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Research Paper

Effect of tillage and crop-establishment techniques on productivity, profitability and soil health under maize (*Zea mays*)–maize–field pea (*Pisum sativum*) cropping system

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ABSTRACT

A field experiment was conducted at ICAR Research Complex for North-Eastern Hills Region Tripura Centre, Tripura (W), to study effect of tillage and crop-establishment techniques on productivity, profitability and soil health under maize (*Zea mays* L.)–maize–field pea (*Pisum sativum* L.) cropping system. The experiment comprised 6 treatments, viz. conventional tillage with flat bed planting (CT-FB), conventional tillage with ridge and furrow planting (CT-RF), conventional tillage with raised bed planting (CT-RB), no-till with flat bed planting (NT-FB), no-till with ridge and furrow planting (NT-RF) and no-till with raised bed planting (NT-RB). Green cobs yield of summer maize was 25.3–27.4% and field pea seed yield was 17.9–32.2% higher under NT-RF and NT-RB than CT-RF. Rainy season (*kharif*) maize grown under NT-RF recorded 12.66% less grain yield than the CT-RF. The NT-RB resulted in the maximum system productivity to the tune of 16.34 and 14.55 t/ha in 2012–13 and 2013–14, respectively. The average system productivity was 6.1% higher under systems than to CT systems. Net returns and benefit: cost ratios showed the similar trends as shown by system productivity. Under the NT-FB, soil organic carbon was 13.2% higher than CT-FB. However, the CT-RB recorded higher soil pH as compared to all the other treatments. The available nitrogen, phosphorus and potassium were higher with NT systems compared to CT systems. Therefore, cultivation of maize–maize–field pea cropping system under NT-RB system may be adopted for higher productivity and profitability and for sustaining the soil health.

***Key words* :** Crop establishment techniques, Maize–maize–field pea cropping system, Net return, Soil organic carbon, System productivity, Tillage

Soils under the high rainfall (>2,000 mm/annum) fragile ecosystem of North Eastern Himalayan region of India are predominantly under rice or maize cultivation and have several soil-related constraints (Saha *et al*., 2012). Ghosh *et al*., (2010) reported loss of fertile topsoil by erosion, high losses of water through runoff, etc. and inappropriate land-use system. Soil hydro-physical constraints can severely limit crop production even if nutritional constraints are alleviated by addition of chemical amendments (Bandyopadhyay *et al*., 2009). Conventional tillage (CT) system leaves the soil bare (due to repeated ploughing and residue removal or burning) and very susceptible to accelerated erosion (Schneider *et al.,* 2012). Excessive tillage destroys soil structure, disrupts the continuity of soil pores, and reduces the amount of residues on the soil surface, so affecting soil health and productivity of region. Thus, agronomic yields of a majority of crops grown in the mentioned soils tend to be low. Hence it is necessary to identify and adopt appropriate soil and crop-management practices to improve the productivity and sustain soil health. Hence present study was conducted to determine the impacts of conservation tillage and crop establishment techniques on system productivity, profitability and soil health under maize-based cropping systems.

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MATERIALS AND METHODS

The field experiment was conducted at ICAR Research Complex for North Eastern Hills Region Tripura Centre, Tripura (W), (23°54' 24.02" N and 91°18' 58.35" E, 48 m above mean sea-level) during the crop-growing season

(April–March) during 2012–13 and 2013–14. The annual rainfall of Lembucherra is 2,200 mm. Weather condition of the experimental site during the study period is given in Fig. 1. The soil was sandy loam and its initial soil sample had 6.9 g/kg organic C, 287.0 mg/kg available nitrogen (N), 8.7 mg/kg available phosphorus (P) and 289.0 mg/kg available potassium (K). The pH of soil was 5.2 (1:2.5, soil: water ratio). The experiment was laid out in a randomized complete-block design with 3 replications. The details of the tillage practices are: CT-FB, conventional tillage with flat bed planting–4 ploughing with the help of power tiller and plots were prepared to ground level; CT-RF, conventional tillage with ridge and furrow planting–the ridges and furrows are made from the surface, 15 cm deep furrow were made and the removed soil was placed on ridges, finally making 30 cm ridges from base; CT-RB, conventional tillage with raised bed planting–the plots were ploughed conventionally but raised the planting area for about 15 cm above the ground; NT-FB, no-till with flat bed planting–residues of previously grown crop was left on the soil surface, a hand hoe was used to open planting stations; NT-RF, no-till with ridge and furrow planting–the ridges and furrows are made from the surface, 15 cm deep furrow were made and the removed soil was placed on ridges, finally making 30 cm ridges from base made in previous season and repaired in planting season to maintain no-till condition; and NT-RB, no-till with raised bed planting–the plots were ploughed conventionally but raised the planting area for about 15 cm above the ground in previous season and repaired in planting season to maintain no-till condition. All the crop residue after harvest of economic part was retained on soil surface under NT systems and incorporated under CT systems. Glyphosate at 5 ml/litre was applied to control weed in all NT plots. These effects were evaluated under maize–maize–field pea system. Field pea was sown after maize harvest on residual soil moisture. 'DMH 849', a popular hybrid of maize was sown manually at 60 cm × 30 cm spacing during both season and field pea variety 'TRCP 9' was sown at 30 cm × 10 cm spacing. Two hand-weedings were performed 20 and 45 days after sowing (DAS) for CT and 1 hand-weeding at 30 DAS for NT treatments. The weed biomass under NT was retained on the surface of NT and removed in case of CT. The net plot size was 4 m × 3 m (gross plot size 5 m × 4 m). Summer maize was sown in the first week of April and harvested in the last week of June both the years. *Kharif* maize was sown in the second week of July and harvested in the last week of September in both the years. After harvest of *kharif* maize, field pea was sown in the first week of November and harvested in the last week of February in both the years.

The plant sampling was done at crop harvesting. At harvest, cobs/plot were counted and converted in per ha basis. The green cob was harvested, when it reached the physiological maturity for table-purpose and green cob yield of maize was measured in t/ha. At the time of harvesting, 10 cobs were randomly selected and their length (cm), girth (cm) and weight (g/cob) were measured. In *kharif* maize, data regarding cob length, cob girth, lines/cob, seeds/cob, 1,000-seed weight were recorded from 5 random plants for each treatments. Grain and stover yields of maize and field pea were obtained from the net plot area (4 m × 3 m) and sun dried. Grain yields were recorded at constant moisture level of 12% for field pea and *kharif* maize.

Initial soil samples were obtained before the start of the experiment and final soil sample were taken after harvest of field pea. Soil samples were obtained from each plot at 0–15 depths for chemical analysis. Soil samples were obtained randomly from three locations in each treatment, composited, dried under laboratory conditions until constant weight, gently ground and passed through a 2-mm

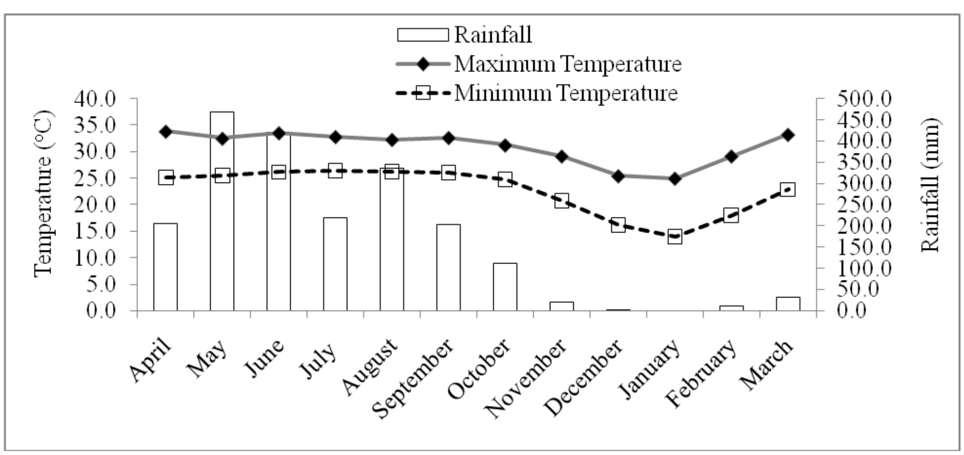

Fig. 1. Weather condition of the experimental site during the study period (mean data of 2 years)

sieve. Soil organic carbon (SOC) by Walkley and Black method, available N was determined by the alkaline permanganate method; available P spectrophotometrically (880 nm) by $NaHCO_3$ extraction and available K flame photometrically by neutral normal NH_4OAc extraction.

Data were subjected to an ANOVA to test the significance of the overall differences among treatments by the "F' test. When the 'F' value was found to be significant, the critical difference (CD) at $p=0.05$ was computed to test the significance of the difference between the two treatment means (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Productivity and profitability

Different crops of maize–maize–field pea cropping system showed variable response to tillage and crop-establishment methods. Both positive and negative effects of tillage on different crops of cropping system was observed. However, the overall impact of NT-based crop establishment techniques on cropping system was positive. The yield attributes and yield of summer maize (Table 1) and field yields (seed, stover and biomass yield) and harvest index (Table 3) were higher, when these crops grown under NT-RB and NT-RF than CT systems. Green cobs yield of summer maize was 25.3–27.4% and field pea seed yield was 17.9–32.2% higher under NT-RF and NT-RB than CT-RF. However, seed, stover and biomass yield of field pea showed no significant difference among the NT-RB, CT-RB and NT-FB. Olson *et al.* (2004) also reported higher productivity under NT than CT. In our study a negative effect of NT systems was seen on grain yield in the wet season, and the yield attributes and yield of *kharif* (wet season) maize were reduced under NT-FB, NT-RF and NT-RB as compared to CT-RB, CT-RF and CT-FB (Table 2). *Kharif* maize grown under NT-RF recorded the lowest yield, being 12.7% less than the CT-RF. A negative yield response of corn to NT was also reported by Chen *et al*. (2011). The NT-RB recorded the maximum system productivity whereas the CT-RF the lowest system productivity. The average system productivity was 6.1% higher under NT systems than CT systems (Table 4). Net returns and benefit: cost ratios showed the similar trends as shown

Table 1. Effect of tillage and crop-establishment techniques on yield parameter and yield of summer maize (mean data of 2 year)

Treatment	Cobs/ha	Cob diameter (cm)	Cob length (cm)	Cob weight (g)	Green cob yield (t/ha)
CT-FB	55,186	13.3	20.3	236.3	10.05
NT-FB	62,593	13.2	21.1	249.8	10.55
CT-RF	55,927	13.2	21.6	229.2	8.95
CT-RB	56,482	12.7	20.0	210.7	10.13
NT-RF	68,704	13.4	22.0	255.8	11.40
NT-RB	63,519	13.9	22.7	272.3	11.18
SEm±	3,247	0.38	0.51	7.6	0.40
CD (P=0.05)	9,849	1.14	1.54	22.92	1.22

CT-FB, Conventional tillage with flat bed planting; CT-RF, conventional tillage with ridge and furrow planting; CT-RB, conventional tillage with raised bed planting; NT-FB, no-till with flat bed planting; NT-RF, no-till with ridge and furrow planting; NT-RB, no-till with raised bed planting

Table 2. Effect of tillage and crop-establishment techniques on yields attributes and yields of *kharif* maize (mean data of 2 years)

Treatment	Cob length (cm)	Cob diameter (cm)	Grain row/cob	Grain/cob	1,000-grain weight (g)	Yield (t/ha)
CT-FB	16.5	13.4	14.7	490.7	191.7	4.78
NT-FB	15.4	13.0	14.2	436.9	190.3	4.77
CT-RF	17.2	14.2	15.4	527.2	194.0	5.07
CT-RB	17.2	14.4	15.4	536.6	194.7	5.06
NT-RF	15.3	12.5	14.0	412.8	188.2	4.50
NT-RB	16.1	13.4	14.3	443.6	190.4	4.68
SEm±	0.47	0.41	0.27	19.71	0.93	0.13
CD (P=0.05)	NS	1.28	0.86	59.8	2.81	0.40

CT-FB, Conventional tillage with flat bed planting; CT-RF, conventional tillage with ridge and furrow planting; CT-RB, conventional tillage with raised bed planting; NT-FB, no-till with flat bed planting; NT-RF, no-till with ridge and furrow planting; NT-RB, no-till with raised bed planting

Table 3. Effect of tillage and crop-establishment techniques on yield and harvest index of field pea (mean data of 2 years)

Treatment	Seed yield (kg/ha)	Stover yield (kg/ha)	Biomass yield (kg/ha)	Harvest index
CT-FB	923.5	3,607.0	4,530.0	0.21
NT-FB	1,034.5	3,866.0	4,900.0	0.22
CT-RF	846.0	3,351.0	4,197.0	0.20
CT-RB	1,046.0	4,180.5	5,226.5	0.20
NT-RF	997.5	2,898.0	3,895.0	0.26
NT-RB	1,118.5	3,598.5	4,716.5	0.24
SEm±	36.5	233.0	240.0	0.01
CD (P=0.05)	111.0	706.0	728.0	0.04

by system productivity. The more system productivity and less cost of cultivation supported the higher net returns and benefit: cost ratio under NT systems as compared to CT systems.

Soil health

Soil organic carbon (SOC) at 0–15 cm soil depth was higher with NT-FB, followed by NT-RB>NT-RF>CT-RB>CT-RF>CT-FB (Table 5). The NT-FB recorded 13.2% higher SOC than CT-FB (Iqbal *et al*., 2011). However the lowest SOC was obtained with CT-FB and CT-RF. Under CT-RB soil pH was higher than the all other treatments. Lopez-Fando and Pardo (2009) also reported reduction in soil pH under NT systems. The higher available NPK concentrations occurred under NT systems compared to CT systems (Lopez-Fando and Pardo, 2009). The NT-RB recorded the highest available NPK compared with all the treatments (Table 5). Mina *et al*. (2008) also observed significantly higher available N, P and K in NT systems than in CT systems.

Adoption of NT based crop establishment techniques enhanced the system productivity and profitability of maize–maize–field pea cropping system. The average system productivity was 6.1% higher under NT systems than CT systems. The NT based crop establishment techniques helped the soil to restore more organic matter content and prevent the exposure to external factors; this led to the accumulation of organic carbon on soil and increased the available nutrient in soil. Therefore, cultivation of maize–maize–field pea cropping system under NT-RB system may be for higher productivity and profitability and for

Table 4. Effect of tillage and crop-establishment techniques on system productivity and profitability

Treatment	System productivity (MEY t/ha)			Net returns (× 10³ ₹/ha)	Benefit: cost ratio
	2012–13	2013–14	Mean		
CT-FB	15.13	13.41	14.27	147.6	3.22
NT-FB	15.37	14.62	15.00	152.6	3.63
CT-RF	14.37	12.86	13.62	129.4	2.73
CT-RB	15.63	14.24	14.94	152.7	3.04
NT-RF	15.78	14.40	15.09	156.7	3.60
NT-RB	16.34	14.55	15.45	162.9	3.70
SEm±	0.37	0.35	0.29	4.3	0.07
CD (P=0.05)	1.13	1.05	0.87	13.1	0.21

CT-FB, Conventional tillage with flat bed planting; CT-RF, conventional tillage with ridge and furrow planting; CT-RB, conventional tillage with raised bed planting; NT-FB, no-till with flat bed planting; NT-RF, no-till with ridge and furrow planting; NT-RB, no-till with raised bed planting

Table 5. Effect of tillage and crop-establishment techniques on soil chemical properties after completion of experiment

Treatment	Soil organic carbon (g/kg)	pH	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
CT-FB	7.13	5.83	286.0	8.6	288.0
NT-FB	8.63	5.80	330.2	9.1	330.9
CT-RF	7.13	5.76	283.0	8.7	293.5
CT-RB	7.17	6.04	294.3	8.8	296.3
NT-RF	7.60	5.31	335.2	8.9	325.1
NT-RB	8.07	5.60	338.0	9.2	328.0
SEm±	0.12	0.27	3.28	0.12	2.40
CD (P=0.05)	0.38	NS	9.96	0.36	7.27

CT-FB, Conventional tillage with flat bed planting; CT-RF, conventional tillage with ridge and furrow planting; CT-RB, conventional tillage with raised bed planting; NT-FB, no-till with flat bed planting; NT-RF, no-till with ridge and furrow planting; NT-RB, no-till with raised bed planting sustaining the soil health.

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