



Research Article

Crop Microenvironment and Yield of Maize under Conservation Practices

REKHA KUMARI MEENA¹, ANANTA VASHISTH*¹ AND T.K. DAS²

¹Division of Agricultural Physics, ²Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi-110012

ABSTRACT

An experiment was conducted to find out suitable resource conservation technology during the *kharif*, 2014 at the research farm of ICAR-Indian Agricultural research Institute, New Delhi to evaluate the effect of various tillage practices on micrometeorological and yield of maize crop in maize-wheat cropping system. Crop was sown under conventional treatment and different conservation practices such as zero tilled permanent narrow bed (PNB), zero tilled permanent narrow bed plus residue (PNB+R), zero tilled permanent broad bed (PBB), zero tilled permanent broad bed plus residue (PBB+R), zero tilled flat bed (ZT), zero tilled flat bed plus residue (ZT+R). Results showed that conservation practice improved the crop microenvironment by modification of soil physical environment, soil temperature and moisture retention. Due to better crop microenvironment under conservation practices there was better crop yield in maize.

Key words: Thermal indices, Temperature, Relative humidity, Yield, Maize, Conservation practice

Introduction

Agriculture is highly susceptible to climate change. Frequent heat waves, warm and humid weather increase the intensity of pests, diseases and impoverishment of crops. Increase in crop production must be achieved by reducing the risk and losses in agricultural production. Modifications are required in modern agriculture practices to pace with the changing climate, and to reduce the impact and vulnerability (Smith *et al.*, 2009). No tillage and residue management affect crop growth, yield and also help to sustain the crop production. No tillage with presence of crop residue on the soil surface improved properties of soil like quality and resource utilisation ability (Ghosh *et al.*, 2010). System

and management affecting microclimate of the crop should be properly understood for effective management (Olanya *et al.*, 2006). Use of correct tillage methods may contribute to higher profits, crop yields, soil improvement and protection, weed control and optimum use of water resources since tillage has a direct impact on soil and water quality (Hanna *et al.*, 2009). Micrometeorology of crop can affect the crop production to a great extent. Keeping in view of above points, different conservation agriculture practices and their impact on modification of microenvironment, crop growth and yield have been studied.

Materials and Methods

The present study was carried out in the experimental field of ICAR-Indian Agricultural research Institute (IARI), New Delhi (28°35' N latitude; 77°12' E longitude; altitude of 228.16 m

*Corresponding author,
Email: ananta.iari@gmail.com

above mean sea level). The soil type is alluvium and texture is sandy clay loam (fine loamy, illitic, Typic Haplustept) with medium to weak angular blocky structure. The soil is non-calcareous and neutral in reaction, poor in available N, medium in available P and organic carbon content.

Maize (*Zea mays* L.) variety BIO 9637 was sown on 5th July 2014. The field experiment was conducted with different conservation treatments: zero tilled permanent narrow-bed (PNB), zero tilled permanent narrow-bed sowing with residue retention (PNB + R), zero tilled permanent broad-bed (PBB), zero tilled permanent broad-bed with residue (PBB + R), zero tilled flat bed (ZT FB), zero tilled flat bed with residue (ZT FB+R)] along with conventional treatment (CT), arranged in a randomized block design (RBD) with three replications. Daily weather data during crop growing period were collected from the agrometeorological observatory of the Division of Agricultural Physics close to the experimental site. Soil moisture at different depths was recorded by gravimetric method, and soil temperature at different depths was measured with the help of soil thermometer. Air temperature and relative humidity within crop canopy were measured at canopy mid-height with the help of a pocket weather tracker (Model: Kestrel 4000) at around 14:30 hours (i.e., time of occurrence of daily maximum temperature). Observations on different crop growth parameters such as leaf area and biomass were recorded at different crop growth stages. Measurements of LAI were carried out in a field at 30 days intervals using LAI-2000 Plant Canopy Analyzer (LI-COR, USA). For biomass, three plants were selected randomly in each plot, oven-dried at 65°C for 48 h and dry-weights were taken. Seed yields were measured after harvest.

Different thermal indices were calculated at physiological maturity under different conservation practices along with conventional practice as given by following equations:

- Growing degree days (GDD) = $\sum \{(T_{\max} + T_{\min}) / 2\} - T_b$
- Helio thermal units (HTD) = $\sum \text{GDD} \times \text{SSH}$

- Photo thermal units (PTU) = $\sum \text{GDD} \times \text{Day length}$
- Relative temperature disparity (RTD) = $\sum \{(T_{\max} - T_{\min}) / T_{\max}\} \times 100$
- Photo thermal index (PTI) = $\text{GDD} / \text{Growing day}$
- Heat use efficiency (HUE) = $\text{Yield} / \text{GDD}$

Statistical analysis viz., computation of correlation coefficients, critical difference and student t test was carried out using Excel and SPSS packages (Version 10.0). The required graphs were drawn using MS Excel software packages.

Result and Discussion

Weather during crop growing period (kharif 2014)

Daily weather data during crop growing period were compared with the normal values. Crop growth period of maize was from 5th July to 20th October, 2014. The maximum temperature was 0.3-5.6°C lower than the normal during forty eight days, rest of days the maximum temperature was more than the normal by 0.1-7.5°C. The minimum temperature was lower than normal by 0.1-4.5°C in eighty five days, other days the minimum temperature was 0.1-5.4°C higher than the normal. Total rainfall received during this period was 512.8 mm (607.4 mm normal rainfall) and total rainy days were twenty seven. Maximum rainfall was 120.6 mm on 18th July and second highest was 55.6 mm on 3rd July. Bright sunshine hour was 1.0-7.1 h lower than normal in sixty nine days and in rest of days, observed value was 1.2-4.5 h higher than normal. Evaporation during different days of *kharif* season was 0.1-3.6 mm lower than the normal in forty four days of growing season, in other days evaporation was 0.1-6 mm higher than normal value. Wind speed was 0.1-12.7 km h⁻¹ higher than the normal during different days of growing season, except forty days it was 0.1-2.7 km h⁻¹ lower than the normal. Percentage value of maximum relative humidity measured at 7.21 AM was lower than the normal throughout the crop growing period, except sixty

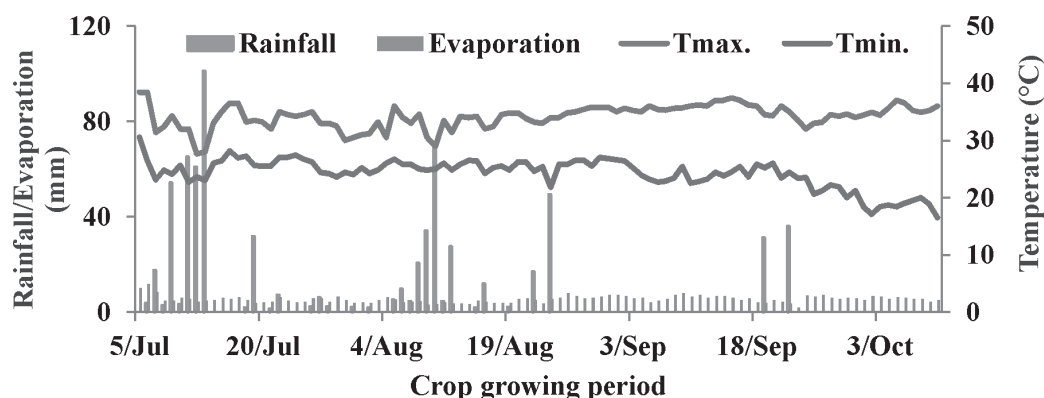


Fig. 1. Daily weather data during Kharif, 2014 crop growing period

nine days, it was 2 to 23% higher than the normal. Percentage value of minimum relative humidity measured at 2.21 PM was found 1-2.7% lower than the normal during forty days, rest of the crop growing period it was 0.1-12.7% more than normal (Fig. 1).

Soil moisture and soil temperature

Soil moisture was monitored two-three days before irrigation at 25, 45, 70 and 90 days after sowing (DAS) during crop season. The data on soil moisture as affected by the date of sampling, soil depth, and tillage treatment. Soil moisture gradually decreased from sowing to harvesting of the crop. The crop microenvironment was affected by soil moisture profile in upper layer (0-15 cm) of the soil. At 25 DAS, maximum soil moisture was recorded in 0-15 cm layer under ZT+R (10.8%) treatment followed by ZT (10.2%), PBB+R (9.5%), PNB+R (8.9%) and CT (8.5%) treatment at weight basis. Lower soil moisture was obtained under PBB (8.0%) and PNB (7.6%) treatments. PNB and PBB treatments had significantly lower moisture content than the other treatments, although it was sufficient to fulfil crop water requirement. ZT+R and ZT treatments had non-significant difference in soil moisture content, similarly PNB+R and PBB+R treatments also had non-significant difference. ZT+R, ZT, PBB+R and PNB+R treatments had higher moisture content than CT treatment. Soil moisture content increased with increase in soil depth, and the difference between treatments decreased with the increase of soil depth. At 60 cm depth, most of

treatments had similar soil moisture content. Similar trend was observed throughout the growing period. At 45 DAS, the soil moisture uptake increased as plants grow steadily and at 70 and 90 DAS, maximum uptake of soil moisture was recorded as root depth increased at flowering stage; similarly at grain filling stage more soil moisture were extracted. ZT treatment had 8.6% soil moisture content followed by ZT (8.1%), PBB+R (7.6%), PNB+R (7.4%), CT (7.1%), PBB (6.2%) and PNB (5.9 %) in 15 cm of soil layer at 90 DAS. ZT+R had 21-30%, ZT had 15-20%, PBB+R had 8-10% and PNB+R had 3-5% higher soil moisture content than the CT treatment. PBB treatment had 10-13% and PNB treatment had 16-20% lower soil moisture contents than the CT treatment. The PNB+R had marginally higher soil moisture content. PNB and PBB treatment had sufficient moisture for fulfil crop water demand. Indicating these treatments saved nearly 10-20% soil moisture content (Fig. 2).

Soil temperature was measured in maize crop at 30, 60, 90 and 105 DAS. At 30 DAS, PNB and PBB treatments were found at par, but other treatments were significantly differed to each other. Maximum soil temperature was found in PNB followed by PBB, CT, PNB+R, PBB+R, ZT and ZT+R treatments. Variation in soil temperature between ZT+R and PNB treatment was 3.4°C. At initial period, soil temperature variation between treatments was more because at that time crop residue effect was dominant and crop shading effect was less. As crop residues degraded and crop growth increased, soil

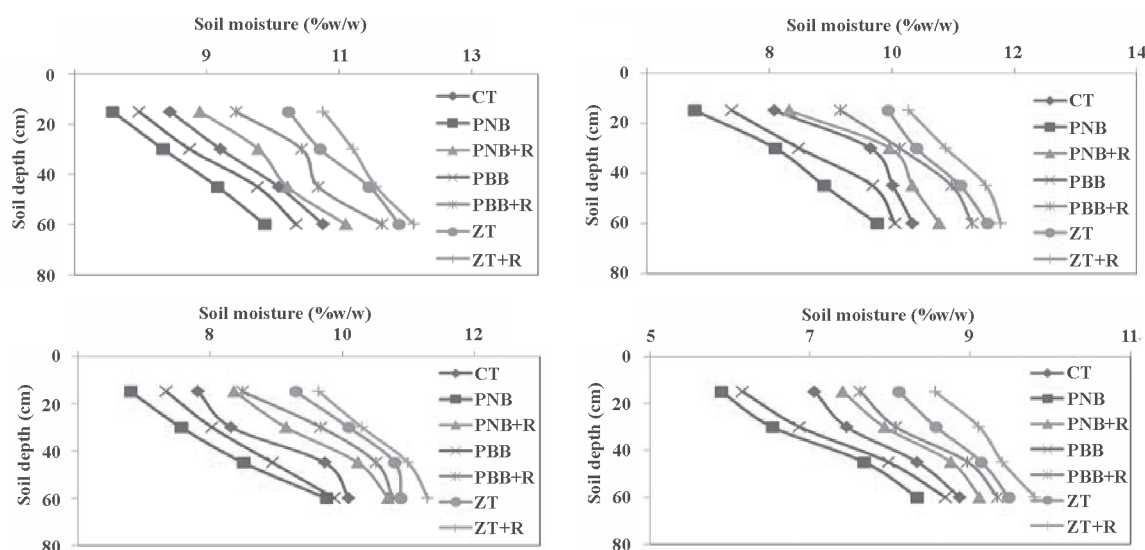


Fig. 2. Soil moisture under different conservation and conventional practice in maize during crop growing season at (a) 25 (b) 45 (c) 70 and (d) 90 DAS

temperature difference within treatments reduced. At 60 DAS, CT treatment had similar value as that of PBB and PNB+R treatments. PNB and PBB treatments had non-significant differences. PNB+R and PBB+R treatments also had non-significant differences for soil temperature at 60 DAS. ZT treatment was significantly differed to ZT+R but non-significant with PBB+R treatment. Similar results were found at 90 DAS. The difference in soil temperature between ZT+R and PNB treatments at 60 DAS was 2.8°C which was lower than the soil temperature measured at 30

DAS. Variation in soil temperature between ZT+R and PNB was 3.1°C at 90 DAS. At 105 DAS, soil temperature between PNB and ZT+R treatment was 2.1°C. Soil temperature in case of residue treatments significantly differed than the non residue treatments (Fig. 3). Similar findings were found under conservation practices for wheat crop by Meena *et al* (2017), and for cotton crop by Aggarwal *et al* (2017). Surface residue reflects solar radiation and insulates the soil surface to reduce the soil temperature (Shinners *et al.*, 1993; Van Wijk *et al.*, 1959). Crop rotation can helps

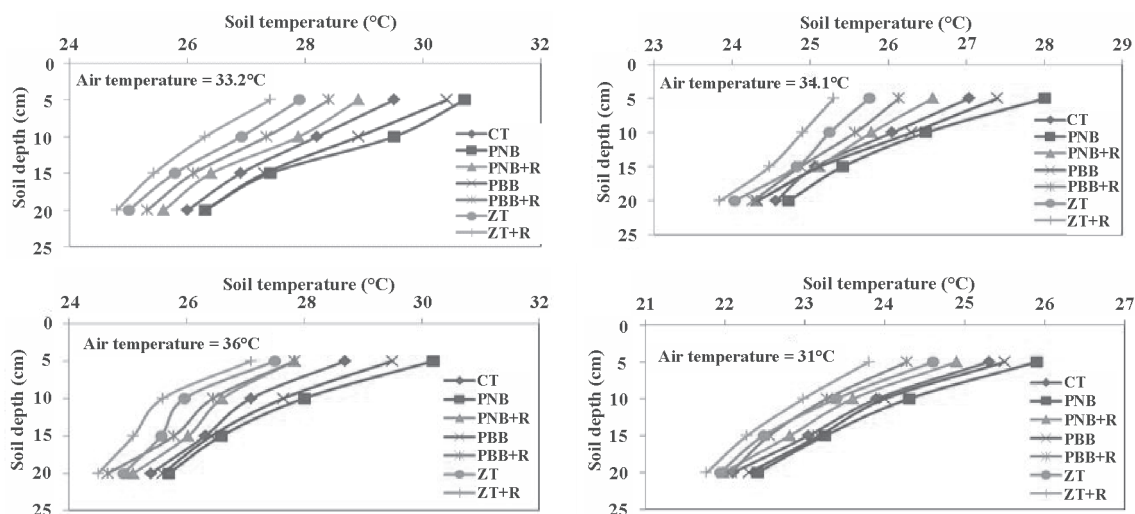


Fig. 3. Soil temperature (°C) under different conservation and conventional practice in wheat during crop growing season in maize at (a) 30 (b) 60 (c) 90 and (d) 120 DAS

in enhancing the soil water content and availability especially in rainfed agriculture (Roder, 1989).

Thermal indices

Total heat units consumed by maize crop to reach physiological maturity under conservation and conventional practices were analysed. Growing degree days (GDD) required to reach physiological maturity was lower under CT treatment (3098°C days). Conservation treatments required higher growing degree days than CT treatment because the residue retained treatment had longer days-to-maturity than those without residue. The PBB+R and PBB required higher growing degree days to reach maturity followed by ZT+R, ZT, PNB+R and PNB treatments. However differences among treatments were marginal. Similar trends were also recorded for heliothermal unit (HTU), photothermal index (PTI), relative temperature disparity (RTD) and photothermal unit (PTU). All indices had higher values under PBB+R and PBB treatments because there was a little delay in physiological maturity under these treatments (Table 1).

HUE was found higher under different conservation treatments as compared to CT. The PBB+R and PBB treatments had non-significant difference, but they had higher HUE than other treatments. Conservation treatments had HUE between 1.56-1.84 kg/ha/°C days. The maximum value of HUE was under PBB+R (1.84 kg/ha/°C days) and minimum was under CT treatment (1.37 kg/ha/°C days) (Table 1).

Temporal variation in air temperature and relative humidity within the canopy

There were non-significant variations in air temperature above the canopy. Air temperature recorded within the canopy showed differences among the treatments. Initially when crop plant growth was less, there were non-significant differences; when plant growth increased, leaf area increased resulting increase in shading effect (Table 2). The temperature within the canopy ranged between 38.4°C to 39°C after 40 DAS. Most of conservation practices had marginal differences but PBB+R and CT treatment had 0.6°C temperature difference. Similar trend was observed at 65 DAS. The difference within PBB+R and CT treatment increased up to 1.4 °C at 85 DAS because this treatment had better plant height and LAI than CT. At this time, PBB+R and PBB treatments had trivial difference but they had significantly lower temperature within canopy

Table 2. Temporal variation in air temperature within maize canopy under different conservation and conventional practices

Treatment	40 DAS	65 DAS	85 DAS	95 DAS
CT	39.03 ^a	34.23 ^a	36.80 ^a	36.23
PNB	39.01 ^a	34.03 ^{ab}	36.50 ^{ab}	36.20
PNB+R	38.67 ^b	33.69 ^{bc}	36.10 ^{bc}	36.11
PBB	38.55 ^{bc}	33.79 ^{bc}	35.60 ^{de}	35.72
PBB+R	38.42 ^c	33.20 ^d	35.40 ^e	35.68
ZT	38.50 ^{bc}	33.60 ^c	36.10 ^{bc}	36.22
ZT+R	38.57 ^{bc}	33.49 ^{cd}	35.90 ^{cd}	35.91
<i>LSD (0.05)</i>	0.55	0.61	0.52	NS

Table 1. Thermal indices in maize crop under conservation and conventional practices

Treatment	GDD (°C day)	HTU (°C day hour)	PTI (°C day/day)	RTD (°C day hour)	PTU (kg/ha/°C day)	HUE
CT	3098	18613	29.34	3083	39874	1.37 ^e
PNB	3130	18778	29.39	3168	40223	1.56 ^d
PNB+R	3130	18778	29.39	3168	40223	1.68 ^c
PBB	3204	18896	29.61	3299	41044	1.81 ^{ab}
PBB+R	3204	18896	29.61	3299	41044	1.84 ^a
ZT	3155	18797	29.43	3213	40490	1.71 ^c
ZT+R	3179	18797	29.55	3260	40759	1.77 ^b
<i>LSD (0.05)</i>	NS	NS	NS	NS	NS	0.16

than other treatments. Maximum temperature was recorded under CT. At 95 DAS when maize plant reached near to physiological maturity, there was little difference in temperature within canopy because at that time most of leaves dried and was in senescence.

Relative humidity (RH) profile showed opposite trend with respect to that of temperature profile i.e., RH measured within the canopy was higher than the value measured above the canopy because of the shading effect of leaves, lesser transmission of solar radiation, less air movement and build up of evaporative water vapour. PBB+R treatment had maximum RH. On a clear day, RH within the canopy ranged between 46.3% and 52.4% at 40 DAS. The variation within CT and PBB+R treatment was around 5.6%. With plant growth the RH variation within treatments increased (Table 3).

Table 3. Temporal variation in relative humidity within crop canopy in maize under different conservation practices along with conventional practice

Treatment	40 DAS	60 DAS	80 DAS	95 DAS
CT	46.3 ^e	40.8 ^e	45.2 ^e	52.8 ^f
PNB	48.8 ^d	42.3 ^d	46.4 ^d	54.4 ^e
PNB+R	49.3 ^d	44.5 ^c	48.8 ^c	55.4 ^d
PBB	50.2 ^c	46.5 ^{ab}	51.6 ^{ab}	56.8 ^{ab}
PBB+R	52.4 ^a	46.9 ^a	52.2 ^a	57.2 ^a
ZT	49.3 ^d	45.6 ^b	50.7 ^{ab}	55.6 ^{cd}
ZT+R	51.2 ^b	46.1 ^{ab}	51.1 ^{ab}	56.2 ^{bc}
<i>LSD (0.05)</i>	2.2	1.6	2.7	1.8

At 80 DAS, maximum RH was found under PBB+R treatment (52.1%) followed by PBB (51.6%), ZT+R (51.1%) and ZT (50.7%) treatments. These treatments had marginal difference but they had significantly higher values of RH than rest of treatments. Lowest RH was under CT (45.2%). At 95 DAS when maize plants appear near to maturity and most of leaves dried and shaded, the RH difference reduced. PBB+R treatment had RH 57.2% followed by PBB (56.8%), ZT+R (56.2%), ZT (55.6%), PNB+R (55.4%), PNB (54.3%) and lowest value of RH was recorded under CT (52.8%). The CT

treatment had significantly lower RH value as compared to other conservation treatments.

Leaf area index and biomass of maize

At 30 DAS, PBB+R treatment showed significantly higher LAI (2.95) followed by PBB (2.81), ZT+R (2.74), ZT (2.67), PNB+R (2.53), PNB (2.48) and CT (2.47) treatment. At 60 DAS, LAI value increased up to 4.58 in PBB+R treatment followed by PBB (4.52), ZT+R (4.41) and ZT (4.33) treatment. The CT and PNB had non-significant differences in LAI at 30 and 60 DAS. At 90 DAS, maximum LAI was observed in PBB+R treatment (5.18) followed by PBB (5.05), ZT+R (4.87), ZT (4.77), PNB +R (4.63) and PNB (4.54) treatment. Significantly higher LAI was observed in PBB+R treatment and lowest value was found in CT (4.46) treatment at 90 DAS (Fig. 4). Increased quantity of surface residue was found to have a significant effect on plant available water, thus lowering the water stress and causing increase in LAI (Scopel *et al.*, 2004). Sangakkara *et al.* (2004) reported that mulches increased leaf area and crop growth rates and the leaf area indices of cassava and sweet potato increased (21% in cassava and 10% in sweet potato) by incorporation of legume leaf mulch.

Significant differences in biomass accumulation were observed for different treatments at 30 DAS (Fig. 4). Initially, higher biomass accumulation was recorded in PBB, PBB+R, ZT and ZT+R (3.1-3.5 t ha⁻¹). These treatments had higher biomass over PNB+R, PNB and CT treatments. These had biomass accumulation in between 2.5-2.9 t ha⁻¹. At 60 DAS, higher biomass was accumulated by PBB+R treatment (6.9 t ha⁻¹) followed by PBB (6.7 t ha⁻¹) and ZT+R (6.5 t ha⁻¹). However at 60 DAS, plant biomass in PBB+R and PBB treatments was non-significant. But at 90 DAS, perceptible differences were observed with significantly higher biomass accumulation in PBB+R treatment (9.1 t ha⁻¹) followed by PBB treatment (8.8 t ha⁻¹) over other treatments. The lowest biomass accumulation was obtained in CT treatment (6.7 t ha⁻¹). Meena *et al.* (2017) reported that

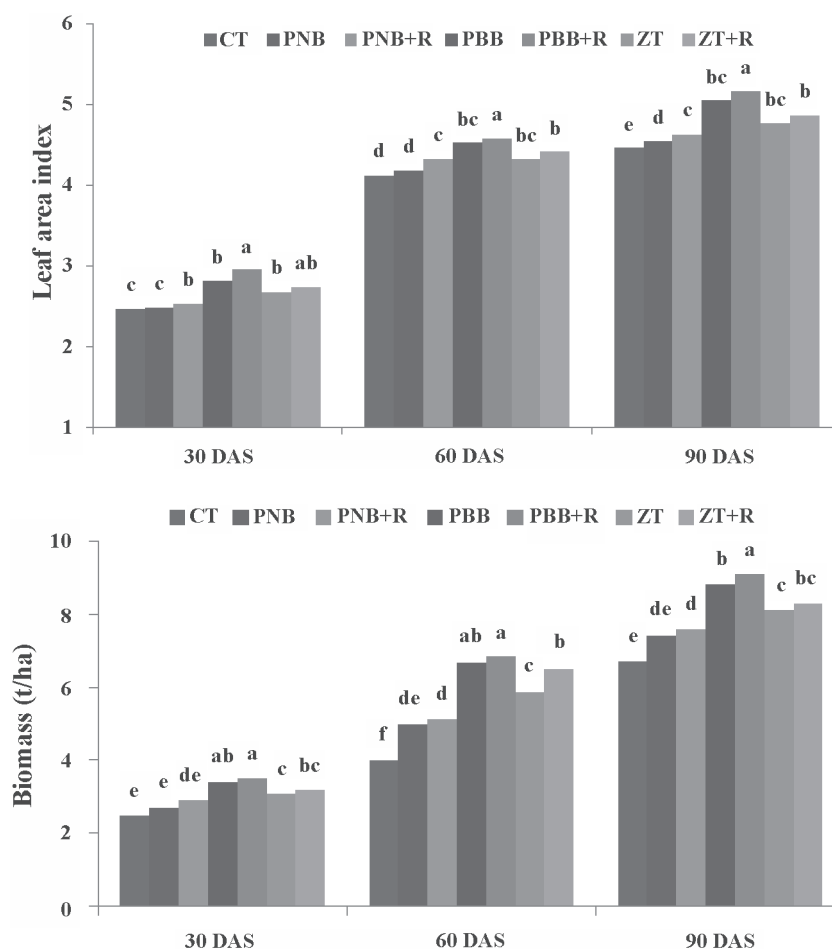


Fig. 4. Leaf area index and biomass and under conservation and conventional practices in maize during crop growing season

conservation practices had higher value of leaf area index and biomass for wheat crop as compared to the corresponding value in conventional practices.

Yield and yield attributes of maize crop under different conservation practices along with conventional practice

Different Conservation treatments improved soil condition which effects the crop growth, resulting increased crop yield, one thousand seed weight, cob weight and seeds per cob under different conservation practices as compared to conventional treatment. PBB+R had maximum yield (5736 kg ha⁻¹) followed by PBB (5632 kg ha⁻¹), ZT+R (5598 kg ha⁻¹), ZT (5411 kg ha⁻¹), PNB+R (5286 kg ha⁻¹) and PNB (4924 kg ha⁻¹) treatment (Table 4). Lowest yield was found

under CT treatment (4246 kg ha⁻¹). PBB had 35% more yield as compared to CT treatment. PBB had 32.6%, ZT+R had 31.8%, ZT had 27.4%, PNB+ R had 24.5% and PNB had 15.9% more yield as compared to CT treatment. Similar to yield, PBB+R had maximum 1000 seed weight (296 g), cob weight (147 g) and seeds per cob (393). CT treatment had minimum values for 1000 seed weight (231 g), cob weight (109 g) and seeds per cob (277). PBB, PBB+R, ZT and ZT+R treatment had non-significant difference but these treatments had higher value of yield as compared to corresponding value in other treatments. Meena *et al.* (2017) also reported the higher value of wheat crop yield in conservation practices as compared to the conventional practices. Moreno *et al.* (1997) recorded marginally higher yields in wheat and sunflower in the conservation treatment

Table 4. Yield and yield attributes in maize crop under different Conservation practices along conventional practice

Treatment	Seed yield (kg ha ⁻¹)	1000 seed weight (g)	Cob weight (g)	Seeds/cob
CT	4246 ^c	231 ^e	109 ^c	277 ^f
PNB	4924 ^b	244 ^d	114 ^c	299 ^e
PNB+R	5286 ^{ab}	257 ^c	120 ^c	322 ^d
PBB	5632 ^a	292 ^{ab}	145 ^a	390 ^a
PBB+R	5736 ^a	296 ^a	147 ^a	393 ^a
ZT	5411 ^{ab}	265 ^c	132 ^b	340 ^c
ZT+R	5598 ^a	283 ^b	139 ^{ab}	368 ^b
LSD (0.05)	341	38	18	56

Table 5. Pearson correlation coefficients of maize grain yield with agro-meteorological indices in maize-wheat cropping system at harvest

	YIELD	GDD	HTU	PTI	RTD	PTU	HUE
YIELD	1.00						
GDD	0.92**	1.00					
HTU	0.93**	0.92**	1.00				
PTI	0.87**	0.88**	0.85**	1.00			
RTD	0.89*	0.96**	0.96**	0.85*	1.00		
PTU	0.91**	0.94**	0.96**	0.88**	0.99**	1.00	
HUE	0.94**	0.92**	0.95*	0.85*	0.80*	0.85*	1.00

*significant at the 0.05 level; **significant at the 0.01 level

(CT) than in the traditional tillage. Further they summarised that when the precipitation is far below the normal, CT appears highly effective in improving both soil water recharge and water conservation.

The correlation analysis of maize grain yield with agro-meteorological indices at harvest indicates that grain yield were highly significant and positively correlated with growing degree days at harvest (Table 5). In maize, GDD, HTU, PTI, RTD, PTU, HUE and yield relationship were found significant. Maize yield was positively correlated with GDD ($r = 0.92^{**}$), HTU ($r = 0.93^{**}$), PTI ($r = 0.87^{**}$), RTD ($r = 0.89^{*}$), PTU ($r = 0.91^{**}$) and HUE ($r = 0.94^{**}$).

Conclusions

From the study it was observed among all the conservation treatments, higher yield was

recorded in zero tilled permanent broad bed plus residue (PBB+R) followed by zero tillage broad bed (PBB), zero tilled flat bed plus residue (ZT+R), zero tillage flat bed (ZT), zero tilled permanent narrow bed plus residue (PNB+ R), zero tilled permanent narrow bed (PNB), conventional practice (CT) system. The higher value of crop yield in conservation practices as compared to the conventional practices may be due do the better soil and crop micro environment during different crop growth stages.

References

- Aggarwal, P, Bhattacharyya, R., Mishra, A.K., Das, T.K., Šimunek, J., Pramanik, P., Sudhishri, S., Vashisth, A., Krishnan, P., Chakraborty, D. and Kamble, K.H. 2017. Modelling soil water balance and root water uptake in cotton grown under different soil conservation practices in the Indo-Gangetic Plain. *Agriculture, Ecosystems and Environment* **240**: 287-299.

- Ghosh, P.K., Das, A., Saha, R., Kharkrang, E., Tripathi, A.K., Munda, G.C. and Ngachan, S.V. 2010. Conservation agriculture towards achieving food security in North East India. *Current Science* **99**(7): 915-21.
- Hanna, M. and Al-Kaisi, M.M. 2009. Resources conservation practices; Managing understanding soil compaction. Iowa University Extension article PM 1094. On line <http://www.extension.iastate.edu/Publications/PM1901B.pdf>.
- Meena, Rekha kumari, Vashisth, Ananta, Aggarwal, P., Bhattacharyya, R., Das, T.K. and Singh, S.D. 2017. Effect of Different Conservation Practices on Growth and Yield of Wheat (*Triticum aestivum* L.) crop. *Journal of Agricultural Physics* **17**(1): 96-104.
- Moreno, F., Pelegrin, F., Fernandez, J.E. and Murillo, J.M. 1997. Soil physical properties, water depletion and crop development under traditional and conservation tillage in southern Spain. *Soil and Tillage Research* **41**: 25-42.
- Olanya, O.M., Ojiambo, P.S. and Nyankanga, R.O. 2006. Dynamics of development of late blight in potato and comparative resistance to cultivar in highland tropics. *Canadian Journal of Plant Pathology* **28**: 84-94.
- Roder, W., Mason, S.C., Clegg, M.D. and Kniefp, K.R. 1989. Yield-soil relationships in sorghum-soybean cropping systems with different fertilizer regimes. *Agronomy Journal* **81**(3): 470-75.
- Sangakkara, U.R., Bandaranayake, P.S.R.D., Gajanayake, J.N. and Stamp, P. 2004. Plant populations and yield of rainfed maize grown in wet and dry seasons of the tropics. *Maydica* **49**: 83-88.
- Scopel, E., Fernando, A., Da Silva, M., Corbeels, M., François, A. and Maraux, F.I. 2004. Modelling crop residue mulching effects on water use and production of maize under semi-arid and humid tropical conditions. *Agronomie* **24**: 383-395.
- Smith, W.N., Desjardins, R.L. and Patty, E. 2009. The net flux of carbon from agricultural soils in soil properties root growth grain yield and water use efficiency of winter wheat in Canada 1970-2010. *Global Change Biology* **6**: 557-568.
- Shinners, K.J., Nelson, W.S. and Wang, R. 1993. Effects of residue-free band width on soil temperature and water content. *Trans. ASAE*. **37**: 39-49.
- Van Wijk, W.R., Larson, W.E. and Burrows, W.C. 1959. Soil temperature and the early growth of corn from mulched and unmulched soil. *Soil Science Society of America Proceedings* **23**: 428-434.

Received: February 10, 2017; Accepted: June 24, 2017