



Productivity of maize (*Zea mays*) – wheat (*Triticum aestivum*) system under different tillage and crop establishment practices

HARI RAM*, D.S. KLER, YADVINDER SINGH AND KRISHAN KUMAR

Punjab Agricultural University, Ludhiana, Punjab 141 004

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ABSTRACT

The experiment with eight treatments: Flat conventional tillage (CT) in *kharif* followed by CT in *rabi* (CT/CT)], Flat CT/no tillage (NT) (CT/NT), NT/NT, NT + wheat straw mulch @ 5 t/ha(S)/NT (NT+S/NT), Fresh beds (FB)/flat CT (FB/CT), CT/FB, permanent beds (PB)/permanent beds (PB/PB) and PB+S/PB was conducted at PAU, Ludhiana during *kharif* and *rabi* seasons of 2003-04 and 2004-2005 in RBD with four replications. Straw mulching in PB+S/PB or NT+S/NT reduced the soil temperature and improved photosynthetically active radiation interception that however failed to increase yield of maize and wheat markedly. NT+S/NT and PB+S/PB in maize recorded 10.37 and 3.40% less consumptive use (CU) of water than CT/CT and FB/CT treatments, respectively during 2004. PB+S/PB treatment in wheat recorded significantly lower CU and higher water use efficiency (WUE) than all CT and NT treatments. Soil bulk density recorded in NT/NT (1.50 g/cm³) was significantly higher than CT/CT, FB/CT, CT/FB, PB/PB and PB+S/PB treatments. On an average, the highest net returns (Rs 43,536/ha) were observed in NT/NT treatment. The minimum input energy and energy output/input ratio (13.82) was seen in PB/PB treatment while energy output (3,92,035 MJ/ha/year) was highest in NT+S/NT.

Key words : Bed planting, Maize, Tillage, Watershed management, Wheat

Modern agro-techniques in irrigated agro-ecosystem has threatened the environment safety and degradation of natural resources, especially the land and water. Continuous rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L.) cropping sequence in Punjab has resulted in number of ecological and other disorders like development of hardpan, low input use efficiency including water, more pests etc. besides environmental pollution through emission of gases. Water was expected to be the most scarce ecological factor and costly input in determining agricultural production as watertable in North-Western plains is drastically getting down. Thus, it becomes imperative to sustain the productivity of agricultural systems concomitant with friendly environment and efficient utilization of production resources. There is need for diversification of rice-wheat sequence for higher sustainability of agriculture. Maize (*Zea mays* L.) is a potential *kharif* crop to replace rice. Some of the agronomic practices like zero tillage (ZT) and furrow irrigated raised bed (FIRB) planting are found to be the potential resource conservation technologies (RCTs) which can play a big role to save the scarce natural resource like water. ZT technique is an ecological approach for soil surface management and seed bed prepa-

ration resulting in economics of cultivation, less weed problem, better crop residue management and higher or equal yield (Jain *et al.*, 2007). FIRB planting is a method of planting a crop on top of raised beds with a definite number of rows often one or two per bed. The FIRB planting systems have number of advantages like better irrigation management, better crop establishment, better weed management through inter bed cultivation and less soil compaction (Dhillon *et al.*, 2004). Further, the permanent bed (PB) planting allows the bed to be re-used for succeeding crop and thus has the potential to minimize the cost of cultivation similar to ZT (Sayre and Limon, 2002). Thus, the study was conducted to assess the impact of tillage and planting systems on maize-wheat system.

MATERIALS AND METHODS

Filed experiment was carried out on a fixed site for two years (June 2003 to April 2005) at Punjab Agricultural University, Ludhiana (30°56'N, 75°52' E, 247 m above mean sea level). The soil of the experimental field was loamy sand in texture (Typic Ustochrept order and Samana series) was neutral in reaction (pH 7.24), low in organic carbon (0.34%), medium in available P (15.8 kg/ha) and ammonium acetate extractable K (180.5 kg/ha). The experiment was carried out in RBD with eight treat-

*Corresponding author (E mail: hr_saharan@yahoo.com)

ments T_1 : Flat sowing with conventional tillage (CT) in *kharif* - CT in *rabi* (CT/CT); T_2 : CT - no tillage (NT); T_3 : NT/NT; T_4 : NT + wheat straw mulch @ 5 t/ha (NT+S)/NT; T_5 : fresh raised beds (FB)/flat CT (FB/CT); T_6 : CT FB; T_7 : permanent raised beds (PB) - permanent raised beds (PB/PB) and T_8 : PB + wheat straw mulch @ 5 t/ha (PB+S/PB) and were replicated four times. In CT, one disc ploughing followed by two runs of cultivators and planking was done. Similarly, sowing on fresh raised beds (FB) was done after following CT. The fresh and permanent raised beds were of 67.5 cm width having 37.5 cm top and 30 cm furrow made with tractor drawn bed planter. PB which were established for non-experimental wheat crop in *rabi* 2002-03 were used. The PBs were reshaped for sowing wheat in both seasons. In no tillage (NT) treatments, crops were directly sown in the field without any tillage. In PB, sowing of crops was done on undisturbed beds. Before sowing, weeds were controlled using paraquat @ 0.35 kg/ha in NT and PB. Wheat straw chopped with the help of chopper to the size of about 10 cm to 15 cm was applied in NT+S/NT and PB+S/PB treatments. A rainfall of 571.7 + 92.2 mm during 2003-04 and 328.5 + 145.2 mm during 2004-05 were recorded in *kharif* + *rabi* seasons. Maize 'Paras' was sown on 20 June, 2003 and 15 June, 2004 using a seed rate of 20 kg/ha at a spacing of 60 cm x 22 cm in flat conventional tillage and zero tillage treatments and harvested on 1 October, 2003 and 27 September, 2004. In bed planting, one row on the top of the bed was sown with plant-to-plant spacing of 20 cm to get same plant population in raised bed sowing as in flat treatments on area basis. Wheat 'PBW 343' was sown on 12 November, 2003 and 5 November, 2004. using a seed rate 100 kg/ha in flat and 75 kg/ha in bed planted treatments and harvested on 6 April, 2004 and 20 April, 2005. In maize, atrazine 50 WP @ 1 kg/ha was applied as pre-emergence to control weeds. In wheat, fenoxaprop-p-ethyl 10 EC @ 0.1 kg/ha and 2, 4-D @ 0.62 kg/ha (35 days after sowing) were applied to control grassy and broad leaf weeds. The recommended dose of fertilizers i.e. 120 + 26.4 + 25 kg N+P+K/ha were applied to both the crops in each season. Entire P and K fertilizers were applied at the sowing. In maize, N was applied in three equal splits (at sowing, knee high and tasseling stage) whereas in wheat, nitrogen was applied in two equal splits (one at sowing and other after first irrigation). The depth of each irrigation applied was 7 cm in CT and NT and 5 cm in FB and PB treatments in both crops. The irrigations to maize was given on IW:CPE ratio of 1.0. After pre-sowing irrigation, maize did not receive any irrigation during 2003 but received four irrigations in flat CT and NT treatments and five irrigations in beds during 2004. Wheat received four irrigations during 2003-04 and three during 2004-05. Irriga-

tion water was measured with the help of parshall flume. The soil temperature at 5 cm depth was recorded at 2:30 pm. The data on photosynthetically active radiation interception (PARI) in % were recorded periodically. The consumptive water use (CU) and water use efficiency (WUE) was calculated by standard formulae. The bulk density and cumulative infiltration rate were determined after each crop cycle, whereas, organic carbon was determined after completion of two cropping cycles. Energy input, output (grain + stover/straw) and output/input ratio were calculated using energy equivalents as suggested by Devasenapathy *et al.* (2009) and Khaledian *et al.* (2010). Economic analysis was done based on prevailing market prices in respective years.

RESULTS AND DISCUSSION

Soil temperature and photosynthetically active radiation

Maize: The NT+S/NT treatment significantly reduced soil temperature when compared with CT/CT. Similarly, soil temperature recorded in PB+S/PB treatment upto emergence was 1.9°C and 0.8°C less than CT/CT and 3.0°C and 3.4°C less than FB/CT during 2003 and 2004, respectively. The soil temperature up to emergence was higher in bed planted maize when compared with flat sown crop owing to exposure of more surface area to the incident solar radiation than that of flat CT treatments. Soil temperature recorded at various other growth stages of maize showed that NT+S/NT and PB+S/PB reduced soil temperature at knee high and silking stages than NT/NT and PB/PB treatments, respectively. This may be due to the fact that mulch did not allow the solar radiation to contact the soil surface. Burrows and Larson (1992) reported reduced soil temperature under mulched conditions. Photosynthetically active radiation interception (PARI) by the crop increased up to silking stage of the crop and declined thereafter (Table 1). The non-significant results during 2003 for light interception might be due to similar growth at 30 DAS with well distributed rainfall. Significantly higher light interception was recorded in PB+S/PB than all other treatments but it was statistically on par with NT+S/NT during 2004. The higher light interception in straw-mulched treatments of NT+S/NT during 2003 and PB+S/PB during 2004 might be due to better crop growth.

Wheat: Soil temperature recorded in CT/FB was significantly higher than CT/CT (Table 2). At 30 DAS and anthesis stage, NT+S/NT recorded minimum soil temperature, it might be due to maximum solar radiation interception. NT+S/NT recorded highest PARI in wheat throughout the crop growth that being statistically on par with NT and conventional flat treatments was significantly higher than all bed planted treatments (CT/FB, PB/PB and PB+S/

PB). No tillage treatments (NT/NT, CT/NT) recorded almost similar PARI as recorded in CT/CT treatment. Fresh beds (CT/FB) recorded slightly higher PARI when compared with permanent beds. Higher light interception in NT+S/NT treatment might be due better growth of the crop.

Yield attributes and yield

Maize: Yield attributing characters and grain yield of maize did not differ significantly among various treatments (Table 3). Kaputsa *et al.* (1996) reported similar effects of different tillage methods on maize.

Wheat : NT+S/NT treatment being statistically on par with CT/CT, CT/NT, NT/NT and FB/CT recorded significantly higher effective tillers/m² than CT/FB, PB/PB and

PB+S/PB treatments (Table 4). Lower density of tillers on bed planted crop were also reported by Dhillon *et al.* (2004). Maximum number of grains/ear was recorded in fresh beds (CT/FB) which was statistically on par with PB+S/PB and PB/PB treatments but significantly more than CT/CT, CT/NT, NT/NT, FB/CT and NT+S/NT treatments. Higher grains/ear were compensated by the low tiller density in bed planted wheat. Different treatments could not affect the 1,000-grain weight significantly. The grain yield of wheat could not vary significantly among various treatments. However, the effective tillers were less in bed planting treatments but higher grains/ear, and higher test weight compensated the low tiller density. These results were in line with those reported by Dhillon *et al.* (2004). Similar grain yields under conventional and no tillage were also obtained by Jain *et al.* (2007).

Table 1. Soil temperature (°C) and photosynthetically active radiation interception (PARI) at different growth stages of maize

Treatment	Maize									
	Soil temperature (°C)					PARI (%)				
	Emergence		Knee high (30 DAS)		Silking(R1)		Knee high(30 DAS)		Silking(R1)	
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
CT/CT	34.8	40.1	33.9	34.9	32.7	22.9	60.4	62.7	88.8	89.0
CT/NT	34.9	40.1	34.1	35.4	32.7	23.3	59.4	61.2	88.2	88.6
NT/NT	34.7	40.6	33.4	34.8	32.2	22.8	60.2	61.3	89.2	90.0
NT+S/NT	32.7	37.8	33.1	32.3	31.0	21.4	65.6	70.8	90.0	92.4
FB/CT	35.9	42.7	33.9	35.2	32.8	22.8	60.7	62.8	89.0	90.6
CT/FB	34.8	40.0	33.8	34.0	32.3	23.1	60.5	62.4	89.2	88.7
PB/PB	36.0	42.8	34.5	33.7	32.9	22.5	59.3	61.2	88.0	90.6
PB+S/PB	32.9	39.3	33.2	32.9	32.5	22.2	65.2	71.1	88.2	92.7
SEm±	0.7	0.6	0.7	0.6	0.8	0.7	2.1	0.8	0.8	1.6
CD (P=0.05)	2.0	1.8	1.9	1.8	NS	NS	NS	2.5	NS	NS

CT, Conventional tillage; NT, No tillage; NT+S/NT, NT+Wheat straw mulch @ 5 t/ha/NT; FB/CT, Fresh Beds/flat CT; CT/FB, Conventional tillage/Fresh Beds; PB/PB, Permanent beds/permanent beds; PB+S/PB, Permanent beds+wheat straw mulch/permanent beds

Table 2. Soil temperature (°C) and photosynthetically active radiation interception (PARI) at different growth stages of wheat

Treatment	Wheat									
	Soil temperature (°C)					PARI (%)				
	Emergence		30 DAS		Boot		30 DAS		Boot	
	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05
CT/CT	23.1	26.8	20.4	19.5	19.9	14.7	45.2	43.8	97.3	94.7
CT/NT	23.6	26.7	20.4	19.2	19.6	14.4	45.8	43.5	97.6	94.7
NT/NT	23.6	26.7	20.5	19.1	20.2	14.4	44.6	44.2	97.5	95.0
NT+S/NT	23.2	26.5	20.2	18.5	19.2	14.2	45.9	44.6	98.4	95.5
FB/CT	23.3	26.8	20.3	19.4	19.3	14.4	45.3	43.6	97.6	94.6
CT/FB	26.2	29.3	21.2	20.3	20.2	14.9	42.9	41.9	91.8	88.5
PB/PB	26.4	29.5	21.3	20.5	21.0	15.0	42.3	41.0	90.5	88.1
PB+S/PB	26.3	29.3	21.2	20.7	20.4	15.9	42.8	41.5	90.7	87.3
SEm±	0.7	0.7	0.7	0.3	0.7	0.7	0.5	0.5	0.9	0.9
CD (P=0.05)	2.1	2.1	2.0	1.0	NS	NS	1.6	1.5	2.7	2.5

CT, Conventional tillage; NT, No tillage; NT+S/NT, NT+Wheat straw mulch @ 5 t/ha/NT; FB/CT, Fresh Beds/flat CT; CT/FB, Conventional tillage/Fresh Beds; PB/PB, Permanent beds/permanent beds; PB+S/PB, Permanent beds+wheat straw mulch/permanent beds

Consumptive use (CU) and water use efficiency (WUE)

Maize: Almost similar CU and WUE in all the treatments were recorded during 2003, as the rains (571.7 mm) were well distributed (Table 3). However, maximum CU and WUE by crop was recorded in NT+S/NT treatment during 2003 and PB+S/PB in 2004, respectively. The NT+S/NT and PB+S/PB recorded 10.37 and 3.40% less CU than CT/CT and FB/CT treatments, respectively during 2004. The reduced CU in mulched treatments was due to less evaporation of water from the soil surface. Similarly, higher WUE was also reported in no tillage (Chauhan *et al.*, 2000) and bed planting (Kaur and Mahey, 2005) in earlier studies.

Wheat: The treatments of PB+S/PB being on par with CT/FB and PB/PB recorded significantly lower CU and higher WUE than all CT and NT treatments (Table 4).

Less CU in bed planted treatments might be due to less amount of irrigation water applied than flat CT and NT treatments. Aggarwal *et al.* (2002) recorded similar results of lower water use in bed planted wheat.

Soil studies

The studies showed that NT/NT treatment recorded highest bulk density in 0-15 cm soil depth which was significantly higher than CT/CT, FB/CT, CT/FB, PB/PB and PB+S/PB treatments but was statistically on par with CT/NT and NT+S/NT treatments (Table 5). NT+S/NT and PB+S/PB slightly reduced the bulk density when compared to PB/PB and NT/NT treatments. Higher bulk density in NT/NT might be due to undisturbed soil surface. These results are in accordance with those obtained by Kumar *et al.* (2002). Aggarwal and Goswami (2003) also

Table 3. Yield attributing characters and grain yield of maize as influenced by tillage and crop establishment practices

Treatment	Maize											
	Cobs/plant		Grains/cob		100-grain weight (g)		Grain yield (t/ha)		Consumptive water use (cm)		Water use efficiency (kg/ha-cm)	
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
CT/CT	0.94	0.94	55.1	54.5	28.0	28.1	5.51	5.45	47.75	49.46	115.4	110.2
CT/NT	0.94	0.95	54.8	54.1	27.9	27.7	5.49	5.42	48.05	48.65	114.2	111.3
NT/NT	0.95	0.95	55.6	54.7	28.1	28.2	5.57	5.47	48.06	48.01	115.9	114.0
NT+S/NT	0.96	0.95	56.3	56.5	28.1	28.3	5.64	5.66	46.45	44.33	121.3	127.6
FB/CT	0.95	0.94	55.1	56.3	28.0	28.3	5.52	5.63	49.54	44.11	115.8	127.7
CT/FB	0.95	0.95	55.3	54.3	28.0	28.1	5.54	5.44	47.84	49.22	111.4	110.4
PB/PB	0.94	0.95	54.1	56.1	27.6	28.2	5.41	5.61	48.64	45.45	111.3	123.5
PB+S/PB	0.94	0.96	55.0	58.5	28.0	28.4	5.50	5.85	48.84	42.61	112.7	137.3
SEm±	0.01	0.01	0.5	1.6	0.2	0.3	0.09	0.10	0.85	0.65	1.7	2.2
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.91	5.1	6.5

CT, Conventional tillage; NT, No tillage; NT+S/NT, NT+Wheat straw mulch @ 5 t/ha/NT; FB/CT, Fresh Beds/flat CT; CT/FB, Conventional tillage/Fresh Beds; PB/PB, Permanent beds/permanent beds; PB+S/PB, Permanent beds+wheat straw mulch/permanent beds

Table 4. Yield attributing characters and grain yield of wheat as influenced by tillage and crop establishment practices

Treatment	Wheat													
	Effective tillers (/m ²)		Ear length (cm)		Grains/ear		1,000-grain weight (g)		Grain yield (t/ha)		Consumptive water use (cm)		Water use efficiency (kg/ha-cm)	
	03-04	04-05	03-04	04-05	03-04	04-05	03-04	04-05	03-04	04-05	03-04	04-05	03-04	04-05
CT/CT	306.0	295.0	8.93	9.00	44.1	44.4	42.1	41.8	5.48	5.25	49.89	45.51	109.9	115.4
CT/NT	306.1	295.6	8.96	9.05	44.8	44.6	42.5	41.9	5.49	5.26	50.22	44.92	109.3	117.1
NT/NT	305.3	296.0	8.92	9.07	44.5	44.8	42.8	42.0	5.46	5.27	50.52	44.52	108.1	118.3
NT+S/NT	308.4	297.2	9.10	9.10	44.9	44.9	42.9	42.2	5.52	5.28	49.52	44.88	111.5	117.7
FB/CT	306.4	295.2	9.00	9.01	44.8	44.4	42.8	41.7	5.50	5.25	50.72	45.83	108.4	114.6
CT/FB	276.2	265.5	9.85	9.87	49.9	49.3	43.8	42.8	5.46	5.25	46.25	41.17	118.2	127.6
PB/PB	273.1	258.5	9.75	9.80	48.3	49.0	43.8	42.5	5.30	5.11	46.39	40.08	114.3	127.6
PB+S/PB	274.8	264.3	9.80	9.83	49.6	49.1	43.6	42.7	5.43	5.23	45.73	39.88	118.6	131.0
SEm±	9.6	8.5	0.15	0.17	1.0	0.9	0.6	0.4	0.09	0.07	0.72	0.99	2.1	2.0
CD (P=0.05)	28.1	25.1	0.43	0.51	2.8	2.7	NS	NS	NS	NS	2.11	2.92	6.1	5.8

CT, Conventional tillage; NT, No tillage; NT+S/NT, NT+Wheat straw mulch @ 5 t/ha/NT; FB/CT, Fresh Beds/flat CT; CT/FB, Conventional tillage/Fresh Beds; PB/PB, Permanent beds/permanent beds; PB+S/PB, Permanent beds+wheat straw mulch/permanent beds

Table 5. Soil properties, economics and energy indicators (mean of 2 seasons) of maize-wheat sequence as influenced by tillage and crop establishment practices

Treatment	Bulk density (g/cm ³)	Cumulative infiltration (cm/hr)	Organic carbon (%)	Cost of cultivation (Rs/ha)	Net returns (Rs/ha)	B:C ratio	Input energy (x10 ³ MJ/ha/year)	Output energy (x 10 ⁶ MJ/ha/year)	Output/ input ratio		
CT/CT	1.46	7.74	0.358	37,555	38,891	42,081	40,639	1.09	31.25	371.6	12.41
CT/NT	1.48	7.85	0.360	36,227	37,566	43,329	41,888	1.16	30.13	385.7	12.85
NT/NT	1.50	7.87	0.375	34,902	36,241	44,855	43,536	1.25	29.09	387.8	13.38
NT+S/NT	1.48	8.03	0.423	42,904	44,241	37,780	36,515	0.86	90.29	392.0	4.34
FB/CT	1.43	7.74	0.355	37,308	38,888	42,855	41,480	1.12	30.63	389.2	12.73
CT/FB	1.40	7.95	0.356	37,114	38,497	42,263	40,730	1.10	30.27	383.5	12.74
PB/PB	1.47	7.98	0.374	34,556	35,851	42,956	42,329	1.20	27.69	381.7	13.82
PB+S/PB	1.45	8.09	0.421	42,557	43,851	36,434	36,175	0.85	89.07	388.7	4.37
CD (P=0.05)	0.03	0.15	NS								
Initial	1.45	7.75	0.340								

found less bulk density in beds. The highest cumulative infiltration was recorded in PB+S/PB treatment which was statistically on par with PB/PB, CT/FB and NT+S/NT, but significantly higher than all other treatments. Higher infiltration in NT and PB with mulch was in agreement with the findings of Shaver *et al.* (2002). The effect of treatments on organic carbon content of soil was found to be non-significant. However, slightly higher organic carbon in straw mulched treatment (0-30 cm layer) was seen that might be due to cumulative effect of decomposed straw added i.e. 10 t/ha in two seasons.

Economics and energetics

The highest net returns and B:C ratio were observed in NT/NT due to low cost of cultivation. Similar results of higher net income in no tillage (Landers *et al.*, 2001) and permanent bed planting (Sayre and Limon, 2002) were also reported. The energy input was minimum in PB/PB treatment (Table 5) which might be due to minimum energy used in tillage and less irrigation water used in this treatment. The energy input and output were highest in NT+S/NT due to high energy used as straw mulch and slightly higher yields, respectively. The energy output/input ratio was highest in PB/PB (13.82) treatment might be due to minimum energy input.

Based on the data relating to the microenvironment, yield attributes, grain yield, consumptive water use, energy used and benefit cost ratio, no tillage and permanent bed planting have the possibility of adopting these resource conservation technologies in maize and wheat in sequence.

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