b	6.97 ^b	6.53
SEm (±)	0.019	0.015	0.014	0.018	0.035
LSD _{0.05}	ns	0.29*	0.28*	0.36*	ns
CV, %	8.4	5.1	4.8	5	10.4
Mulching practices (Sub-plot)					
Rice straw	4.71 ^a	5.94 ^a	6.03 ^a	7.73 ^a	7.09
Rice husk	4.31 ^b	5.68 ^b	5.88 ^b	6.99 ^b	6.48
Saw dust	4.31 ^b	5.66 ^{bc}	5.76 ^{bc}	7.05 ^b	6.56
Sugarcane trashes	4.25 ^b	5.46 ^c	5.58 ^c	6.8 ^b	6.48
Dried leaves	4.65 ^a	5.99 ^a	6.08 ^a	7.61 ^a	7.24
SEm (±)	0.032	0.025	0.024	0.042	0.041
LSD _{0.05}	0.26**	0.21***	0.19***	0.34***	0.34***
CV, %	5.7	3.4	3.2	4.7	4.9

Means followed by the same letter (s) within a column are not significantly different from each other at 5% level of significance by DMRT; ***= significant at p<0.001, **= significant at p<0.01 and *= significant at p<0.05 and ns: not significantly different at 5% (p >0.05). SEM = Standard error of mean, LSD = Least significant difference, CV = Coefficient of variation and DAP = Days after planting

Tillage and mulching interaction significantly affected leaf number at 70 DAP, with the highest (6.3) from zero tillage combined with rice straw and dried leaves mulch.

Weed number per plot

Weed count per plot was significantly higher in zero tillage at 30, 50, and 70 DAP (p<0.05) (Table 5), peaking at 22.5 (50 DAP) and lowest at 5.5 (90 DAP).

Table 4: Weed numbers per plot of garlic influenced by tillage and mulching practices at Godawari, Kailali, 2021/22

Treatments	Weed numbers per plot				
	30 DAP	50 DAP	70 DAP	90 DAP	110 DAP
Tillage methods (Main plot)					
Zero tillage	20 ^a	22.5 ^a	16.95 ^a	5.5	9.5
Conventional tillage	10.55 ^b	11.25 ^b	11.25 ^b	5.6	8.9
SEm (±)	0.10	0.15	0.21	0.067	0.047
LSD _{0.05}	2.04***	3.09**	4.20*	ns	ns
CV, %	13.2	18.2	29.6	23.9	10.1
Mulching practices (Sub-plot)					
Rice straw	11.625 ^b	12.13 ^b	11.00 ^c	4.13 ^b	5.50 ^c
Rice husk	17.75 ^a	20.38 ^a	15.13 ^b	6.38 ^a	8.63 ^b
Saw dust	19.50 ^a	21.5 ^a	16.00 ^{ab}	6.00 ^a	11.88 ^a
Sugarcane trashes	18.38 ^a	20.75 ^a	17.88 ^a	6.75 ^a	12.63 ^a
Dried leaves	9.125 ^b	9.63 ^b	10.50 ^c	4.5 ^b	7.38 ^{bc}
SEm (±)	0.38	0.44	0.27	0.11	0.23
LSD _{0.05}	3.16***	3.59***	2.21***	0.94***	1.88***
CV, %	20.1	20.6	15.1	16.4	19.8

Means followed by the same letter (s) within a column are not significantly different from each other at 5% level of significance by DMRT; ***= significant at p<0.001, **= significant at p<0.01 and *= significant at p<0.05 and ns: not significantly different at 5% (p >0.05). SEM = Standard error of mean, LSD = Least significant difference, CV = Coefficient of variation and DAP = Days after planting

Increased weed pressure under zero tillage aligns with findings by (Carr et al 2012) and (Gruber and Claupein 2009), due to shallow seed placement and reduced disturbance. In contrast, conventional tillage buries weed seeds deeper, reducing germination (Javaid et al 2022, Manalil et al 2018). Mulching also showed significant effects at all DAP. Sawdust gave the highest weed counts at 30 and 50 DAP, followed by sugarcane trash and rice husk. Dried leaves and rice straw showed the fewest weeds across stages. Findings by (Gupta and Gupta 1987, Ramakrishna et al 2006) showed rice straw mulch effectively reduced weeds and boosted yields. Mulches suppress weeds by blocking light and reducing evapotranspiration (Iqbal et al 2020, Rathore et al 1998).

Tillage and mulching interaction significantly affected weed numbers at 30, 50, and 70 DAP ($p < 0.05$). Zero tillage with sugarcane trash had the highest weed counts, while the lowest were from conventional tillage with dried leaves (30, 50 DAP) and rice straw (70 DAP).

Yield and yield attributing parameters

Clove number per bulb

Total clove and marketable clove per bulb differed significantly by tillage and mulching ($p < 0.05$) (Table 6). Zero tillage yielded more total (31.74) and marketable cloves (23.46) than conventional. Among mulches, rice straw had the highest (30.11 and 24.83), and sugarcane trash had the lowest marketable cloves (19.13). Zero tillage with rice straw gave the highest (33.35 and 28.53), while conventional with sawdust gave the lowest (24.84 and 15.03). Similarly, a study also shows higher garlic yield parameters under zero tillage, including greater bulb diameter, clove number, and bulb weight ((Hossain et al 2020).

Table 5: Clove number per bulb of garlic influenced by tillage and mulching practices at Godawari, Kailali, 2021/22

Treatments	Total clove per bulb	Marketable clove per bulb
Tillage methods (Main-plot)		
Zero tillage	31.74 ^a	23.46 ^a
Conventional tillage	27.12 ^b	19.04 ^b
SEm (\pm)	0.11	0.12
LSD _{0.05}	2.21**	2.47**
CV, %	7.5	11.5
Mulching practices (Sub plot)		
Rice straw	30.11	24.83 ^a
Rice husk	28.56	20.63 ^b
Saw dust	29.22	19.13 ^b
Sugarcane trashes	29.67	18.27 ^b
Dried leaves	29.59	23.38 ^a
SEm (\pm)	0.26	0.32
LSD _{0.05}	ns	2.66***
CV, %	7.1	12.1

Means followed by the same letter (s) within a column are not significantly different from each other at 5% level of significance by DMRT; ***= significant at $p < 0.001$, **= significant at $p < 0.01$ and *= significant at $p < 0.05$ and ns= not significantly different at 5% ($p > 0.05$). SEM = Standard error of mean, LSD = Least significant difference, CV = Coefficient of variation

Yield parameters

Bulb weight and diameter were significantly higher under zero tillage (27.65 g, 3.59 cm) than conventional (20.59 g, 3.03 cm) ($p < 0.05$) (Table 7). Rice straw mulch gave the heaviest bulbs (27.68 g), while sugarcane trash had the lowest (21.28 g). In Nepal, zero tillage increased garlic yield by 4% (Pokhrel & Soni, 2018), and by 51.85% in China with rice stubble planting (Liu et al 2021). Improved yield may result from better soil structure, moisture retention, and organic matter (Hazarika et al 2018; Hossain et al., 2020). Rice straw (3.52 cm) and dried leaves (3.51 cm) gave the largest bulb diameters, while sugarcane trash had the smallest (3.1 cm). Economic yield was highest under zero tillage (17.57 mt/ha) and rice straw mulch (17.56 mt/ha). These findings align with (Awe et al 2015), who noted rice straw mulch improves water use efficiency and microbial biomass. Rice straw (C/N 51:1) and dried leaves (50:1) performed better than sugarcane trash (60.19:1) (Alagesan and Dheeba 2010) rice husk (85:1) (Thiyageshwari et al 2018), and sawdust (200–500:1) due to their lower C/N ratios, promoting faster decomposition (Boyd 2009). Straw mulch also stabilizes soil temperature (Chen et al 2007) and reduces weed infestation, contributing to higher yields.

Table 6: Yield parameters of garlic influenced by tillage and mulching practices at Godawari, Kailali, 2021/22

Treatments	Yield parameters		
	Bulb diameter (cm)	Bulb weight (g)	Economic yield (mt/ha)
Tillage methods (Main plot)			
Zero tillage	3.59 ^a	27.65 ^a	17.56 ^a
Conventional tillage	3.03 ^b	20.59 ^b	13.08 ^b
SEm (±)	0.016	0.20	0.128
LSD _{0.05}	0.32*	4.03*	2.56*
CV, %	9.5	16.6	16.9
Mulching practices (Sub-plot)			
Rice straw	3.52 ^a	27.68 ^a	17.57 ^a
Rice husk	3.32 ^b	23.83 ^c	15.13 ^c
Saw dust	3.12 ^c	21.74 ^d	13.81 ^c
Sugarcane trashes	3.1 ^c	21.28 ^d	13.51 ^d
Dried leaves	3.51 ^a	26.11 ^b	16.57 ^b
SEm (±)	0.021	0.19	0.12
LSD _{0.05}	0.24***	1.56***	0.99***
CV, %	5	6.5	6.3

Means followed by the same letter (s) within a column are not significantly different from each other at 5% level of significance by DMRT; ***= significant at p<0.001, **= significant at p<0.01 and *= significant at p<0.05 and ns: not significantly different at 5% (p >0.05). SEM = Standard error of mean, LSD = Least significant difference, CV = Coefficient of variation

Tillage–mulch interaction significantly influenced bulb weight, diameter, and yield (p<0.05). Zero tillage with rice straw gave the heaviest bulbs (31.21 g) and the highest yield (19.82 t/ha), while dried leaves gave the largest diameter (3.75 cm). The lowest values were from conventional tillage with sawdust.

Economic analysis of garlic production

Net income and benefit cost ratio

Net returns and B: C ratio varied with method of tillage, mulching practices and their combinations of different treatments. At the time of harvest price of garlic in Kailali district varied from NRs. 120 kg⁻¹ to NRs. 200 kg⁻¹. The highest net return (NRs. /Ha 2719715) was recorded at the treatment zero tillage with rice straw mulching. Higher profit was due to higher bulb yield and more gross return. The lowest net return (NRs. /Ha 1322879) was recorded at the treatment conventional tillage with saw dust mulching. The B: C ratio was the highest (11.77) at the treatment zero tillage with rice straw mulching followed by zero tillage with dried leaves mulching (11.41). On the contrast, lowest B: C ratio (5.63) was observed from the treatment conventional tillage with saw dust mulching.

Table 7: Cost of production (NRs.ha-1) of garlic at different combinations of tillage and mulching practices at Godavari, Kailali, 2021/22

Treatments	Land preparation and labor	Planting material	Mulching practices	Manure and fertilizer	Others	Total
T1M1	28750	135000	24800	55000	9000	252550
T1M2	28750	135000	34680	55000	9000	262430
T1M3	28750	135000	31750	55000	9000	259500
T1M4	28750	135000	35720	55000	9000	263470
T1M5	28750	135000	19840	55000	9000	247590
T2M1	55000	135000	24800	55000	9000	278800
T2M2	55000	135000	34680	55000	9000	288680
T2M3	55000	135000	31750	55000	9000	285750
T2M4	55000	135000	35720	55000	9000	289720
T2M5	55000	135000	19840	55000	9000	273840

T1= Zero tillage, T2= Conventional tillage, M1= Rice straw mulch, M2= Rice husk mulch, M3= Saw dust mulch, M4= Sugarcane mulch, M5= Dried leaves mulch, NRs= Nepali Rupees

Table 8: Benefit cost ratio of garlic production at different combination of tillage and mulching practices at Godawari, Kailali, 2021/22

Treatments	Bulb yield (Kg ha ⁻¹)	Price (NRs Kg ⁻¹)	Gross income (NRs.)	Total cost (NRs.)	Net return (NRs.)	B:C ratio
T1M1	19815.1	120	2972265	252550	2719715	11.77
T1M2	17364.03	120	2604605	262430	2342175	9.92
T1M3	16886.03	120	2532905	259500	2273405	9.76
T1M4	14905.42	120	2235813	263470	1972343	8.49
T1M5	18831.75	120	2824763	247590	2577173	11.41
T2M1	15332.04	120	2299806	278800	2021006	8.25
T2M2	15332.04	120	2299806	288680	2011126	7.97
T2M3	10724.19	120	1608629	285750	1322879	5.63
T2M4	12115.98	120	1817397	289720	1527677	6.27
T2M5	14317.46	120	2147619	273840	1873779	7.84

T1= Zero tillage, T2= Conventional tillage, M1= Rice straw mulch, M2= Rice husk mulch, M3+ Saw dust mulch, M4= Sugarcane mulch, M5= Dried leaves mulch, NRs= Nepali Rupees, B:C = Benefit:Cost

Soil parameters

Effect of tillage and mulching on soil physical and chemical properties

Soil properties varied differently to tillage and mulching. Soil pH slightly increased post-harvest, highest (0.22) in conventional tillage with rice straw and lowest (0.04) in zero tillage with sawdust. Rice straw decomposition can increase soil acidity due to its higher content of organic acids like oxalic acid, which releases hydrogen ions (Wang et al 2022). Contrarily, higher cellulose and hemicellulose and lower lignin content in sawdust allow faster decomposition and may result in less acidity (Bernd et al 2017). Organic matter increased most (0.86) in zero tillage with dried leaves, and least (0.41) in zero tillage with sugarcane trash. Bulk density increased most (0.21) in conventional tillage with rice straw, and least (0.04) in zero tillage with sugarcane trash. Soil texture and NPK levels remained mostly unchanged. (He et al 2011) and (Mohammadshirazi et al 2017) suggested that no-till farming helps reduce soil bulk density, especially in compacted soils.

Correlation between yield and other parameters

Yield showed a significant positive correlation ($p < 0.05$) with plant height ($r = 0.77$), (fig. 1), and clove diameter ($r = 0.76$) (Fig. 2). Plant height explained 60% ($R^2 = 0.60$), and clove diameter 61% ($R^2 = 0.61$) of the yield variation, with the rest attributed to other factors.

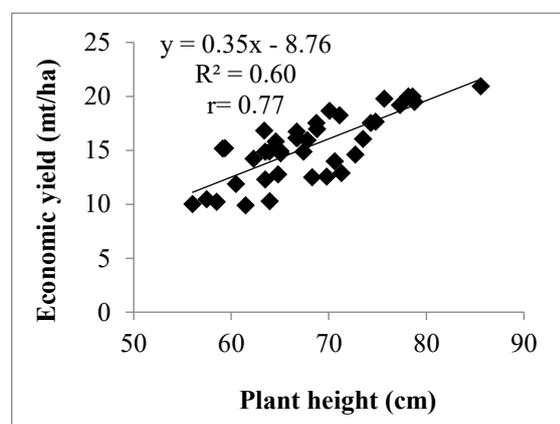


Figure 1. Correlation between yield and plant height of garlic at Godawari, Kailali, 2021/22

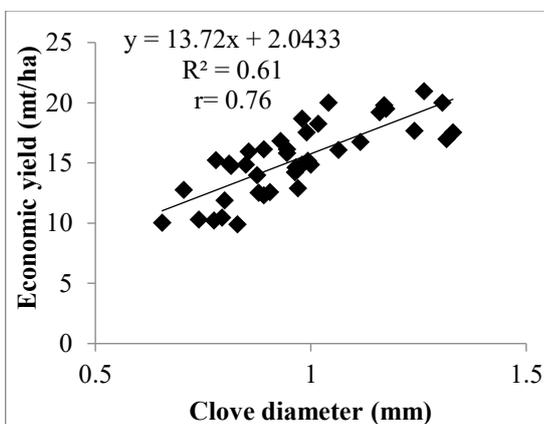


Figure 2. Correlation between yield and clove diameter of garlic at Godawari, Kailali, 2021/22

Economic parameters

Net returns and B: C ratio varied with tillage methods, mulching practices, and their combinations. Garlic, a high-value crop, sold for NRs. 120–200/kg in Kailali during harvest. The highest net return (NRs. 2,719,715/ha) and B: C ratio (11.77) were recorded under zero tillage with rice straw mulching, while the lowest net return (NRs. 1,322,879/ha) and B: C ratio (5.63) occurred under conventional tillage with sawdust mulching.

CONCLUSION

The research findings demonstrate the significant impact of different tillage and mulching practices on garlic (*Allium sativum* L.) growth and yield in the Terai region of Nepal. Zero tillage significantly performed better in terms of growth and higher yield than conventional tillage. The retention of rice crop residue on the soil surface, leading to moisture conservation, temperature stability, and increased organic matter content, may be the reason for better performance in zero tillage conditions. Among mulches, rice straw and dried leaves performed best. The interaction of zero tillage with rice straw, as well as dried leaves mulching performed superior results in growth, yield, weed control, and profitability, with the highest B: C ratio in zero tillage with rice straw. Thus, this combination zero tillage along with rice straw and dried mulching is recommended for enhancing garlic production and economics.

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AUTHORS' CONTRIBUTION

Bhawana Bhatta designed the experiment, conducted field and laboratory work, record and analyze the data, and wrote the manuscript. Hom Nath Giri, PhD supervised the research, guided for data analysis, helped in writing the manuscript, critically reviewed, evaluated and edited the manuscript.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The article's publication is approved by all authors and by the responsible authorities where the work was carried out.

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