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Impact of different tillage methods on growth, development and productivity of maize (*Zea mays*)-wheat (*Tritcum aestivum*) cropping system

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Abstract: An experiment was conducted on a silty clay loam soil of Palampur during 2009–2011, to study the effect of different tillage methods in maize (*Zea mays* L.) wheat {*Triticum aestivum* (L.) emend. Fiori & Paol.} cropping system. Results revealed that in maize crop, tillage methods in *kharif* season resulted in significantly highest emergence count (27.1 plant/m^2) under manual seed drill. While, multi-crop planter recorded in significantly taller plants (55.4 cm) at 30 DAS; higher dry matter accumulation 81.0, 990.0 and 4184.4 g/m^2 at 30, 60 and 90 DAS, respectively and CGR (30.3 g/day/m^2) at 30-60 DAS. Tillage methods in *rabi* season resulted in higher emergence count (17.6 plant/m^2) under zero tillage. This treatment also recorded advanced emergence by 1.2 to 1.5 days. In wheat crop, tillage methods in *kharif* season resulted in significantly highest emergence count (307.6 plant/m^2), taller plants (13.1 cm) at 30 DAS, dry matter accumulation (625.3 g/m^2) at 120 DAS and CGR (14.4 g/day/m^2) at 90-120 DAS under conventional tillage. While, tillage methods in *rabi* season resulted in significantly highest emergence count (369.5 plants/m^2), tallest plants (17.7, 92.6 and 101.0 cm at 60, 120 and at harvest, respectively) with multi-crop planter. While, zero tillage recorded significantly higher CGR (15.8 g/day/m^2) and RGR (0.027 g/g/day) during 120-harvest stage. Zero tillage produced statistically at par crop yield and rainwater-use efficiency of both crops with other tillage treatments. Hence, zero tillage can be as good as other intensive tillage system besides lower input cost and environmental security.

Keywords: CGR, Maize-wheat, Rainwater use efficiency, RGR, Zero tillage

INTRODUCTION

Himachal Pradesh is the only state in the country whose 89.96 percent population lives in rural area having agriculture as main occupation (Anonymous, 2015). And about 14 percent of the total State Gross Domestic Product comes from agriculture and its allied sectors. Maize-wheat cropping system is the most dominant cropping system in the State and is followed under rainfed conditions as about 80% of cultivated area lacks irrigation facilities resulting in lower productivity. Further, uneven distributions of rains on undulating land holding do not encourage hill farmers to adopt new farming practices as their counterparts. Under rainfed condition, using suitable tillage practices according to climate and soil characteristics is very important, because of its effect on soil properties which varies from region to region (Mujdeci *et al.,* 2010). Modified management practices including intensive tillage operations are being advocated for improving resource-use efficiency and crop productivity. However, research results showed that intensive tillage practices declined soil structure and stability over years due to depletion of soil organic matter, resulting in soil susceptible to erosion (Schneider *et al.,* 2012). The conventional (intensive) tillage systems thus may not be suited to hilly areas already prone to excessive soil erosion hazards. Therefore, minimum and zero tillage are recommended for Indian Himalayan region due to reduced cultivation cost, higher retention of soil water and increased soil organic carbon (Bhattacharyya *et al.,* 2012).

Adoption of resource conserving technologies like zero tillage has emerged as a means of achieving the sustainability of intensive cropping systems (Sharma *et al.,* 2012). In zero tillage, the crops are sown with minimum disturbance of soil by placing the seeds in a narrow slit about 3-4 cm wide and 4-7 cm deep without land preparation. Inspite of reducing cultivation cost, zero tillage also improve the soil fertility through increased soil carbon accumulation and biological activity (Bhan and Behera, 2014) and mitigate the green

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house gas emission (Timsina and Connor, 2001). Hence, to increase and sustain the productivity of agricultural systems it is important to identify appropriate soil management practices concomitant with friendly environment and efficient utilization of production resources. Thus, the present experiment was designed to evaluate the effect of different tillage/planting techniques on growth, development and yield of maize-wheat cropping system.

MATERIALS AND METHODS

An experiment was conducted for maize-wheat cropping system at Palampur during *kharif* 2009 to *rabi* 2011. The geographical co-ordinates of experimental field were $32^0$6' N latitude and $76^0$3' E longitude and an altitude of 1,290 meters above mean sea level. The soil of the experimental site was silty clay loam in texture with pH 5.06, had 1.1% organic carbon, 323.0 kg/ha alkaline permanganate oxidized N, 25.8 kg/ha available P and 276.4 kg/ha 1N ammonium acetate exchangeable K at the time of initiation of study. During *kharif* season maize crop experienced well distributed rainfall of 1,342.1 and 2,148.0 mm during 2009 and 2010, respectively. During *rabi* season wheat crop received 361.9 and 557.2 mm rainfall during 2009-10 and 2010-11, respectively. Maize–wheat system was raised in sequence with 16 treatment combinations in strip–plot design with 3 replications. Treatments in horizontal plots were (Maize, *kharif*): M_1-sowing by power tiller-operated zero till drill; M_2-sowing by power tiller-operated multi-crop planter; M_3-sowing by manually operated seed drill; M_4-sowing by conventional method (sowing behind the hand plough); and in vertical plots (wheat, *rabi*): W_1-sowing by power tiller-operated zero till drill; W_2-sowing by power tiller operated multi-crop planter; W_3-sowing by manually operated seed drill; W_4-sowing by conventional method (sowing behind the hand plough). Maize 'Girija Composite' and wheat 'HPW 155' were sown during both the years under irrigated conditions. The recommended dose of N, P_2O_5 and K_2O for maize and wheat was 120:60:40 and 120:60:30 kg/ha, respectively. Entire P and K were applied at the time of sowing to both the crops. In maize, N was applied in 3 equal splits (at sowing, knee-high and tasseling stage) whereas in wheat, half N at the time of sowing and remaining N was applied in 2 splits at tillering and earing stage. To control the weeds, Atrazine at 1.25 kg/ha followed by (fb.) 2,4-D at 1.00 kg/ha in maize crop and Isoproturon at 1.20 kg/ha fb. 2,4-D at 1.00 kg/ha in wheat crop were applied during both years. However, at later growth period of crops, weeds were also removed manually. All observations for each character were subjected to statistical analysis according to the standard method (Gomez and Gomez 1984) and were tested at 5 per cent level of significance to interpret the treatment differences. Pooling was done over the seasons and mean data are given. Crop growth rate (CGR) and relative growth rate (RGR) of both crops was calculated by the formulae outlined by Watson (1962). Rainwater-use efficiency (RWUE) of both crops was computed as per Mupangwa *et al.* (2016).

RESULTS AND DISCUSSION

Maize crop

Growth studies: Tillage/planting techniques in *kharif* (Table 1) showed that emergence count was highest (27.1 plant/m^2) in manual seed drill followed by multi-crop planter. The count in these two treatments was about 3 and 2 times higher than the required normal population. This showed that the machines have used higher seed rate and for their proper calibration still more work has to be done. However, the low emergence count in zero tillage might be due to more compact soil and less soil-seed contact. Tillage methods in *rabi* also showed that emergence count was above the optimum under all the treatments. But it was significantly higher under zero till seeded plots (17.6 plants/m^2) over conventional and multi-crop planter planted crop.

Tillage methods in *kharif* further showed that sowing with multi-crop planter remaining at par with manual seed drill resulted in significantly taller plants (55.4 cm) at 30 DAS; and higher dry matter accumulation 81.0, 990.0 and 4184.4 g/m^2 at 30, 60 and 90 DAS, respectively and CGR (30.3 g/day/m^2) during 30-60 DAS as compared to zero tillage. While, conventional tillage remaining at par with zero tillage recorded significantly higher RGR (0.098 g/g/day) over multi-crop planter and manual seed drill. This increase in growth parameters under multi-crop planter could be ascribed to better pulverization of soil which might have helped in better air exchange, soil moisture and nutrient availability resulting in higher values of all growth parameters over zero tillage. The lower growth of maize in zero tillage may be ascribed to greater soil bulk density and soil penetration resistance which adversely affects the root growth resulting less nutrients removal from soil and high crop-weed competition. Chopra and

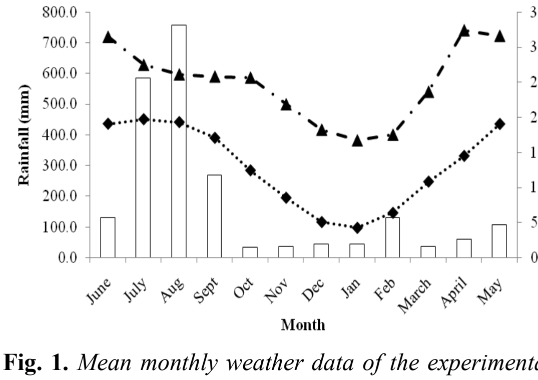

Fig. 1. *Mean monthly weather data of the experimental site (mean of 2009-2011).*

Table 1. Effect of treatments on emergence count and growth parameters of maize (Pooled data of 2009-2011).

Treatment	Emergence count (No/m^2)	Plant height (cm)			Dry matter accumulation (g/m^2)			CGR (g/day/m^2)		RGR (g/g/day)	
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30-60 DAS	60-90 DAS	30-60 DAS	60-90 DAS
Kharif											
Zero tillage (M_1)	9.8	39.4	213.6	243.7	39.7	635.4	2910.4	19.9	75.8	0.093	0.051
Multi-crop planter (M_2)	16.1	55.4	215.4	247.1	81.0	990.0	4184.4	30.3	106.5	0.085	0.048
Manual seed drill (M_3)	27.1	55.3	228.2	252.3	76.7	941.3	3951.2	28.8	100.3	0.084	0.048
Conventional tillage (M_4)	9.7	40.8	220.3	251.8	44.6	773.0	3580.5	24.3	93.6	0.098	0.052
SEm±	0.54	2.02	3.14	2.79	6.29	64.99	249.59	2.02	6.33	0.003	0.001
CD= (0.05)	1.9	7.0	NS	NS	21.8	224.9	863.7	7.0	NS	0.010	NS
Rabi											
Zero tillage (W_1)	17.6	48.3	216.1	241.1	57.7	819.7	3681.7	25.4	95.4	0.091	0.051
Multi-crop planter (W_2)	14.5	47.9	218.0	251.1	67.8	820.5	3614.9	25.1	93.1	0.086	0.051
Manual seed drill (W_3)	16.5	47.6	222.4	252.8	56.5	838.3	3733.9	26.1	96.5	0.092	0.050
Conventional tillage (W_4)	14.0	47.2	220.8	249.8	60.1	861.2	3596.0	26.7	91.2	0.090	0.048
SEm±	0.77	0.61	6.30	3.13	7.28	40.58	141.44	1.39	3.56	0.004	0.001
CD= (0.05)	2.7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2. Effect of treatments on phenological stages, productivity and RWUE of maize (Pooled data of 2009-2011).

Treatment	Days to			Green cob yield (kg/ha)	Green fodder yield (kg/ha)	Biological yield (kg/ha)	Harvest index	RWUE (kg/ha/mm)
	Emergence	Tasseling	Harvest					
Kharif								
Zero tillage (M_1)	10.1	63.8	96.0	6493.2	45428.5	51921.7	0.13	3.72
Multi-crop planter (M_2)	9.9	62.7	95.5	7397.4	42773.1	50170.5	0.15	4.24
Manual seed drill (M_3)	10.2	62.0	96.0	8057.0	44009.7	52066.7	0.16	4.62
Conventional tillage (M_4)	9.9	63.6	95.7	7393.3	45454.5	52847.9	0.14	4.24
SEm±	0.17	0.26	0.34	468.9	1379.75	1477.60	0.009	0.269
CD= (0.05)	NS	0.9	NS	NS	NS	NS	NS	NS
Rabi								
Zero tillage (W_1)	9.8	62.9	95.8	7199.5	43983.7	51183.1	0.14	4.13
Multi-crop planter (W_2)	10.0	62.8	95.8	7408.4	45272.3	52680.7	0.14	4.25
Manual seed drill (W_3)	10.3	63.3	95.7	7663.3	43450.0	51113.3	0.15	4.39
Conventional tillage (W_4)	10.1	63.0	95.8	7069.8	44959.9	52029.7	0.14	4.05
SEm±	0.08	0.14	0.30	353.13	809.37	523.01	0.008	0.202
CD= (0.05)	0.3	NS	NS	NS	NS	NS	NS	NS

Table 3. Effect of treatments on emergence count and growth parameters of wheat (Pooled data of 2009-2011).

Treatment	Emergence count (No/ m^2)	Plant height (cm)					Dry matter accumulation (g/m^2)				
		30 DAS	60 DAS	90 DAS	120 DAS	At harvest	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
Kharif											
Zero tillage (M_1)	281.7	12.6	16.9	37.6	88.3	96.3	7.5	28.1	91.7	584.6	1129.4
Multi-crop planter (M_2)	287.2	12.7	17.1	37.0	89.6	96.6	8.1	27.5	88.8	542.8	1098.8
Manual seed drill (M_3)	273.1	13.2	16.8	36.9	88.3	96.6	7.4	28.0	80.2	572.2	1106.5
Conventional tillage (M_4)	307.6	13.1	16.7	36.8	89.0	97.9	7.4	27.6	88.7	625.3	1076.1
SEm±	5.87	0.09	0.20	0.66	0.53	0.67	0.25	1.78	4.65	14.29	20.99
CD= (0.05)	20.3	0.3	NS	NS	NS	NS	NS	NS	NS	49.4	NS
Rabi											
Zero tillage (W_1)	284.5	12.6	16.5	36.4	86.3	91.7	6.7	25.7	80.6	485.0	1061.7
Multi-crop planter (W_2)	369.5	13.6	17.7	38.8	92.6	101.0	8.1	30.1	100.0	595.4	1124.3
Manual seed drill (W_3)	254.8	12.7	16.7	36.0	86.8	96.5	7.1	29.1	82.1	606.1	1107.6
Conventional tillage (W_4)	240.8	12.7	16.7	37.1	89.4	98.2	8.5	26.2	86.7	638.4	1117.1
SEm±	10.93	0.27	0.23	0.74	0.39	1.47	0.80	1.94	7.06	18.74	30.23
CD= (0.05)	37.8	NS	0.8	NS	1.4	5.1	NS	NS	NS	64.8	NS

Table 4. Effect of treatments on growth parameters and phenological stages of wheat (Pooled data of 2009-2011).

Treatment	CGR ($g/day/m^2$)				RGR (g/g/day)				Days to			
	30-60 DAS	60-90 DAS	90-120 DAS	120-At harvest	30-60 DAS	60-90 DAS	90-120 DAS	120-At harvest	Emergence	Tillering	Earing	Maturity
Kharif												
Zero tillage (M_1)	0.6	1.7	13.4	14.9	0.057	0.042	0.062	0.023	16.8	50.9	118.9	160.6
Multi-crop planter (M_2)	0.6	1.6	12.2	15.1	0.053	0.041	0.062	0.024	17.0	51.0	119.0	160.1
Manual seed drill (M_3)	0.6	1.4	13.2	14.6	0.055	0.037	0.066	0.022	16.7	50.9	119.0	160.0
Conventional tillage (M_4)	0.6	1.7	14.4	12.5	0.055	0.041	0.066	0.018	16.8	51.0	119.0	160.1
SEm±	0.05	0.13	0.32	0.54	0.004	0.004	0.001	0.001	0.06	0.08	0.12	0.19
CD= (0.05)	NS	NS	1.1	1.9	NS	NS	NS	0.003	NS	NS	NS	NS
Rabi												
Zero tillage (W_1)	0.6	1.4	10.6	15.8	0.054	0.040	0.060	0.027	16.8	50.4	118.6	159.3
Multi-crop planter (W_2)	0.7	1.8	13.3	14.5	0.062	0.041	0.060	0.022	16.9	50.0	118.4	159.6
Manual seed drill (W_3)	0.7	1.5	14.6	13.4	0.056	0.039	0.069	0.020	16.9	51.8	119.5	161.5
Conventional tillage (W_4)	0.6	1.6	14.8	13.3	0.048	0.042	0.068	0.019	16.7	51.5	119.4	160.4
SEm±	0.05	0.16	0.42	0.47	0.005	0.003	0.002	0.001	0.11	0.20	0.24	0.33
CD= (0.05)	NS	NS	1.4	1.6	NS	NS	0.007	0.002	NS	0.7	0.8	1.2

Table 5. Effect of treatments on productivity and RWUE of wheat (Pooled data of 2009-2011).

Treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index	RWUE (kg/ha/mm)
Kharif					
Zero tillage (M_1)	3579.1	5006.6	8585.7	0.42	7.79
Multi-crop planter (M_2)	3543.8	5070.9	8614.7	0.41	7.71
Manual seed drill (M_3)	3581.0	5281.4	8862.4	0.40	7.79
Conventional tillage (M_4)	3668.8	5387.2	9056.0	0.40	7.98
SEm±	137.15	143.83	297.09	0.003	0.298
CD= (0.05)	NS	NS	NS	0.01	NS
Rabi					
Zero tillage (W_1)	3302.1	4893.0	8195.0	0.40	7.19
Multi-crop planter (W_2)	3884.1	5383.6	9267.7	0.42	8.45
Manual seed drill (W_3)	3558.7	5087.2	8645.9	0.41	7.74
Conventional tillage (W_4)	3627.9	5382.4	9010.3	0.40	7.89
SEm±	119.94	180.47	289.64	0.005	0.261
CD= (0.05)	NS	NS	NS	NS	NS

Angiras (2008) and Yusuf (2006) also reported similar results under zero tillage as compared to tillage systems. Tillage methods in *rabi* did not shows any significant results on growth parameters of maize.

Development studies: Zero tillage being statistically at par with conventional tillage took significantly more days to tasseling as compared to manual seed drill and multi-crop planter sown maize in *kharif* season (Table 2). Both of the later *i.e.* manual seed drilled and multi-crop planter were at par with each other. This could be ascribed to the prolonged vegetative phase of the crop under high crop-weed competition and unfavourable soil conditions in zero and conventional tillage. Tillage methods in *rabi* showed significant effect on days to emergence where, manual seed drill remaining at par with conventional tillage took significantly more number of days to emergence which was at par with conventional tillage. Zero tillage in *rabi* had advanced emergence of maize by 0.2 to 0.5 days than the other tillage management techniques. This might be due proper placement of seed for quick emergence under the zero till drill planting. Days to tasseling and harvesting were not significantly influenced by tillage methods in *rabi* season.

Yield: Green cob, green fodder, biological yield and harvest index was not significantly influenced by tillage methods in *kharif* as well as *rabi* season (Table 2). However, the green cob yield was comparatively more under manual seed drill, but the differences were not significant. The lower population under zero tillage did not significantly influenced cob yield of maize. But maize green cob yield under the zero till sowing was low enough over the other treatments. The results further revealed that all tillage systems produced statistically similar grain yield which is quite encouraging regarding zero tillage because of lower inputs cost. Less soil disturbance under zero tilled soil might have increased the microbial population and organic biomass which further might have increased the yield which compensated by compensating the slower growth of crop at the end. The results are in accordance with Ram *et al.* (2010), who reported that maize yield did not differ significantly among zero tillage and conventional tillage.

RWUE: Tillage methods in *kharif* as well as *rabi* season did not significantly influenced the RWUE of maize. However, manual seed drill recorded higher values in both season as compared to other treatments. Higher value in this tillage method might be due to higher water retention which resulted in higher economic yield hence higher RWUE.

Wheat crop

Growth studies: Tillage/planting techniques in *kharif* and *rabi* season significantly influenced the emergence count of wheat. During *kharif* seasons, conventional tillage resulted in significantly highest emergence count (307.6 plant/m^2) over all other tillage methods which were significantly at par with each others. Tillage methods in *rabi* showed that emergence count was significantly highest under multi-crop planter (369.5 plant/m^2) as compared to others.

In case of plant height and dry matter accumulation, tillage methods in *kharif* showed that manual seed drill remaining at par with conventional tillage had taller plants (13.2 cm) at 30 DAS. However, slower growth under zero tillage and multi-crop planter was compensated at later stages. Conventional tillage also recorded highest dry matter accumulation (625.3 g/m^2) at 120 DAS as compared to other tillage methods. At harvest, zero tillage was as good as others which was owed to less intra-row competition and increased resource use efficiency as compared to others. Tillage methods in *rabi* showed a different trend where multi-crop planter recorded tallest plants 17.7, 92.6 and 101.0 cm at 60, 120 and at harvest, respectively as compared to other treatments. While, conventional tillage remaining at par with manual seed drill and multi-crop planter resulted in higher dry matter accumulation (638.4 g/m^2) at 120 DAS. Zero tillage recorded lowest dry matter accumulation at all growth stages indicating visible ill effects which are expected to be further pronounced over the years. This was observed by build-up of certain perennial weeds species such as *Cynodon dactylon* after the harvest of wheat crop. Also, the roots of wheat crop in no till drill plants were shallower and were not able to extract the nutrients and moisture available at deeper layers. However, higher dry matters in conventional seeding might be due to better soil conditions like lower bulk density, better nutrient and moisture availability from deeper layer. Higher dry matter accumulation in conventional seeding due to good soil conditions due to better pulverization of soil than the other tillage treatments was in accordance with Khan *et al.* (2014). Tillage/planting techniques in *kharif* season significantly influenced the CGR (90-120 DAS and 120-harvest) and RGR (120-harvest) (Table 4). Conventional tillage (14.4 g/day/m^2) remaining at par with zero tillage (13.4 g/day/m^2) recorded significantly higher CGR during 90-120 DAS while same treatment recorded lowest CGR (12.5 g/day/m^2) during 120-harvest stage. RGR during 120-harvest stage was higher in multi-crop planter (0.024 g/g/day) which was at par with zero tillage and manual seed drill. Tillage/planting techniques in *rabi* season showed that CGR and RGR during 90-120 DAS were higher in conventional tillage (14.8 g/day/m^2 and 0.068 g/g/day, respectively) which was at par with manual seed drill. However, during 120-harvest stage zero tillage recorded higher CGR (15.8 g/day/m^2) and RGR (0.027 g/g/day) as compared to other tillage methods.

Development studies: Tillage/planting techniques in *kharif* season did not significantly influence the phenophases of wheat (Table 4). While tillage in *rabi* season showed that multi-crop planter and zero till seeding remaining at par with each other took lesser number of days (1.5 to 1.8 days) to tillering, earing and maturity than manual seed drill and conventionally seeded crop.

Yield: Like maize yield, wheat grain yield was not significantly different either owing to tillage treatments in *kharif* as well as *rabi* season (Table 5). However, the grain yield was comparatively more under conventional tillage and multi-crop planter, but the differences were not significant. The comparable (similar) effect of tillage/planting treatments suggested that there is no need to go for intensive tillage operations and zero tillage can be a good practice under the present condition atleast for the initial years. The farmers of the state can follow any method of their choice depending upon the resources available Similar grain yield under zero and conventional tillage was also noted by Monsefi *et al.*(2016) showing that wheat can be grown very successfully under zero tillage condition as the productivity was nearly similar compared with conventional tillage. However, zero tillage in *kharif* season recorded significantly higher harvest index which was at par with multi-crop planter as compared to conventional tillage and manual seed drill planting. This might be due to higher economic and straw yield ratio under zero tillage.

RWUE: Likewise in maize crop, tillage methods in *kharif* as well as *rabi* season did not significantly influenced the RWUE of wheat. However, conventional tillage in *kharif* and multi-crop planter in *rabi* season recorded higher values of RWUE as compared to other owing to higher yield in these treatments.

Conclusion

The present study concluded that sowing of maize (*Z. mays*) with manual seed drill and wheat (*T. aestivum*) under multi-crop planter was more beneficial for improving productivity and profitability of *Z. mays.* Further, both the crops can be grown very successfully under zero tillage as the productivity was nearly similar compared with conventional tillage. Similarly, grain yield is quite encouraging regarding zero tillage because of lower input cost and environmental security. This further suggested that there is no need to go for intensive tillage operations and zero tillage can be as good as other practices under the present condition at least for the initial years.

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