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ORIGINAL RESEARCH ARTICLE

Performance of kharif maize under conservation tillage in silty clay loam soil

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ABSTRACT

Maize is a major staple food as well as potential cash crop for millions of people, mostly grown in the winter season in Bangladesh under conventional tillage practice. But huge area of cultivable land remains fallow in kharif-1 season in Sylhet region as well as other parts of Bangladesh. Hence, we aimed to identify the best variety and tillage method to grow maize in silty clay loam soil in kharif season. An experiment was conducted to study the performance of six maize varieties in the Kharif-I season (summer) under three tillage methods in silty clay loam soil of Eastern Surma-Kushiyara floodplain (AEZ-20). The experiment was arranged in RCBD with three replications to observe yield contributing traits and yield performance of maize. Among the varieties, BARI Hybrid Maize-16 showed the highest yield attributes and grain yield followed by BARI Hybrid Maize-13 and BARI Hybrid Maize-9. Based on tillage, the maximum number of leaves per plant, cob length and diameter, kernel rows per cob, kernels per row, kernels per cob, highest grain yield, and stover yields were recorded in conventional tillage. Therefore, considering the yield and tillage methods, BARI Hybrid Maize-16 showed the best yield performance under conventional tillage in the kharif-I season in silty clay loam soil of Eastern Surma-Kushiyara floodplain of Bangladesh.

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INTRODUCTION

Maize (*Zea mays* L.) is the world's leading cereal crop, ranking second in Bangladesh for area coverage (0.472 m ha) and total grain production (4.02 m t) (FAO, 2021). To cover up the predicted expansion of cereal consumption, primary cereal crops alone will need to increase by 70% by 2050 (Cairns *et al*., 2013). In Bangladesh, maize fields have quickly spread in the last decade and entered the food chain as flour blends and indirectly as cattle feed. It is mostly used in poultry business, accounting for 90% of annual maize consumption (Islam *et al*., 2019). However, maize production is affected by low yielding variety, erratic weather, poor soil fertility, lack of irrigation facilities, insect and pest attacks, and market instability (Paul *et al*., 2015). From Bangladesh's agroedaphic point of view, maize can be grown all over the country under a wide range of soil conditions. Variations in maize varieties significantly influence grain yield performance. Hybrid varieties yield more than twice as much as native varieties (Hasan *et al*., 2018). Maize cultivated in Kharif-I season requires lower irrigation water than rice, creating an opportunity to use fallow or uncultivated land of the Sylhet region.

Tillage is one of the most important crop production elements, accounting for a significant increase in crop production (Cassel *et al*., 1995), and also effective means to mitigate the drought stress (Schneider *et al*., 2017). Tillage operation modifies the physicochemical properties of soil, controls weed and provides a suitable seedbed for plants; adds crop residues to the soil; loosens the soil; increases chemical reactions; and ultimately

improves the physio-chemical state of the soil, leading to increased growth and production (Wasaya *et al*., 2019). Choosing a suitable tillage practice for maize production is a critical factor to ensure optimum crop development and grain yield. In addition, tillage practices affect maize seedling emergence and growth as the variations create different soil conditions. Deep tillage is good for maize cultivation whereas zero tillage is also an appropriate method of sowing but has less advantage than deep and conventional tillage (Memon *et al*., 2011). Conventional tillage creates well-planned seedbeds, reduces weed competition, improves soil aeration, and incorporates organic matter to improve maize production compared to minimum tillage (Khurshid *et al*., 2006). Considering the above facts, the present study was planned to compare the effect of tillage methods on yield contributing traits and yield performance of maize varieties in Kharif-I season in silt clay loam soil of floodplain of the Sylhet region.

MATERIALS AND METHODS

Experimental design

The experimental area was located at Satra village of Sylhet Sadar Upazilla, Sylhet (24°57'17"N and 91°47'52"E) in the North Eastern region of Bangladesh (Eastern Surma-Kushiyara Floodplain, AEZ-20). The soil was silty clay loam with very low organic matter content (1.36%) and acidic in nature (pH 5.2). The N (0.11%) and S (22 ppm) content is low and P (12.0 ppm) content is very low, whereas K (0.17 me/100 g), Zn (94 ppm) and B (0.41 ppm) content is medium. The two-factor experiment was arranged in a randomized complete block design with three replications. First factor contains six maize varieties viz. BARI Hybrid Maize-16 (V1), BARI Hybrid Maize-13 (V2), BARI Hybrid Maize-9 (V3), BARI khoibhutta (V4), Heera 109 (V5) and Super Shine 2760 (V6). Second factor includes three tillage methods viz., conventional tillage (T1), reduced tillage (T2), and zero tillage (T3).

Conventional tillage uses four ploughing with cross-ploughing with power tiller along with laddering, which was done at field capacity conditions to prepare the land. Conservation tillage uses one ploughing with power tiller along with laddering. In case of zero tillage and reduced tillage, weeds were removed from the field and prepared the field for plantation. Recommended levels of fertilizers were applied to the plots at the rate of 160, 40, 105, 40, 3, 1 and 4000 kg ha^{-1} of nitrogen, phosphorus, potassium, sulphur, zinc, boron, and cow-dung, respectively. Each plot was 4.0 m × 2.5 m, with total of 54 plots. Spacing between blocks was 1.0 m and spacing between plots was 0.5 m. Seeds were sown maintaining the spacing 65 cm in a row to row and 25 cm in a plant to plant. Gap filling was done 15 days after sowing. Other necessary operations such as weed management, pest controls and irrigation etc. were performed following standard cultivation practice on high yield goal basis.

Observation and data collection

Grain yield and yield traits, including plant height, leaves per plant, cob length, cob diameter, kernel rows per cob, kernels per row, and kernels per cob, were determined by harvesting ten plants randomly from each plot at full maturity. The weight of 1000 grains and stover yield from each plot were taken using a digital balance and calculated using standard procedures.

Harvest index was calculated by using following formula.

Biological yield = grain yield + straw yield

HI = economic yield/biological yield × 100

Statistical analysis of data

Statistical analysis was conducted using the R software version 3.4.2. Means were separated using least significant difference (LSD) at $p \leq 0.05$ to pinpoint significant differences between treatment means.

RESULTS AND DISCUSSION

In this study, the effect of tillage methods on yield contributing traits and yield of maize varieties were analyzed to observe the performance and increase maize cultivation in Kharif-I for the Sylhet region.

Plant height

Plant height is a crucial genetic character significantly influenced by the varietal effect and varied for crop management strategy (Enujeke *et al*., 2013). It represents the growth and development of the maize varieties. A significant effect on the plant height of maize was found among the varieties. The highest plant height (236.25 cm) was recorded in Super Shine 2760 followed by BARI Hybrid Maize-9 (227.09 cm), and Heera 109 (221.32 cm). The lowest plant height was recorded in BARI Hybrid Maize- 16 (211.82 cm), which is a high-yielding but short stature plant (Table 1). We also observed a significant difference in plant height for tillage operation as the conventional tillage method produced the highest plant height. Conventional tillage produced the highest plant height in maize (Khurshid *et al*. 2006). In tillage methods, the highest plant height was found in conventional tillage (228.53 cm), while the lowest (216.88 cm) was recorded in zero tillage (Table 2). In combined effects, the highest plant height was recorded in V6T1 (239.33 cm) and the lowest result in V3T3 (205.8 cm) (Table 3). Even the combined effect of variety and tillage significantly affected the plant height of maize varieties, similar findings were reported earlier by Memon *et al.* (2013).

Leaves per plant

Leaves per plant is a vital yield-contributing trait of maize as it indicates photosynthetic area. In this study, leaves per plant was significantly affected by a variety of maize, tillage methods, and combined interaction. Heera 109 (15.58) was recorded for the maximum leaves per plant followed by BARI Hybrid

Maize-16 (15.48), and BARI Hybrid Maize- 9 (15.32) (Table 1). The lowest result was found in BARI khoibhutta (15.07) and Super Shine 2760 (15.08). Regarding tillage systems, the highest number of leaves per plant (16.01) was found in conventional tillage and the minimum result (14.76) was recorded in zero tillage (Table 2). Albuquerque *et al.* (2001) exhibited statistically reduction of green leaf numbers with no tillage method compared to conventional tillage, similar to our findings. Combine effects showed the maximum number of leaves per plant in V5T1 (16.47), while the minimum result was recorded in V4T3 (14.57) (Table 3).

Table 1. Plant height and yield contributing character of maize due to effect of variety.

Variety	Plant height (cm)	Leaves plant^{-1} (no.)	Cob length (cm)	Cob diameter (cm)	Kernels rows cob^{-1} (no.)	Kernels row^{-1} (no.)	Kernels cob^{-1} (no.)	1000-grain weight (g)
V_1	211.82c	15.48ab	16.52 a	4.30a	17.33a	31.40b	527.35a	235.38a
V_2	221.27c	15.18bc	15.50b	4.14b	15.93b	31.71b	479.92b	232.88b
V_3	227.09b	15.32abc	15.30bc	4.19 b	17.05a	32.54a	526.91a	226.17c
V_4	213.57c	15.07c	16.24a	4.01c	14.78d	30.24c	420.75c	150.11e
V_5	221.32b	15.58a	14.75cd	3.98c	15.41c	28.62d	414.33c	228.59c
V_6	236.25a	15.08c	14.61d	4.03c	14.86d	27.68e	384.17d	222.72d
LSD	4.47	0.33	0.63	0.1	0.31	0.5	12.5	2.07

V1= BARI Hybrid Maize-16, V2= BARI Hybrid Maize-13, V3= BARI Hybrid Maize- 9, V4= BARI khoibhutta, V5=Heera 109 and V6= Super Shine 2760. Values having different letters varied significantly at $p \leq 0.05$.

Table 2. Plant height and yield contributing character of maize due to different tillage operations.

Tillage	Plant height (cm)	Leaves plant^{-1} (no.)	Cob length (cm)	Cob diameter (cm)	Kernel rows cob^{-1} (no.)	Kernels row^{-1} (no.)	Kernels cob^{-1} (no.)	Thousand grain weight (g)
T1	228.53a	16.01a	15.95a	4.18a	16.06a	30.71a	467.55a	216.82 a
T2	220.25b	15.11b	15.39b	4.10b	15.84ab	30.19b	452.83b	216.59 a
T3	216.88c	14.76c	15.12b	4.05b	15.78b	30.19b	451.33b	214.96 b
LSD	3.16	0.24	0.45	0.07	0.22	0.35	8.85	1.47

T1= Conventional tillage, T2=Reduced tillage and T3= Zero tillage. Values having different letters varied significantly at $p \leq 0.05$.

Table 3. Combined effects of variety and tillage on the yield attributes and yield of maize.

Variety and Tillage	Plant height (cm)	Leaves plant^{-1} (no.)	Cob length (cm)	Cob diameter (cm)	Kernel rows cob^{-1} (no.)	Kernels row^{-1} (no.)	Kernels cob^{-1} (no.)	Thousand grain weight (g)
V1T1	214.13cde	16.26ab	17.14a	4.34a	17.53a	31.77bcd	528.95ab	227.47bc
V2T1	236.07a	15.90abc	15.85bcd	4.24a-d	16.10d	32.13abc	492.07cd	235.88a
V3T1	220.2c	16.13ab	15.72cde	4.27ab	17.43ab	32.63a	540.57a	229.00b
V4T1	218.27cd	15.77bcd	16.87ab	4.10c-g	14.77h	30.73ef	427.17e	151.07e
V5T1	227.53b	16.47a	15.24c-g	4.02efg	15.63def	29.03hi	426.92e	234.37a
V6T1	239.33a	15.5cde	14.87d-g	4.08d-g	14.90gh	27.97jk	389.62fg	223.15d
V1T2	213.63def	15.23d-g	16.19abc	4.31a	17.25abc	32.23de	511.67bc	227.21bc
V2T2	214.33cde	14.87gh	15.42c-f	4.10c-g	15.77de	31.43cde	470.68d	235.27a
V3T2	208.27efg	15.07e-h	15.47c-f	4.18a-e	16.78c	32.57ab	518.67b	227.79bc
V4T2	212.53def	14.90fgh	16.03bc	3.97fg	14.90gh	29.87gh	418.09e	151.54e
V5T2	219.97c	15.47c-f	14.56fg	3.98fg	15.40efg	28.30ij	409.35ef	234.24a
V6T2	235.77a	15.13e-h	14.68efg	4.01fg	14.97gh	27.77jk	388.49fg	223.47d
V1T3	207.7fg	14.97e-h	16.22abc	4.25abc	17.23abc	31.20de	511.42c	225.08cd
V2T3	213.43def	14.80gh	15.23c-g	4.08d-g	15.93de	31.57cde	476.99d	235.00a
V3T3	205.80g	14.77 gh	14.69efg	4.11b-f	16.93bc	32.43ab	521.49ab	227.72bc
V4T3	209.9efg	14.57h	15.82bcd	3.96fg	14.67h	30.13fg	416.99e	150.39e
V5T3	216.47cd	14.83gh	14.45fg	3.94g	15.20fgh	28.53ij	406.71ef	230.02b
V6T3	233.67ab	14.60h	14.28g	3.98fg	14.70h	27.30k	374.40g	221.54d
LSD	6.33	0.58	1.1	0.17	0.53	0.86	21.68	3.59

V1=BARI Hybrid Maize-16, V2=BARI Hybrid Maize-13, V3= BARI Hybrid Maize-9, V4= BARI khoibhutta, V5= Heera 109 and V6= Super Shine 2760 and T1=Conventional tillage, T2=Reduced tillage and T3=Zero tillage. Values having different letters were varied significantly at $p \leq 0.05$.

Cob size

Cob size including cob length and cob diameter was significantly influenced by maize varieties. The highest cob length was recorded in BARI Hybrid Maize-16 (16.52 cm), while the Super Shine 2760 (14.61 cm) showed the lowest cob length (Table 1). In tillage methods, the highest (15.95 cm) cob length was found in the conventional tillage system and the lowest result (15.12 cm) was found in zero tillage (Table 2). Ramos *et al.* (2019) and Shahzad *et al.* (2015) reported similar findings . They found that cob size of maize was affected by tillage methods and the largest cob was observed in conventional tillage. In treatment combinations, V1T1 (17.14 cm) was found to have the highest cob length, while the lowest cob length was recorded at V6T3 (14.28 cm) (Table 3). Cob diameter represents the size of maize kernels and BARI Hybrid Maize-16 showed the highest (4.30 cm) diameter followed by BARI Hybrid Maize- 13 (4.14 cm) and BARI Hybrid Maize-9 (4.19 cm) (Table 1). Regarding tillage methods, the highest cob diameter (4.18 cm) was recorded in conventional tillage practices and the lowest one (4.05 cm) was found in zero tillage (Table 2). The combination treatment V1T1 (4.34 cm) was found to have the maximum cob diameter, while the lowest cob diameter was recorded in V5T3 (3.94 cm) (Table 3).

Yield contributing traits

Certain traits of maize, such as kernel rows per cob, kernels per row, and rows per ear, are highly related to the grain yield (Shi, 2022). Yield contributing traits include kernel rows per cob, kernels per row, and kernels per cob, which showed significant variation in maize varieties. The highest number of kernel rows per cob was recorded in BARI Hybrid Maize-16 (17.33), while the lowest was found in BARI khoibhutta (14.78). BARI Hybrid Maize- 9 variety showed the highest number (32.54) kernels per row and the lowest was recorded in Super Shine 2760 (27.68). The maximum kernels per cob were found at BARI Hybrid Maize -16 (527.35) whereas minimum kernels per cob were recorded on Super Shine 2760 (384.17) (Table 1). Conventional tillage showed the maximum kernel rows per cob (16.06), kernels per row (30.7), and kernels per cob (16.06) in maize. On the other hand, zero tillage systems showed the lowest kernels per cob (15.78), kernels per row (30.19), and kernels per cob (15.78) (Table 2). In treatment combinations, the highest number of kernel rows per cob was recorded in V1T1(17.53) and the lowest result in V4T3 (14.67). V1T1 was found to have the highest kernels per cob (540.57), while the minimum was observed at V6T3 (374.40). In kernels per row, the highest was recorded at V3T1 (32.63) and the lowest at V6T3 (27.30) (Table 3). Conventional tillage showed the highest positive results in these yield contributing traits, matched with the findings of Rashidi *et al.* (2007), Shahid *et al.* (2016), and Karki *et al.* (2015).

Thousand grain weight

Grain weight is an important indicator for evaluating maize quality and yield performance. This study indicates a significant result of thousand-grain weight for maize variety and tillage methods. The highest thousand grain weight was recorded in BARI Hybrid Maize- 16 (235.38g) followed by BARI Hybrid Maize- 13 (232.88 g), whereas the lowest weight was recorded in BARI khoibhutta (150.11g) (Table 1). Regarding tillage methods, conventional tillage showed the highest (216.82 g) thousand grain weight, and the lowest (214.96 g) was recorded in zero tillage (Table 2). In treatment combination, the maximum thousand grain weight (235.88 g) was found in V1T1, while the lowest weight was recorded at V4T3 (150.39 g) (Table 3). BARI Hybrid Maize-16 on conventional tillage produced the highest thousand grain weight. On the other hand, BARI khoibhutta produces the lowest thousand grain weight in all tillage operations. Hasan *et al.* (2018) reported the lowest result in yield contributing traits and grain weight in BARI khoibhutta, similar to our findings.

Yield components

Yield components of maize showed a significant effect on grain yield, stover yield, biological yield, and harvest index. Grain yield is an outcome of numerous complex morphological and physiological processes that occur during a crop's growth and development (Zamir *et al.* 2011, Anjum *et al.* 2019). Maize varieties and tillage methods exerted a significant effect on grain yield in the kharif-1 season. The highest grain yield (7.87 t ha^{-1}) and harvest index (39.08%) were found in BARI Hybrid Maize-16. On the other hand, the lowest grain yield (4.03 t ha^{-1}) and harvest index (26.57%) were recorded in BARI khoibhutta. Super Shine 2760 (13.04 t ha^{-1}) produced the highest stover yield, while the lowest result was found in BARI khoibhutta (11.40 t ha^{-1}) (Figure 1), par at Hasan *et al.* (2018). Conventional tillage showed the highest grain yield (6.58 t ha^{-1}), stover yield (12.18 t ha^{-1}), and harvest

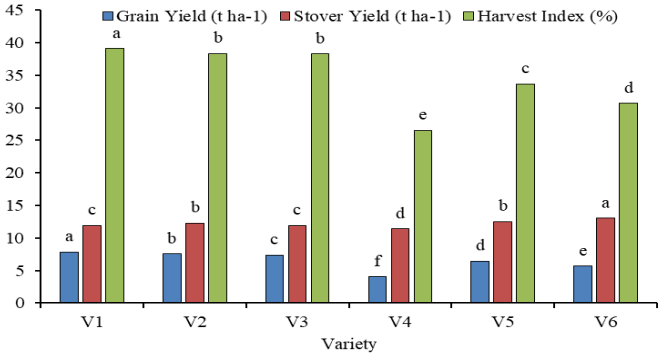


Figure 1. *Grain yield, stover yield, and harvest index of maize varieties. V1=BARI Hybrid Maize-16, V2=BARI Hybrid Maize-13, V3= BARI Hybrid Maize-9, V4= BARI khoibhutta, V5=Heera 109 and V6= Super Shine 2760. Values having different letters varied significantly at p ≤ 0.05.*

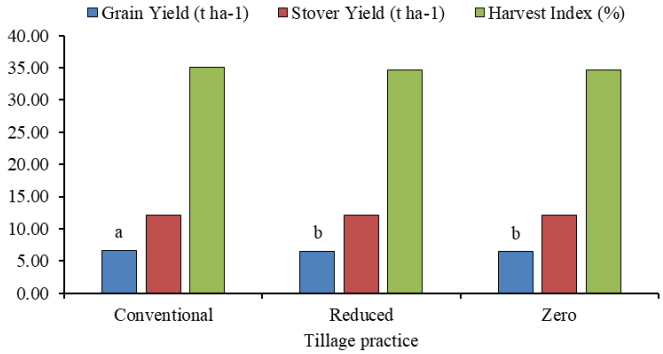


Figure 2. *Grain yield, stover yield, and harvest index of maize under different tillage operations. T1= Conventional tillage, T2= Reduced tillage and T3= Zero tillage. Values having different letters were varied significantly at p ≤ 0.05.*

index (35.07%). In contrast, the lowest grain yield (6.38 t ha^{-1}), stover yield (12.13 t ha^{-1}), and harvest index (34.61%) were recorded on zero tillage (Figure 2). In treatment combinations, the highest grain yield was found in V1T1(7.88 t ha^{-1}), and the lowest was recorded at V6T2 (3.98 t ha^{-1}). Stover yield was the maximum at V4T3 (12.94 t ha^{-1}) and minimum at V6T2 (11.28 t ha^{-1}). The highest harvest index was recorded in V3T1 (39.65%) and the lowest results were recorded in V5T2 (25.99%) (Figure 3). Khan *et al.* (2001), Khurshid *et al.* (2006) and Yusuf (2006), all reported minimum grain yield in zero tillage due to greater soil bulk density and soil penetration resistance, which adversely affects seed emergence, root growth, and removal of soil moisture quickly, agreeing with our findings.

Benefit cost ratio

Benefit cost ratio (BCR) is an index that shows the comparative explanation of a farmer's investment toward crops (Kandil *et al.* 2020). Among the maize varieties, the highest BCR was recorded in BARI hybrid maize-16 (1.52) which was followed by BARI hybrid maize-13 (1.46), while the lowest BCR was recorded in BARI khoibhutta (1.08) (Figure 4a). On the contrary, the highest BCR was found in zero tillage (1.31) and the lowest result was found in reduced tillage (1.24) (Figure 4b). In treatment combinations, the highest BCR was found in V1T3 (1.64) and the lowest result was found in V4T1 (1.07). Hence, BARI hybrid maize-16 in zero tillage showed the highest BCR due to lower cultivation cost whereas the BARI khoibhutta in conventional tillage showed the lowest result (Figure 4c) due to higher cultivation cost agreeing with Gathala *et al.* (2015).

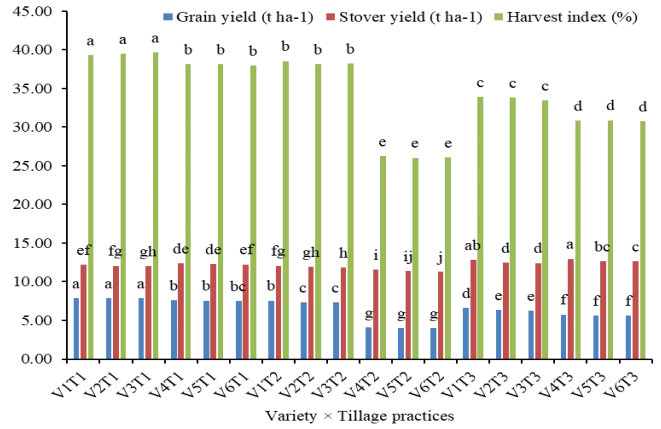
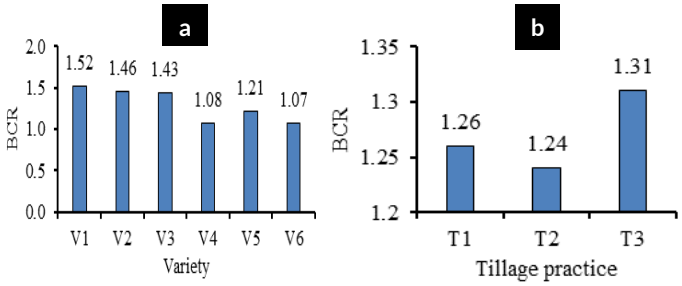


Figure 3. *Grain yield, stover yield and harvest index of maize under combined effects of varieties and tillage. V1=BARI Hybrid Maize-16, V2=BARI Hybrid Maize-13, V3= BARI Hybrid Maize-9, V4=BARI khoibhutta, V5=Heera 109 and V6=Super Shine 2760. T1=Conventional tillage, T2=Reduced tillage and T3=Zero tillage. Values having different letters were varied significantly at p ≤ 0.05.*



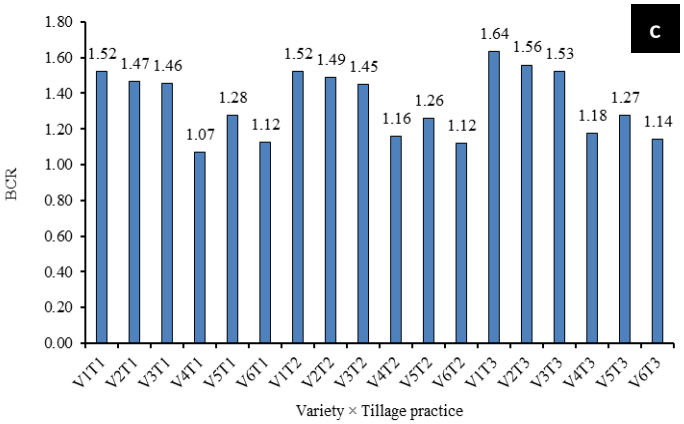


Figure 4. *Benefit cost ratio of maize on as affected by combined effect of variety and tillage method. V1=BARI Hybrid Maize-16, V2=BARI Hybrid Maize-13, V3= BARI Hybrid Maize-9, V4=BARI khoibhutta, V5=Heera 109 and V6=Super Shine 2760. T1=Conventional tillage, T2=Reduced tillage and T3=Zero tillage. Values having different letters were varied significantly at p ≤ 0.05.*

Conclusion

This study examined the effect of three different tillage practices on the performance of six maize varieties. Based on the results obtained, the following conclusions are drawn: the highest yield contributing trails, such as the number of leaves, highest cob length, cob diameter, kernel rows per cob, and kernels per cob were recorded in BARI Hybrid Maize-16. Among the tillage practices, conventional tillage was the most effective methods for those yield contributing characters. Most yield components such as grain yield, biological yield, and harvest index were highest on BARI hybrid maize-16 in conventional tillage. Considering the maize varieties and tillage methods, the BARI Hybrid Maize-16 in conventional tillage method is more appropriate and profitable in the Kharif-I season in silty clay loam texture soil.

DECLARATIONS

Authors contribution

Conceptualization and methodology: MNAP and MH, experiment and data collection: MNAP, MSK, TA and RKD, data analysis: NR, writing-original draft: MNAP, NR and AI, Writing-review, editing and supervision: MH. All authors have read, finalized and agreed to the published version of the manuscript.

Conflicts of interest: The authors declare no conflict of interest.

Ethics approval: This study did not involve any animal or human participant and thus ethical approval was not applicable.

Consent for publication: All co-authors gave their consent to publish.

Data availability: The data that support the findings of this study are available on request from the corresponding author.

Supplementary data: Not available.

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