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Maize-Chickpea Intercropping under Diverse Tillage Systems Enhance the Productivity and Economic Returns

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Abstract: Intercropping is an attractive strategy to increase crop productivity and economic return through the efficient utilization of natural resources and agricultural inputs. A study was conducted to determine the profitable crop arrangement for the maize and chickpea intercropping system in Bangladesh. The experiment was laid out in a split-plot design with three replications. Treatments comprised of three different tillage methods namely conventional tillage (CT), zero tillage (ZT) and raised bed system assigned in the main plot and six different cropping systems viz. sole maize, sole chickpea, maize + chickpea (1:1), maize + chickpea (1:2), maize + chickpea (2:1) and maize + chickpea (2:2) cropping assigned in the sub-plot. The result demonstrated that the yield performance was affected by the tillage method as well as the row arrangement of maize and chickpea as intercrops. The study suggests that intercropping two rows of maize with two rows of chickpea under raised bed system is the most compatible in respect of productivity and profitability.

Key words: Intercropping · Maize · Legume · Chickpea · Tillage · Productivity and Profitability

INTRODUCTION

Intercropping is the cultivation of two or more crops simultaneously on a given piece of land using the resources or ecological processes. It is a potential way of increasing total yield per unit area and time, especially for small holding farmers. The main concept of intercropping is to increase productivity and reliability of production. Furthermore, intercropping gives yield stability over mono-cropping and ensures greater resource use efficiency [1]. A good combination for intercropping is the cereal-legume mixture which can provide one crop component high in carbohydrates and other rich in proteins [2], helps to maintain and improve soil fertility [3] and suppressed weed growth [4]. Maize is a widely spaced crop and there is ample scope to grow short duration intercrops in the interspaces. Legumes are common components of the intercropping system and it has offered an energy-efficient sustainable economy [5]. It has been postulated that non-legumes are benefit from the association of legumes. Intercropping is the technique of small farmer which enhance subsoil N retrieval and increase crop yield from the sole cropping system [6] and finally maximize the net income [1, 7].

Tillage is one of the important processes in agriculture since it contributes up to 20% of crop production factors [8]. It also has a significant effect on soil properties. The type and intensity of tillage affect the sustainability through its influence on soil properties. Conventional tillage decreases soil compaction and provides favourable seedbed preparation, enhances root growth and development, controls weeds and maintains crop yields [9, 10]. But loose soil resulting from frequent tillage is prone to water and wind erosion. Conservation agriculture may be a viable alternative to make maize farming sustainable while conserving the soil. Zero tillage

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with residue retention is advantageous to reducing surface run-off and subsequent soil losses with no loss of yield of maize [9, 11]. In the meantime, maize-based intercropping under reduced or no-tillage system in different crops like soybean[9], wheat [12, 13], common bean [14] and legume [1, 15] etc. have been reported yield improvement, however, in some cases yield reduction under the intercropping system.

Bangladesh is one of the most densely populated countries in the world with a population of over 160 million and a projected population, based on current growth trends, of well over 200 million by 2050 [16]. To meet up the demand for food for such a big population, an intercropping system with other efficient agronomic techniques can be an important tool for getting higher productivity per unit area of land and it improves food security. Considering the background, the present study was undertaken to determine the performance including yield advantages/economic gains obtained from a maize-chickpea intercropping system under different tillage systems and to explore the feasibility and production potential of different maize-chickpea intercropping systems.

MATERIALS AND METHODS

Experimental Site and Materials: The experiment was conducted at the agronomy field laboratory of Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh from November 2016 to April 2017. Geographically the experimental site is located at 24°25"N latitude and 90°50"E longitude. The soil is non-calcareous dark grey flood plain soil under the Sonatola series of Old Brahmaputra alluvial soil (AEZ 9). The topography was a medium low land, fairly leveled and silt loam in texture having a soil pH 6.32. A short stature chickpea (cv. BARI chola-5) was intercrop with BARI hybrid maize-9. The seeds were collected from Bangladesh Agricultural Research Institute (BARI), Joydabpur, Bangladesh.

Treatments and Design: Treatments consisted of three different tillage methods namely conventional tillage (T1), zero tillage (T2) and raised bed system (T3) assigned in the main plot and six different cropping systems namely sole maize (I1), sole chickpea (I2), maize +chickpea (1:1) (I3), maize + chickpea(1:2) (I4), maize + chickpea(2:1) (I5) and maize+ chickpea (2:2) (I6) cropping assigned in the sub plot. The experiment was laid out in a split-plot design with three replications.

Crop Husbandry: The land was prepared well by ploughing and cross-ploughing using rotavator to produce a good environment for seed germination and plant growth. A blanket dose of fertilizer (245-56-96-24-20 kg: N-P-K-Ca-S ha^{-1}) was applied on a high yield goal basis of maize. Normal spacing (70 cm x 30 cm) was followed in sowing maize and chickpea was sown at 30 cm x 10 cm. In intercropping, two rows of chickpea were sown between the maize rows. Irrigation, weeding, pest control, mulching and other intercultural operations were done as per requirement.

Collection of Yield Data: In case of maize, data on plant height (cm), number of leaves $plant^{-1}$, leaf area index, kernels cob^{-1}, 1000 grain weight (g), length of cob (cm), the diameter of cob (cm), grain yield (t ha^{-1}), Stover yield (t ha^{-1}), biological yield (t ha^{-1}), harvest Index (%) were collected from randomly selected ten plants per plot. Similarly, in case of chickpea, data on plant height (cm), number of branches $plant^{-1}$, number of pods $plant^{-1}$, number of seeds pod^{-1}, 1000 seed weight(g), seed yield (t ha^{-1}), Stover yield (t ha^{-1}), biological yield (t ha^{-1}), harvest index (%) were collected from randomly selected ten plants per plot.

Maize equivalent yield was computed by converting the yield of companion crop (chickpea) into the yield of main crop (maize) based on prevailing market price using the following formulae [17].

$$Maize\ equivalent\ yield = Ym + \frac{Yi + Pi}{Pm}$$

where, Ym = Grain yield of intercrop maize, Yi =Grain yield of intercrop chickpea, Pi = Market price of chickpea seed, Pm = Market price of maize grain.

Land equivalent ratio (LER) was used for comparison among the treatments. LER values were computed from the grain yield data of the crops according to the following formula [18].

$$LER = \frac{Intercrop\ yield\ of\ chickpea}{Sole\ crop\ yiled\ of\ chickpea} + \frac{Intercrop\ yield\ of\ maize}{Sole\ crop\ yield\ of\ maize}$$

To determine the total cost of production, gross return and net return, total numbers of labour along with the cost of variable inputs used for different operations were collected to compute the variable cost of different treatments. The grain or seed yield was converted to gross return multiplied by the market price.

Net return was the difference between gross return and total cost of production. To compare the better performance of treatments, benefit-cost ratio (BCR) was calculated using the following formula,

$$Benefit - cost\ Ratio = \frac{Grass\ retrurn\ (Tk / ha)}{Total\ cost\ of\ production\ (Tk / ha)}$$

Statistical analysis of variance of the field experimental data of various parameters was carried out using PROC GLM procedure, version 9.2. Fisher's least significant difference (LSD) test at $P < 0.05$ was used to separate significant differences between and among the means.

RESULTS AND DISCUSSION

Yield Contributing Characteristics of Maize: Effect on plant height: The plant height of maize was not affected significantly by tillage but the maize-chickpea intercropping system was influenced significantly (Table 1). The tallest plant of maize was obtained from$_1$I ((234.0 cm). Among the intercropping systems, I_3 showed the maximum plant height (229.8 cm) and the lowest plant height (213.9 cm) was observed in I_6(Table 1). The plant height was reduced when maize was intercropped with chickpea as there was competition with intercrop (Table 2). Pariyar *et al.* [12] noticed the significant effect on the plant height of maize in the maize-wheat intercropping scheme.

Effect on the Number of Leaves Plant^{-1}: Tillage did not affect significantly on leaves of maize (Table 1) but the maize-chickpea intercropping systems influenced significantly. The highest number of leaves (15.95) was observed in I_1 (sole maize) and the lowest number of leaves (15.27) was observed in I_6 (two rows of maize followed by two rows of chickpea intercropping). The number of leaves plant^{-1} was decreased with the increase of plant density. The combined interaction effects of tillage and cropping systems on the number of leaves plant^{-1} was non-significant (Table 2).

Effect on Leaf Area Index (LAI) at 70 Days: Leaf area index (LAI) of maize varied significantly with intercropping systems and tillage. There was a significant variation in the leaf area index due to the interaction between tillage and cropping systems. Results revealed that the treatment interaction T_3xI_1 (raised bed system × sole maize cropping) showed the highest value of LAI of maize (3.64) (Table 2). The lowest value (2.85) of LAI was found for T_1xI_5 [conventional tillage × maize-chickpea intercropping (2:1)] and T_1xI_6[conventional tillage × maize-chickpea intercropping (2:2)]. The results revealed that LAI decreased with increasing plant density in intercropping treatments. It was reported that increasing plant density decreased leaves per plant in both soles and intercropped maize. Light availability has a great effect on the leaf area. It was found that 30% of shade has a significant effect on the LA of tomato [19]. Reduced light availability in the higher plant densities would have decreased the LA of maize under the intercropping system grow taller and have lower leaf areas if the light infiltration into the canopy is lower. This might be the reason for the lowest LAI measured in the treatments of intercropping.

Effect on Length and Diameter of Cob: Tillage had a non-significant effect on the length of cob (Table 1). Intercropping systems had a significant effect on the length of cob in maize. The sole maize system produced significantly the highest length of cob in maize (18.77 cm) and the lowest cob length (17.14 cm) was observed in I_6 (two rows of maize followed by two rows of chickpea intercropping). Effect of interaction between tillage and cropping system displayed non-significant on cob length of maize (Table 2). Pariyar *et al.* [12] reported non-significant effect on the ear length in the intercropping system. Similarly, tillage had a non-significant effect on cob diameter (Table 1). Intercropping systems had a significant effect on the diameter of cob in maize. The sole maize system produced a significantly higher diameter of cob in maize (5.033 cm) and the lowest cob diameter (4.213 cm) was observed in I_6 (two rows of maize followed by two rows of chickpea intercropping). Effect of interaction between tillage and cropping system displayed a non-significant on cob diameter of maize (Table 2).

Effect on 1000-Grain Weight: Tillage did not affect on 1000- seed weight (g) of maize but was significantly affected by the maize-chickpea intercropping systems. The highest 1000-seed weight (291.2g) was found in a sole situation (I_1) (Table 1). Table 2 showed the effect of interaction between tillage and cropping systems displayed non-significant on 1000-seed of maize. Ahmad *et al*. [7] reported a non-significant effect of intercropping on 1000- grain weight of maize intercropping with soybean.

Table 1: Effect of tillage on yield contributing characters of maize

Effect	Plant height (cm)	No. of Leaves plant^{-1}	No. of Kernels cob^{-1}	1000 grain wt.(g)	Length of Cob(cm)	Diameter of cob(cm)	Harvest index (%)
Tillage							
T_1	223.18	15.43	589.5c	266.04	17.65	4.49	41.173
T_2	224.44	15.67	597.10b	274.62	17.75	4.59	41.25
T_3	225.96	15.76	603.60a	278.65	17.90	4.71	41.08
Sx	2.30	0.090	0.493	4.94	0.188	0.076	0.378
Sig. level	NS	NS	**	NS	NS	NS	NS
CV (%)	3.97	2.23	0.32	7.01	4.10	6.41	3.60
Cropping System							
I_1	234.0a	15.95a	627.3a	291.2a	18.77a	5.033a	46.50a
I_3	229.8ab	15.80a	614.3b	279.4ab	17.99b	4.832a	42.09b
I_4	225.0bc	15.70ab	597.8c	272.4bc	17.55bc	4.517b	39.50c
I_5	219.9cd	15.40bc	582.7d	264.2bc	17.41bc	4.417bc	38.49cd
I_6	213.9d	15.27c	561.6e	258.3 c	17.14c	4.213c	37.18d
Sx	2.94	0.107	0.990	5.15	0.218	0.094	0.466
Sig. level	**	**	**	**	**	**	**
CV (%)	3.92	2.06	0.50	5.66	3.67	6.14	3.42

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); ** = Significant at 1% level of probability, NS = Not significant; T_1 = Conventional Tillage, T_2 = Zero Tillage, T_3 = Raised bed System. I_1 = Sole Maize Cropping, I_3 = Maize-Chickpea Intercropping (1:1), I_4 = Maize-Chickpea Intercropping (1:2), I_5 = maize-chickpea Intercropping (2:1), I_6 =Maize-Chickpea Intercropping (2:2).

Table 2: Interaction effects of tillage and cropping systems on yield and yield contributing characters of maize

Interaction (Tillage x Cropping system)	Plant height (cm)	Number of Leaves plant^{-1}	Leaf area index	Number of Kernels cob^{-1}	1000 grain wt. (g.)	Length of Cob (cm)	Diameter of cob (cm)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T_1xI_1	233.00	15.85	3.61a	620.0c	278.50	18.50	4.90	13.06a	14.97	28.03	46.59
T_1xI_3	228.00	15.50	3.34bc	610.5d	273.33	17.85	4.74	10.00d	13.67	23.67	42.24
T_1xI_4	224.00	15.50	3.17d	590.0g	265.30	17.47	4.40	8.50f	13.10	21.60	39.35
T_1xI_5	218.00	15.30	2.85f	577.0i	260.10	17.37	4.35	8.10g	12.97	21.07	38.44
T_1xI_6	212.90	15.00	2.85f	550.0l	253.00	17.10	4.10	7.30i	12.40	19.70	37.05
T_2xI_1	234.00	16.00	3.62a	626.0b	295.00	18.70	5.00	13.10a	15.00	28.10	46.62
T_2xI_3	230.00	15.90	3.35bc	615.0cd	280.00	18.00	4.89	10.20c	14.06	24.26	42.04
T_2xI_4	225.00	15.79	3.20d	598.3f	275.20	17.50	4.50	8.69e	13.20	21.89	39.70
T_2xI_5	220.20	15.40	2.90ef	582.7h	264.50	17.43	4.40	8.15g	13.00	21.15	38.53
T_2xI_6	213.00	15.30	2.90ef	563.3k	258.40	17.13	4.20	7.45hi	12.50	19.95	37.34
T_3xI_1	235.00	16.00	3.64a	636.0a	300.00	19.10	5.20	13.15a	15.25	28.40	46.30
T_3xI_3	231.50	16.00	3.37b	617.3c	285.00	18.12	4.87	10.50b	14.50	25.00	41.99
T_3xI_4	226.00	15.80	3.25cd	605.0e	276.67	17.69	4.65	8.80e	13.50	22.30	39.46
T_3xI_5	221.50	15.50	3.14d	588.3g	268.00	17.43	4.50	8.20g	13.10	21.30	38.50
T_3xI_6	215.80	15.50	3.00e	571.3j	263.60	17.20	4.34	7.50h	12.70	20.20	37.13
Sx	5.08	0.186	0.037	1.72	8.93	0.377	0.163	0.058	0.604	0.625	0.806
Level of sig.	NS	NS	*	*	NS	NS	NS	*	NS	NS	NS
CV (%)	3.92	2.06	1.97	0.50	5.66	3.67	6.14	1.05	7.70	4.68	3.42

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT);* =Significant at 5% level of probability, NS = Not significant;T_1 = Conventional Tillage, T_2 = Zero Tillage, T_3 = Raised bed System; I_1 = Sole Maize Cropping, I_3 = Maize-Chickpea Intercropping (1:1), I_4 = Maize-Chickpea Intercropping (1:2), I_5 = Maize-Chickpea Intercropping (2:1), I_6=Maize-Chickpea Intercropping (2:2)

Effect on the Number of Kernels Cob^{-1}: The tillage system had a significant effect on kernels cob^{-1} of maize and the intercropping system had also a significant effect on kernels cob^{-1} of maize. Among tillage methods, the highest kernel cob^{-1} (603.6) were reported in T_3 (raised bed system) (Table 1). The highest kernel cob^{-1} of maize (627.3) was found in I_1 (sole maize cropping). Results revealed that the treatment interaction T_3xI_1 (raised bed system × sole maize cropping) showed the highest value of number of kernelscob^{-1} of maize (636.0) and the lowest value (550.01) of the number of kernels cob^{-1} was found for T_1xI_6 [conventional tillage × maize-

hickpea intercropping (2:2)] (Table 2). The lower density of plants in I_1 and I_3 compared to other intercropping systems increased a light interception in plant canopy which was led to high photosynthetic rate of maize and finally produced a higher number of kernels cob^{-1} of maize. An increased number of kernels per cob of maize was also reported in maize-soybean intercropping scheme by Tsegay *et al*. [9].

Effect on Grain Yield: The tillage system had a significant effect on the grain yield of maize. The lowest grain yield was obtained in T_1 (conventional tillage) (Figure 1). The grain yield of maize is influenced by the genetic variation of the maize cultivar as well as the proper environment [20]. In intercropping situation, the highest grain yield (10.23 t ha^{-1}) was obtained in I_3 (one row of maize followed by one row of chickpea intercropping system) and minimum grain yield (7.417 t ha^{-1}) was obtained from the I_6 (two rows of maize followed by two rows of chickpea intercropping) (Figure 2). Maize yield gradually decreased in chickpea rows. Grain yield of maize was in general reduced in the intercropping situation compared to that of sole maize crops. This yield reduction was probably due to an interplant competition for growth resources between maize and chickpea. The grain yield of maize was significantly influenced by the interactions between tillage and cropping systems. Results revealed that the treatment interaction T_3xI_1 (raised bed system × sole maize cropping) showed the highest value of grain yield of maize (13.15 t ha^{-1}) which was statistically identical with T_2xI_1 (zero tillage × sole maize cropping) (13.10 t ha^{-1}) and T_1xI_1 (conventional tillage × sole maize cropping) (13.06 t ha^{-1}) (Table 2). In the case of raised bed system, the soil was looser and water holding by soil was also better with no water stagnancy which facilitated the better growth and development of maize. Ahmad *et al*. [7] reported that maize yield was significantly affected by soybean under the intercropping system.

Effect on Stover Yield: The results revealed that all the treatment interactions had a statistically similar effect on Stover yield. Stover yield was significantly affected by different cropping systems but did not affect by tillage methods. The highest Stover yield (13.81 t ha^{-1}) was found in T_3 (raised bed system) and the lowest Stover yield was found in T_1(conventional tillage) (Figure 1) In intercropping system the highest Stover yield (14.08 t ha^{-1}) was obtained from I_3 (one row of maize followed by one row of chickpea intercropping) and lowest (12.53 t ha^{-1}) Stover yield was obtained from I_6 (two rows of maize followed by two rows of chickpea intercropping) (Figure 2). The Stover yield was reduced when maize was intercropped with chickpea. The combined interaction effects of tillage and cropping systems on Stover yield was non-significant (Table 1). In the maize-wheat intercropping, the tillage system showed insignificant effects on the Stover yield [12].

Effect on Biological Yield: Tillage did not affect on biological yield of maize but was significantly affected by the maize-chickpea intercropping systems. In the tillage system, the highest biological yield was found in T_3 (raised bed system) and the lowest biological yield was found in T_1 (conventional tillage) (Figure 1). The highest biological yield was obtained in sole maize cropping (I_1). In intercropping situation, the highest biological yield was obtained in I_3 (one row of maize followed by one row of chickpea intercropping) and the lowest biological yield was obtained in I_6 (two rows of maize followed by two rows of chickpea intercropping) (Figure 2). The biological yield was reduced when maize was intercropped with chickpea. The effect of interaction between tillage and cropping systems was non-significant on biological yield (Table 2). It was found that all the treatment interactions had a statistically similar effect on biological yield. Ahmad *et al*. [7] reported that biomass yield per hectare of maize yield was affected by soybean during the intercropping scheme.

Effect on Harvest Index: The harvest index of maize did not vary significantly in response to tillage but was significantly affected by cropping systems. The effect of interaction between tillage and cropping systems was non-significant on the harvest index of maize (Table 2). It was found that all the treatment interactions had a statistically similar effect on the harvest index. The results are supported by the findings of Ahmad *et al*. [7] who observed non-significant differences in the harvest index of maize in intercropping with soybean.

Yield Contributing Characteristics of Chickpea

Effect on Plant Height at Harvest: The effect of tillage on plant height of chickpea was non-significant. The plant height of chickpea was significantly influenced by maize-chickpea intercropping systems. The plant height of chickpea was ranged from 59.90 cm in I_2 (sole chickpea) to 39.37 cm in I_3 (one row of chickpea followed by one row of maize). The tallest plant (59.90 cm) was obtained from I_2 (sole chickpea) (Table 3). The effect of interaction between tillage and cropping systems was non-significant on the plant height of chickpea (Table 4).

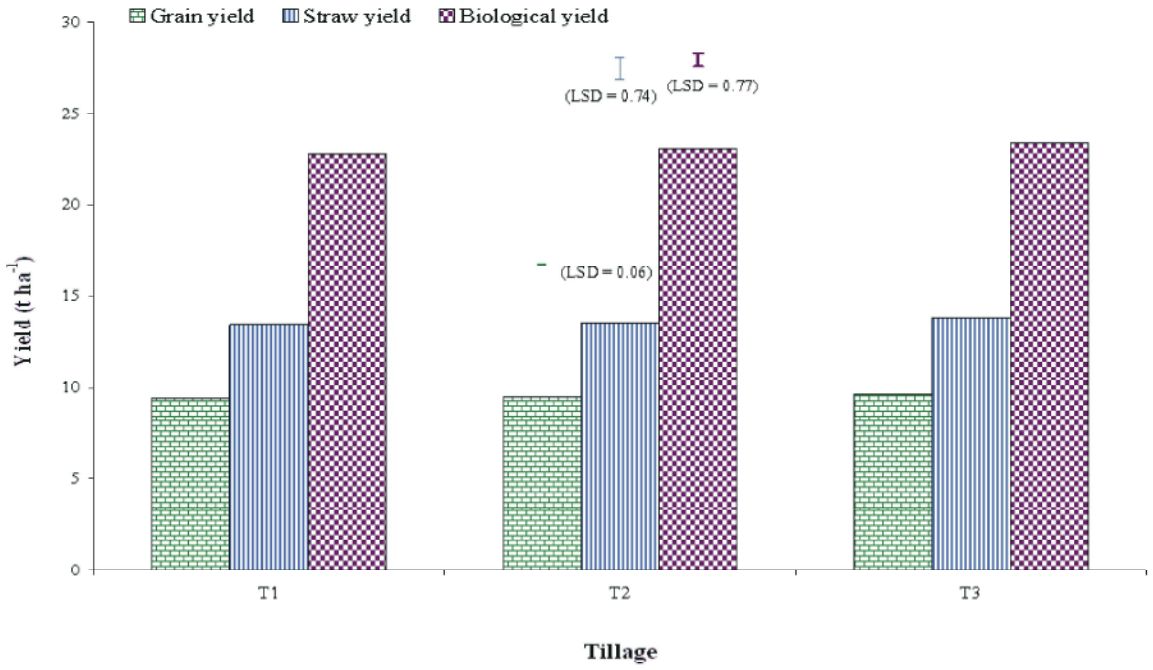

Fig. 1: Grain yield, Stover yield and biological yield of maize under maize-chickpea intercropping in different tillage systems
T_1 = Conventional Tillage, T_2 = Zero Tillage, T_3 = Raised bed System

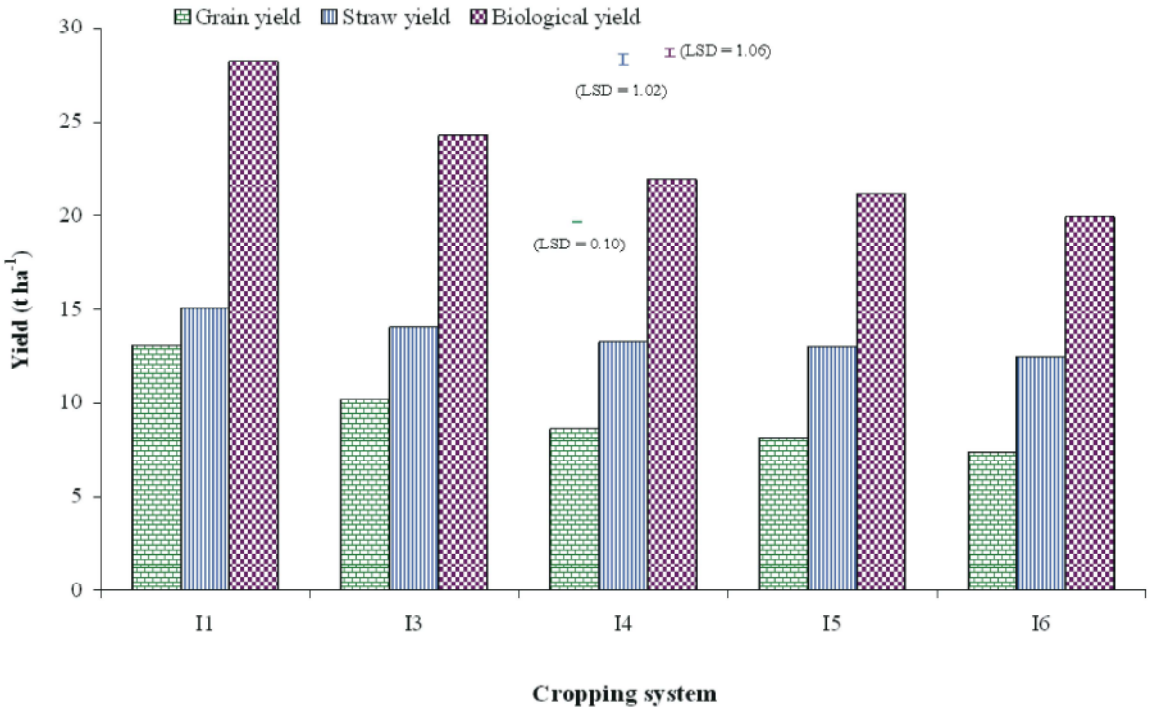

Fig. 2: Grain yield, Stover yield and biological yield of maize under maize-chickpea intercropping systems
I_1 = Sole Maize Cropping, I_3 = Maize-Chickpea Intercropping (1:1), I_4 = Maize-Chickpea Intercropping (1:2), I_5 = Maize- Chickpea Intercropping (2:1), I_6 =Maize-Chickpea Intercropping (2:2).

Table 3: Effect of tillage on yield and yield contributing characters of chickpea

Effect	Plant height (cm)	No. of Branches plant^{-1}	No. of Pods plant^{-1}	No. of Seeds pod^{-1}	1000seed wt. (g)	Harvest Index (%)
Tillage						
T_1	47.55	5.28	41.70c	2.408c	211.60	42.09
T_2	48.74	5.54	42.96b	2.606b	213.24	42.49
T_3	49.52	5.77	43.98a	2.794a	213.91	42.97
Sx	0.422	0.145	0.135	0.008	2.14	0.978
Level of sig.	NS	NS	**	**	NS	NS
CV (%)	3.36	10.18	1.22	1.21	3.88	9.15
Cropping System						
I_2	59.90a	6.500a	49.17a	3.498a	219.00a	47.24a
I_3	39.37e	4.390d	37.00e	1.952e	207.10c	36.05c
I_4	47.00c	5.733b	42.74c	2.506c	212.80abc	39.99b
I_5	42.70d	5.000c	40.60d	2.104d	211.10bc	37.74bc
I_6	54.07b	6.033ab	44.89b	2.955b	214.50ab	45.57a
Sx	0.542	0.182	0.194	0.024	2.29	0.802
Level of sig.	**	**	**	**	**	**
CV (%)	3.34	9.88	1.35	2.72	3.23	5.82

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); NS = Not significant.** =Significant at 1% level of probability, * =Significant at 5% level of probability; T_1 = Conventional Tillage, T_2 = Zero Tillage, T_3 = Raised bed System. I_2 = Sole Chickpea Cropping, I_3 = Maize-Chickpea Intercropping (1:1), I_4 = Maize-Chickpea Intercropping (1:2), I_5 = Maize-Chickpea Intercropping (2:1), I_6 = maize-Chickpea Intercropping (2:2).

Table 4: Interaction effects of tillage and Intercropping System on yield and yield contributing characters of chickpea

Interaction (tillage x cropping system)	Plant height (cm)	No. of Branchesplant^{-1}	No. of Pod plant^{-1}	No. of Seed pod^{-1}	1000 seed wt. (g)	Seed yield (t ha^{-1})	Stover yield(t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
T_1xI_2	59.50	6.00	48.00b	3.29c	217.00	1.86b	2.10	3.96	46.93
T_1xI_3	38.60	4.00	35.00j	1.7 8j	205.00	0.70h	1.22	1.92	36.80
T_1xI_4	45.67	5.50	42.00ef	2.35g	212.60	0.95fg	1.55	2.50	38.05
T_1xI_5	41.00	4.90	39.50gh	1.90i	209.40	0.88g	1.45	2.33	37.78
T_1xI_6	53.00	6.00	44.00d	2.70e	214.00	1.60d	1.92	3.52	45.44
T_2xI_2	60.00	6.50	49.50a	3.45b	219.40	2.00a	2.2	4.20	47.67
T_2xI_3	39.50	4.50	37.00i	1.97i	207.90	0.71h	1.25	1.96	36.61
T_2xI_4	47.00	5.70	43.00de	2.55f	212.67	0.10f	1.58	2.58	38.81
T_2xI_5	43.00	5.00	40.30g	2.10h	211.77	0.89g	1.46	2.35	37.87
T_2xI_6	54.20	6.00	45.01c	2.95d	214.50	1.69cd	2.02	3.71	45.52
T_3xI_2	60.20	7.00	50.00a	3.75a	220.67	2.01a	2.25	4.26	47.24
T_3xI_3	40.00	4.67	39.00h	2.10h	208.50	0.72h	1.30	2.02	35.53
T_3xI_4	48.33	6.00	43.21d	2.60ef	213.20	1.20e	1.60	2.80	42.82
T_3xI_5	44.10	5.10	42.00f	2.30g	212.20	0.90g	1.50	2.40	37.55
T_3xI_6	55.00	6.10	45.67c	3.20c	215.00	1.71c	2.02	3.73	45.74
Sx	0.938	0.316	0.335	0.041	3.97	31.05	83.04	132.77	1.39
Level of significance	NS	NS	**	*	NS	**	NS	NS	NS
CV (%)	3.34	9.88	1.35	2.72	3.23	4.29	8.48	7.80	5.82

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); NS = Not significant. ** =Significant at 1% level of probability, * =Significant at 5% level of probability; T_1 = Conventional Tillage, T_2 = Zero Tillage, T_3 = Raised bed System, I_2 = Sole Chickpea Cropping, I_3 = Maize-Chickpea Intercropping (1:1), I_4 = Maize-Chickpea Intercropping (1:2), I_5 = Maize-Chickpea Intercropping (2:1), I_6 = maize-Chickpea Intercropping (2:2)

Effect on the Number of Branches Plant^{-1}: The number of branches of chickpea was varied significantly with cropping systems but did not vary significantly in response to tillage. The number of branches plant^{-1} varied from 6.50 to 4.39. The highest value (6.50) was found in I_2 (sole chickpea) (Table 3). In the intercrop situation, the highest value (6.033) was found in I_6 (two rows of maize followed by two rows of chickpea intercropping) and the lowest value (4.39) was found in I_3 (one row of maize followed by one row of chickpea) (Table 3). The effect of interaction between tillage and cropping systems was non-significant on the number of branches plant^{-1} of chickpea (Table 4).

Effect on the Number of Pods Plant^{-1}: The number of pods plant^{-1} chickpea was affected significantly by the tillage methods and cropping systems. In tillage systems, the highest value (43.98) of pods plant^{-1} was found in

T_3 (raised bed system). The highest number of pod plant^{-1} (49.17) was found in sole chickpea cropping (I_2). In the intercrop situation, the highest value (44.89) was found in I_6 (two rows of maize followed by two rows of chickpea intercropping). The number of pods plant^{-1} was significantly influenced by the interactions between tillage and cropping systems. Results revealed that, the treatment interaction T_3xI_2 (raised bed system × sole chickpea cropping) showed the highest value (50.0) of the number of pod plant^{-1} of chickpea which was statistically identical with T_2xI_2 (zero tillage × sole chickpea cropping) (49.50) (Table 3). These findings are corroborated with Abera *et al*. [14] stated that the the number of pods per plant in common bean is significantly influenced by cropping systems with maize.

Effect on the Number of Seeds Pod^{-1}: The number of seeds pod^{-1} was significantly affected by different tillage methods and cropping systems. In tillage methods, the highest number of seeds pod^{-1} (2.794) was found in T_3 (raised bed system) and the lowest value (2.408) was found in T_1 (conventional tillage) (Table 3). The highest number of seeds pod^{-1}(3.498) was observed in I_2 (sole chickpea). Among the intercropping systems, the highest number of seeds pod^{-1}(2.95) was found in I_6 (two rows of maize followed by two rows of chickpea intercropping) and the lowest number of seeds pod^{-1} (1.95) was found in I_3 (one row of maize followed by one row of chickpea) (Table 3). The number of seeds pod^{-1} was significantly influenced by the interactions between tillage and cropping systems. Results revealed that the treatment interaction T_3xI_2 (raised bed system × sole chickpea cropping) showed the highest value (3.75) of the number of seed pod^{-1} of chickpea.

Effect on 1000-Seed Weight: 1000-seed weight (g) of chickpea was significantly affected by the maize-chickpea intercropping systems but did not vary significantly in response to tillage methods. The highest 1000-seed weight (219.0 g) was found in I_2 (sole chickpea) (Table 3). In intercropping situation, the highest value (214.0g) was found in I_6 (two rows of maize followed by two rows of chickpea intercropping). The effect of interaction between tillage and cropping systems was non-significant on 1000 seed weight of chickpea (Table 4). The non-significance interactions were observed in common bean seed weight by intercropping systems with maize [14].

Effect on Seed Yield: Seed yield was affected significantly by the tillage methods and cropping systems. In tillage methods, the highest seed yield (1.31 t ha^{-1}) were found in T_3 (raised bed system) and the lowest yield (1.20 t ha^{-1}) was found in T_1 (conventional tillage) (Figure 3). Maximum seed yield (1.96 t ha^{-1}) was obtained from I_2 (sole chickpea). The yield of the chickpea is influenced by the genetic diversity of the chickpea genotypes [21]. In Intercropping situation the highest yield (1.67 t ha^{-1}) was obtained from I_6 (two rows of maize followed by two rows of chickpea intercropping and the lowest yield (0.71 t ha^{-1}) was found in I_3 (one row of maize followed by one row of chickpea intercropping system) (Figure 4). Intercropping significantly reduced the yield of chickpea. The yield of groundnut was lower when intercropped with Brinjal [22]. The interactions between tillage and cropping systems had a significant influence on the grain yield of maize. Results revealed that the treatment interactionT_3x I_2 (raised bed × sole chickpea) showed the highest value of seed yield of maize (2.01 t ha^{-1}) which was statistically identical with T_2xI_2 (zero tillage × sole chickpea cropping) (2.00 t ha^{-1}) (Table 4).

Effect on Stover Yield: The highest Stover yield (1.73 t ha^{-1}) was found in T_3 (raised bed system) (Figure 3). The maximum Stover yield (2.18 t ha^{-1}) was obtained from I_2 (sole chickpea). The intercropping situation, the highest yield (1.98 t ha^{-1}) was obtained from I_6 (two rows of maize followed by two rows of chickpea intercropping) (Figure 4). The effect of interaction between tillage and cropping systems was non-significant on the Stover yield of chickpea (Table 3).

Effect on Biological Yield: In the tillage system, the highest biological yield (3.04 t ha^{-1}) was obtained in T_3 (raised bed system) (Figure 3). The maximum biological yield (4.14 t ha^{-1}) was obtained from I_2 (sole chickpea). The intercropping situation, the highest yield (3.65 t ha^{-1}) was obtained from I_6 (two rows of maize followed by two rows of chickpea intercropping) (Figure 4). The effect of interaction between tillage and cropping systems was non-significant on biological yield (Table 4). Ngwira *et al.* [15] stated that leguminous crops improve biomass production in intercrop.

Effect on Harvest Index: Harvest Index was significantly affected by different cropping systems but did not vary significantly in response to tillage. The highest harvest index (47.24%) was found in I_2 (sole chickpea cropping). In intercropping situation, the highest harvest index (45.57%) was found in I_6 (two rows of maize followed by two rows of chickpea intercropping) and the lowest

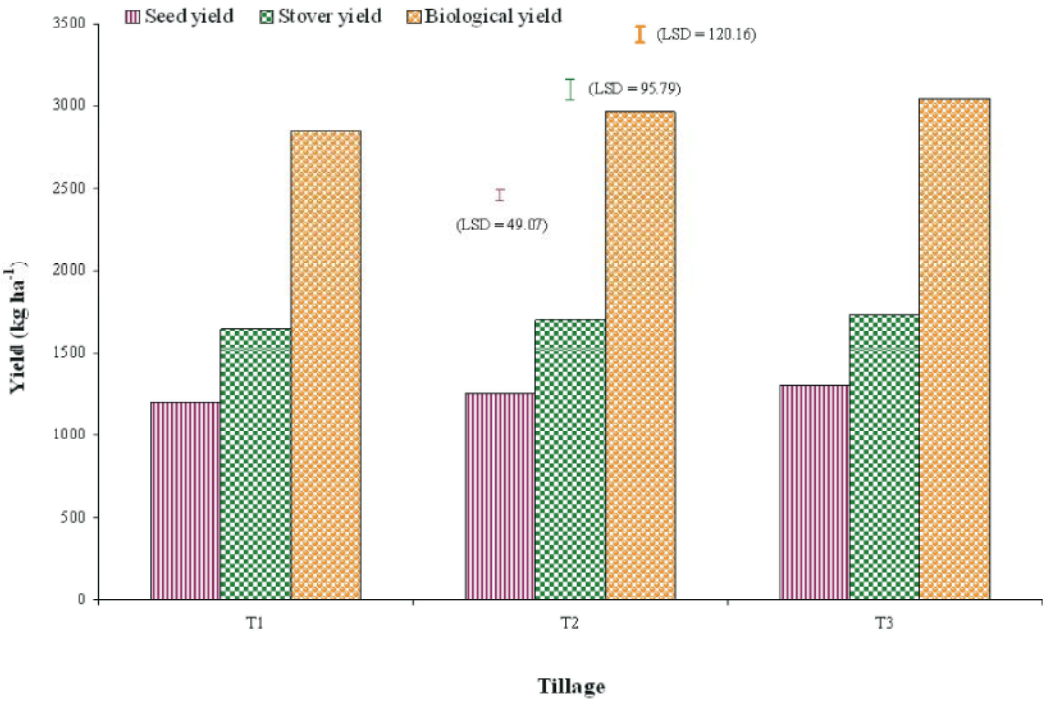

Fig 3: Seed yield, Stover yield and biological yield of chickpea under maize-chickpea intercropping in different tillage systems

T_1 = Conventional Tillage, T_2 = Zero Tillage, T_3 = Raised bed System

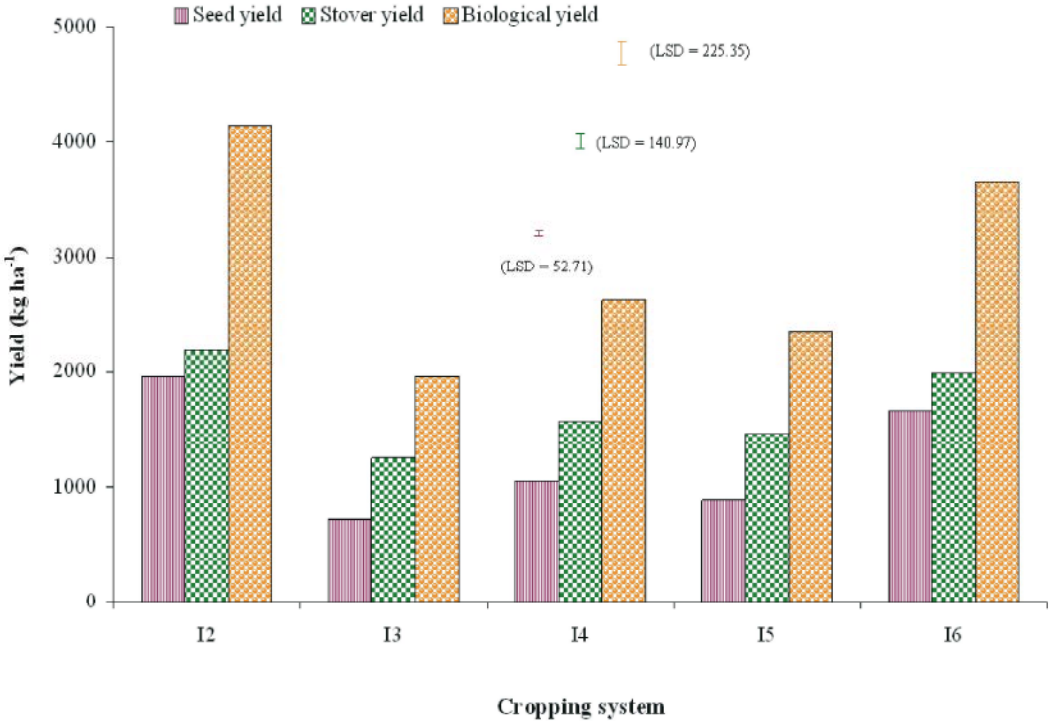

Fig. 4: Seed yield, Stover yield and biological yield of chickpea under maize-chickpea intercropping system

I_2 = Sole Chickpea Cropping, I_3 = Maize-Chickpea Intercropping (1:1), I_4 = Maize-Chickpea Intercropping (1:2), I_5 = Maize-Chickpea Intercropping (2:1), I_6 = maize-Chickpea Intercropping (2:2)

Table 5: Maize equivalent yield and land equivalent ratio (LER) under maize-chickpea intercropping systems

	Grain/Seed yield (tha^{-1})				
Tillage method/cropping systems	Maize	Chickpea	Total yield (t ha^{-1})	Maize equivalent yield (t ha^{-1})	LER
T_1	9.39	1.199	10.59	13.72	1.33
T_2	9.52	1.26	10.78	14.06	1.37
T_3	9.63	1.31	10.94	14.35	1.402
I_1	13.10		13.10		1.00
I_2		1.96	1.96		1.00
I_3	10.23	0.71	10.94	12.79	1.14
I_4	8.66	1.05	9.71	12.46	1.19
I_5	8.15	0.89	9.04	11.36	1.07
I_6	7.42	1.67	9.08	13.43	1.417

T_1 = conventional tillage, T_2 = zero tillage, T_3 =raised bed system, I_1 = Sole Maize Cropping, I_2 = Sole Chickpea Cropping, I_3 = Maize-Chickpea Intercropping (1:1), I_4 = Maize-Chickpea Intercropping (1:2), I_5 = Maize- Chickpea Intercropping (2:1), I_6 =Maize-Chickpea Intercropping (2:2)

Table 6: Economic analysis of different treatments and cropping systems

	Grain Yield (t ha^{-1})		Gross return (Tk /ha)					
Tillage/ cropping systems	Maize t ha^{-1}	Chickpea t ha^{-1}	Maize	Chickpea	Total(Tk/ha)	Total cost of Production (Tk/ha)	Net return	BCR
T_1	9.39	1.19	169056	77935	246991	160000	86991	1.54
T_2	9.51	1.25	171324	81770	253094	145003	108091	1.74
T_3	9.63	1.30	173340	84955	258295	146500	111795	1.76
I_1	13.10		235800		235800	155000	80800	1.52
I_2		1.95		127205	127205	85500	41705	1.49
I_3	10.23	0.70	184140	46065.5	230205.5	137000	93205.5	1.68
I_4	8.66	1.05	155934	68315	224249	118500	105749	1.89
I_5	8.15	0.89	146700	16023.6	162723.6	94000	68723	1.73
I_6	7.41	1.67	133506	108290	241796	120000	121796	2.01

Price: Maize @18 Tk/kg and Chickpea @ 65 tk/kg, T_1 = conventional tillage, T_2 = zero tillage, T_3 =raised bed system, I_1 = Sole Maize Cropping, I_2 = Sole Chickpea Cropping, I_3 = Maize-Chickpea Intercropping (1:1). I_4 = Maize-Chickpea Intercropping (1:2), I_5 = Maize- Chickpea Intercropping (2:1), I_6 = Maize-Chickpea Intercropping (2:2)

harvest index (36.05%) was found in I_3 (one row of maize followed by one row of chickpea intercropping system) (Table 3). The effect of interaction between tillage and cropping systems was non-significant on harvest index (Table 4). Undie *et al.* [23] reported a non-significance effect on intercropping with maize-soybean on harvest index.

Productivity and Economic Return Analysis: Maize equivalent yield: Maize equivalent yield was significantly affected by the maize-chickpea intercropping systems (Table 5). The highest maize equivalent yield (13.43 t ha^{-1}) was obtained from the treatment I_6 (two rows of maize followed by two rows of chickpea intercropping). The highest equivalent yield was attributed to the higher price of chickpea seed. Maize equivalent yield was increased when maize was intercropped with chickpea. Rahman *et al*. [24] reported the similar results. Sarno *et al.* [25] also stated that higher equivalent yields were obtained with intercropping.

Land Equivalent Ratio (LER): The land equivalent ratio was varied in maize-chickpea intercropping systems (Table 5). Treatment I_6 (two rows of maize followed by two rows of intercropping) is shown the highest LER and higher than sole maize cropping. If maize and chickpea grow separately it takes more land but intercropping treatments land utilization could be saved which is advantage while cultivable land decreases day by day. Ahmad *et al*. [7] reported that intercropping increased land equivalent ratio (LER). Sarno *et al.* [25] stated that lie land equivalent ratio (LER) values were found to be greater with intercropping than sole cropping.

Gross Return (Tk/Ha): The gross return in maize and chickpea intercropping under different tillage systems is shown in (Table 6). It was found that the intercropping treatments always gave a better gross return than the sole crops. So, it was clear that in the intercropping treatments the gross return was better than the sole cropping practices. The highest gross return (241796 tk ha^{-1}) was

obtained from the I_6 (two rows of maize followed by two rows of chickpea intercropping). The maximum gross income was noticed in maize-wheat intercropping due to the deduction of labour cost for removal of residue kept in the field [12].

Net Return (Tk/ha): Net return over variable cost was found encouraging in the intercropping treatments. Out of the four intercropped treatments the highest net return (121796tk/ha) was found in I_6 (two rows maize intercropped with two rows chickpea). These were mainly due to the higher yield of maize and the higher market price of chickpea (Table 6). Ahmad *et al*. [7] stated that all intercropping systems have the potentiality for getting net income than that of the pure stand.

Benefit-Cost Ratio (BCR): When the benefit-cost ratio of each treatment was examined it is found that the treatment of I_6 (two rows maize intercropped with two rows chickpea) gave the highest benefit-cost ratio (2.01). The lowest benefit-cost ratio (1.49) was obtained from the sole crop of chickpea which also gave the lowest net return (Table 6). Intercropping system had higher output compared to the mono-cropping system due to the effective usage of growth resources by the component crops [7].

Intercropping provides numerous benefits like yield improvement, sustainability of crop production, environmental surveillance and ensure proper ecosystem services. The present research result demonstrated the beneficial impacts of the properly managed intercropping which ehnances the yield of crops grown with minimum input. However, growing two or more crops together as intercropping requires extra care and management to reduce the competition among the crop species.

CONCLUSION

In the present experiment, maize and chickpea produced the highest seed yield in the sole cropping system while it was reduced in the intercropping systems. In intercropping, the highest seed yield (1.67 t ha^{-1}) of chickpea was obtained from (two rows of maize followed by two rows of intercropping) because of more plant population than the I_3 (one row of maize followed by one row of chickpea intercropping). Among tillage systems highest equivalent yield (14.35 t ha^{-1}), LER (1.402), total gross return (258295 tk ha^{-1}), net return (111795 tk ha^{-1}) and BCR (1.76) were found in T_3 (raised bed system). From the findings of the study, it might be concluded that two rows of maize between two rows of chickpea intercropping under raised bed system gave the higher combined yield, maize equivalent yield, net return, LER and BCR over normal planting of maize and this combination could achieve higher productivity and profitability.

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