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Effects of Tillage Operations on Changes of Carbon-di-oxide (CO_2) Load and Yield of Wheat (*Triticum aestivum* L.)

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A B S T R A C T

A field experiment was conducted with wheat to study the effect of tillage operations on the changes of the CO_2- balance and reflection thereof, if any, on the yield of the crop. The organic sources in the form of decomposed paddy straw and farm yard manure (FYM) were applied in soil and the changes of the CO_2-in and CO_2-out were observed at the conventional (CT) and zero tillage (ZT) practices. The maximum level of CO_2-in (914.06 ppm) and CO_2-out (859.43 ppm) were recorded under the CT. The magnitude of yield differences of wheat was in the order of the treatment T_9>T_6 (where, T_9; full dose of paddy straw and FYM and T_6; half dose of paddy straw and full FYM). A close correlation was observed between the CO_2- balance and ambient temperature at the proximity of the leaf surfaces corresponding to different treatments. The gradual decrease of CO_2-out (ppm) was observed upto the day five (D_5) when the maximum leaf – temperature was on day two (D_2) under each treatment.

Introduction

The soil ecosystem as well as the soil organic carbon (SOC) are influenced by tillage like conservation tillage (CT) and zero tillage (ZT) practices. It was observed that microbial carbon (MBC), particulate organic carbon (POC) and dissolved organic carbon (DOC) were higher in no-tillage in comparison to conventional tillage practice in surface soil (up to 10cm) in wheat field (Enke *et al.*, 2015) in addition to the factors, such as root distribution, field environments and exogenous organic matter, affecting labile organic carbon in soil during growing period of the crops (Fuentes, *et al.*, 2010 and Van den Berg, *et al.*, 2012). Besides, input of straw and root residue can enhance soil SOC contents in surface soil due to decomposition of organic matter (Fontaine *et al.*, 2007) although, the SOC distribution might be different in conventional tillage and no-tillage due to different root distribution in soils (Baker *et al.*, 2007). The soil organic C is a major component of the global C with the estimated 1500 Gt representing more than the combined stocks of the atmosphere and biosphere (Lal, 2004) which can be increased in the surface soil under conservation tillage (CT) with deeper burial of straw residues (Blanco and Lal, 2008). Emission of CO_2 from soils to the atmosphere is the result of the losses of soil organic carbon. It was observed that CO_2-flux under NT were always lower and transformation from CT to NT with crop intensification was suitable to increase carbon inputs and reduction of soil CO_2 flux (Alvaro *et al.*, 2008).

Agricultural systems having greater potential to sequester soil carbon have been widely accepted on global climate change aspect (Ogle *et al.*, 2003). Carbon (C) inputs through plant biomass and C loss due to the activities of soil organism resulting from the agricultural management aspects, have considerable effect on sequestration of C in soil which can be stored to a greater extent by adoption of no-tillage management with continuous C inputs through litter and root activity (Carter, 2005; Puget and Lal, 2005). The changes in soil-climate have impact on the global environment as SOC contents influence the agricultural productivity. Potential of soil carbon sequestration or release of C as $CO_2$to the atmosphere are important function for adoption of mitigation strategy as well as climate change modelling (Lal *et al.*, 2007).

The large scale CO_2 emission from soils to the atmosphere is due to mineralization of SOC. Soil micrometeorological conditions and management practices leads to the process of soil CO_2 emission (Paustian *et al.*, 2000), where soil temperature is one of the variables affecting soil CO_2 emissions (Bajracharya *et al.*, 2000). The tillage practices or soil management practices can modify the soil properties causing CO_2 emissions. The conventional tillage (CT) enhances soil microbial activity due to the breakdown of soil macro aggregates under intensive tillage systems which lead to an increase in soil CO_2emissions. Hence, the SOC can be enhanced by reducing tillage intensity along with return of C inputs to the field and can decrease in CO_2 emissions (Curtin, 2000). The climatic factors, such as rainfall and maximum temperature, including vegetation cover can play a key role in controlling SOC stock (Gray *et al.*, 2016). Nonetheless, the production of organic matter and its mineralization is controlled by climate and loss of soil SOC was found to be highest in cool moist conditions (Sanderman *et al.*, 2010; Cotching, 2012; Badgery *et al.*, 2013). The climate, soil type and land management altogether can meaningfully estimate SOC storage in soil (Wang *et al.*, 2014). The soil carbon stock can mitigate increasing atmospheric-C levels occurring from human induced climate change (Smith, 2012; IPCC, 2014). The association of SOC with soil health and agricultural productivity provides an added incentive to promote soil C levels (Sanderman *et al.*, 2010), where the precipitation and temperature- the two climatic factors are the key driver of soil SOC (Minasny *et al.*, 2013; Hobley *et al.*, 2015). It was found that, CO_2 emission was higher in conventional tillage compare to NT in spring and it was also observed that after establishment of the crops, soils stopped loosing C (Smith *et al.*, 2000) and the organic matter mineralization is responsible for CO_2 production (Paustian *et al.*, 1997). Emission of CO_2 process is dependent on soil climate, C source, nutrients other biological factors, that can be reduced by adoption of NT than CT (Lal, 2000). Due to oxidation of soil organic matter, root and microbial respiration and return of unharvested plant residue the major green house gas CO_2 is emitted from crop lands (Sainju *et al.,* 2008). On the other hand, by absorption of CO_2 in plant biomass through photosynthesis and conversion to soil organic matter after return of plant residue to soil resulted C sequestration. Hence, soil carbon storage depends on the balance between the amount of plant residue C fixed through photosynthesis and the rate of C mineralization as CO_2 emission from soil (Sainju *et al.,* 2008).

Experimental results indicated that improved yield in crop may be obtained by selection of genotypes with high harvest index plant and growing of crops under elevated CO_2 results in higher biomass production (Kulshrestha and Jain, 1982; Sharma, *et al.,* 2004). It was also observed that leaf photosynthesis rate changes with leaf age, time of the day and sink strength (Ghildiyal and Sirohi, 1986; Ghildiyal *et al.,* 1987).

Based on the above perspectives, the study was conducted to find out the effect of conventional and zero tillage on CO_2balance and reflection thereof, if any, towards the yield of wheat.

Materials and Methods

Experimental site

The field-experiment was carried out during 2014-15 and 2015-16 with wheat (*Triticum aestivum* L.) on the agricultural farm of Uttar Banga Krishi Vishwavidyalaya, Pundibari, Cooch Behar, 736165, West Bengal.

The agricultural farm is located within the *Terai* region and its geographical location is N 26°23’59.9’’ latitude and E 89°23’24’’ longitude. The farm’s elevation is 185 mt above the Mean Sea Level (MSL). The farm’s experiments were carried out during two winter season 2014-2015 and 2015- 2016.

Experimental soil

The topography of the study area was upland with good drainage facilities. The texture of the soil was sandy loam. The composite soil samples from the experimental site was collected and analyzed before starting of the field trial.

Cropping history of experimental plot

A cropping sequence of rice –wheat was practiced in the study area.

Test crop

Wheat (*Triticum aestivum* L.) Variety: K-1006

The experimental design adopted was RBD (Randomised Block Design) in which there were two different tillage operations i.e., i) conventional tillage and ii) zero tillage and nine treatments with three-fold replications making a total of 27 (twenty seven) plots for each tillage and total of 54 (fifty four) plots, each measuring 5m x 4m having total area $1596.5m^2$ (Table 1). The row to row spacing for both zero and conventional management practices were maintained 23 cm with 2.5-3.9cm depth having a seed rate of 100 kg ha^{-1} for raising the wheat crop.

Leaf temperature, CO_2 -input, CO_2 -output of leaf were measured for five consecutive days at flowering stage under conventional and zero tillage system respectively for nine treatments during the cropping season (2014-15 and 2015-16) with IRIGA -Hand-Held Portable Photosynthesis System. The effect of treatment on CO_2 –balance under ZT was measured for consecutive five days at flowering stage of wheat for two years. The day three (D_3) had been taken as reference for observation. Statistical analysis was done by SPSS (Version 16.0) and MSTAT-C.

Results and Discussion

From the meterological data obtained from Gramin Krishi Mousam Seva Kendra, Pundibari, Cooch beharand IMD, it was recorded that, minimum temperature in the first year was in the month of November, 2014 (10.17ºC) and in the month of January, 2016 (9.48ºC), during the second year of study (Figure 1), while the maximum temperature was observed during March, 2015 (30.11ºC) and in March, 2016 (30.69ºC) in the first and second year respectively.

The relative humidity was maximum in January, 2015 (90.28%) and in January, 2016 (91.19%) and the minimum during March, 2015 (55.93%) and March, 2016 (55.52%) in first and second year respectively. The average rainfall was recorded in January, 2015 (0.75 mm) and in January, 2016 (0.17 mm) during the first and second year respectively. Hence, a wide range of variation on temperature, humidity and rainfall was observed during 2015 ─ 2016 at the study area.

The effect of different treatments (T_1 to T_9) on the change of CO_2-balances (Figure 2 to Figure 5) depicted the effects of organic input (FYM or Straw) under CT and ZT practices *vis - a- vis* the impact of temperature corresponding to the CO_2-balances in leaf at different treatments (Figure 2 to Figure 5). The maximum value of CO_2-in (ppm) under conventional tillage (CT) was found in the treatment T_2 on D_4 day and almost uniform trend was observed in other treatments (Figure 2). Besides, a steady trend of CO_2-in was found on the remaining four days except there was a slight variation on D_5 under treatment T_8. The variations in leaf-temperature on experimental days corresponding to the different treatments was observed, where the minimum leaf-temperature was recorded on D_1 day (Figure 2). The level of CO_2-out (ppm) was different under CT on D_4 day among different treatments, out of which maximum CO_2-out was recorded at the treatment T_6 on that day (Figure 3). The trend of CO_2-out on remaining four days showed almost uniformity with different treatments. The variation of leaf-temperature was observed between $D_1$and D_3 (Figure 3).

The variation of CO_2-in under zero tillage (ZT) was observed between D_4 and D_5 days and the maximum CO_2-in was observed on D_4 day at the treatment T_7 (Figure 4). The variation of CO_2-in (ppm) on D_5 for each treatment was observed except at the T_4, T_5 and T_6 treatments, with little changes and for the remaining three days (D_1, D_2 and D_3) the level of CO_2-in (ppm) was almost same (Figure 4).

There was little variation on D_4 in CO_2-out at the treatment T_6 in ZT management (Fig. 5). However, on D_5 day, there was a gradual decrease in the level of CO_2-out (ppm) between T_1 to T_3 and being uniform between T_4 and T_8 treatments and the lowest on D_5 at the treatment $T_{9.}$ The maximum leaf-temperature was recorded on D_2 and that of minimum on D_1 under each treatment (Figure 5).

From the pool data it was observed (Table 2) that the highest value of CO_2-in (914.06 ppm) and CO_2-out (859.43 ppm) were recorded under the treatment T_2 and lowest level of CO_2-in (765.11 ppm) at T_4 and CO_2-out (745.14 ppm) at T_7 treatment in CT. The highest CO_2-in (811.42 ppm) was recorded in treatment $T_7$and lowest CO_2-in (769.89 ppm) was at T_6. The highest CO_2-out (803.96 ppm) was recorded at T_1, whereas, the lowest CO_2-out (764.79 ppm) was at treatment $T_{5.}$ Experimental results showed that the balance of CO_2 under different treatments (T1toT9) was dependent on leaf temperature**.** At the treatment T9, better balance in CO2 release from leaf during photosynthesis was observed than other treatments at various leaf - temperature and relative humidity considering the yield maximization of wheat (Figure 6) both under CT and ZT practices, where, the zero tillage operation had better balance in CO_2-in and CO_2-out from leaf during photosynthesis, compare to conventional tillage (CT).

The magnitude of yield differences of wheat both under CT and ZT was in the order of the treatments asT_9>T_6>T_3 where the organic input as FYM and decomposed straw were applied, which might have some effect on nutrient mobilization to the crop and better aggregation of soil during the crop growth period. The input of CO_2 through external sources along with solar energy utilization could enhance the probabilities and scope for improvement of photosynthates (Sharma and Ghildiyal, 2005) which might be enhanced during the high radiation environment.

The difference in yield both under CT and ZT could be sustained by assimilation and management of C supplied through the decomposed FYM and paddy straw for the treatment T_6 and T_9, where the 'C' required for grain filling was mostly provided by flag leaf photosynthesis (Evans *et al.*, 1975) where, the sink strength is equally important as the activities of source were enhanced.

The performance under elevated CO_2 (Ainsworth, *et al.*, 2004) might have some effect on 'C' requirement for photosynthetic performances of wheat although, the plant species and day length are other important factors on the balance of sucrose on starch content of the given species.

Table.1 Treatment details

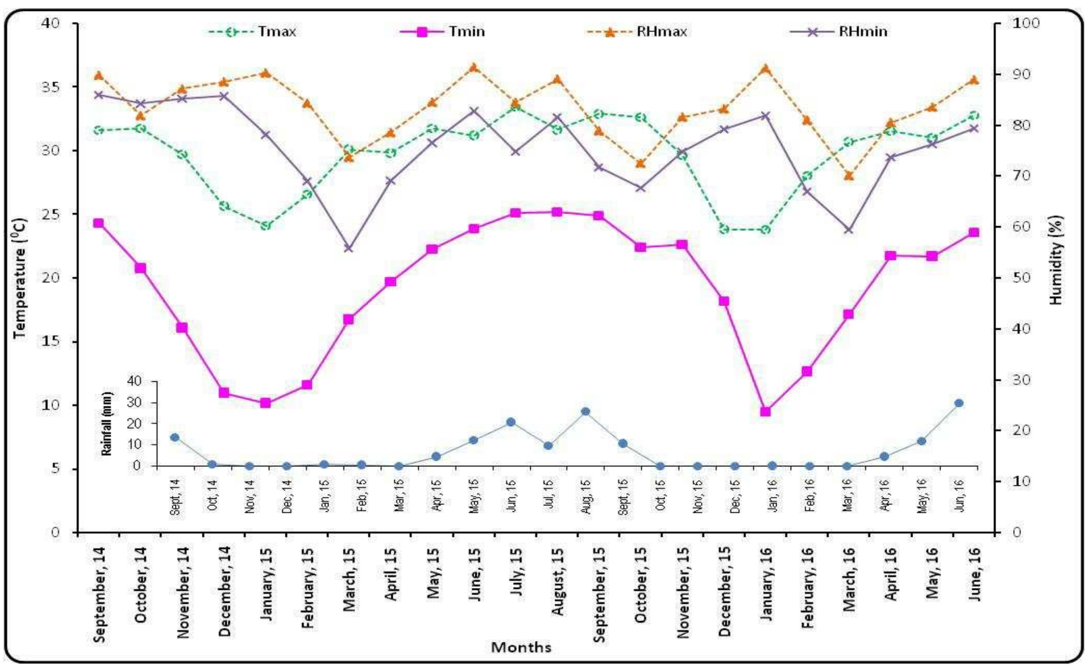
Treatment details			
Conventional Tillage		**Zero Tillage**	
Treatments	**Doses**	**Treatments**	**Doses**
T_1	100% (N:P:K) + S_0F_0	T_1	100% (N:P:K) + S_0F_0
T_2	100% (N:P:K) + $S_0F_{1/2}$	T_2	100% (N:P:K) + $S_0F_{1/2}$
T_3	100% (N:P:K) + S_0F_1	T_3	100% (N:P:K) + S_0F_1
T_4	100% (N:P:K) + $S_1/_2F_0$	T_4	100% (N:P:K) + $S_{1/2}F_0$
T_5	100% (N:P:K) + $S_1/_2F_{1/2}$	T_5	100% (N:P:K) + $S_{1/2}F_{1/2}$
T_6	100% (N:P:K) + $S_1/_2F_1$	T_6	100% (N:P:K) + $S_1/_2F_1$
T_7	100% (N:P:K) + S_1F_0	T_7	100% (N:P:K) + S_1F_0
T_8	100% (N:P:K) + $S_1F_{1/2}$	T_8	100% (N:P:K) + $S_1F_{1/2}$
T_9	100% (N:P:K) + S_1F_1	T_9	100% (N:P:K) + S_1F_1
N: P: K =100:60:40 kg ha^{-1} (Recommended doses as 100%) **N: Nitrogen; P: Phosphorus; K: Potassium** **Paddy Straw (S) = 10 tons/ha (Full dose) ; Farm Yard Manure (F) = 10 tons/ha (Full dose)** **$S_1/_2$= 5 tons/ha $F_{1/2}$= 5 tons/ha**			

Where, S= Paddy Straw F= Farm Yard Manure S_o= No Paddy Straw F_o= No Farm Yard Manure; $S_{1/2}$= Half Paddy Straw $F_{1/2}$= Half Farm Yard Manure, Crop- Wheat; Variety-K 1006

Table.2 Effects of treatment on carbon di oxide balance under CT and ZT

Treatments	Conventional tillage			Zero-tillage		
	Temperature (^{0}C)	CO_2-in	CO_2-out	Temperature (^{0}C)	CO_2-in	CO_2-out
		(ppm)			(ppm)	
T_1	24.52	777.73^b	756.19^b	24.44	800.01^{ab}	803.96^a
T_2	24.60	914.06^a	859.43^a	24.56	791.94^{abc}	792.59^{ab}
T_3	24.83	801.63^b	775.35^b	24.37	801.75^{ab}	780.43^{ab}
T_4	24.21	765.11^b	746.50^b	23.67	781.49^{bc}	766.83^b
T_5	24.61	864.78^a	783.99^b	24.11	780.30^{bc}	764.79^b
T_6	24.49	794.32^b	782.96^b	23.51	769.89^c	765.36^b
T_7	24.62	768.91^b	745.14^b	23.83	811.42^a	770.50^b
T_8	24.86	798.11^b	770.17^b	23.90	797.86^{ab}	803.13^a
T_9	25.06	774.68^b	754.41^b	23.77	777.00^{bc}	767.82^b
SEm (±)	-	21.57	7.93	-	17.94	9.27
CD (P=0.05)	-	62.15	22.80	-	51.68	26.70
CV (%)	-	6.55	2.46	-	5.67	2.91

Fig.1 Changes of temperature and relative humidity during the crop growth period



Source: Gramin Krishi Mousam SevaKendra, Pundibari, Coochbeharand IMD.

Fig.2 EffectsoftreatmentsonCO_2-inunder conventional tillage operations

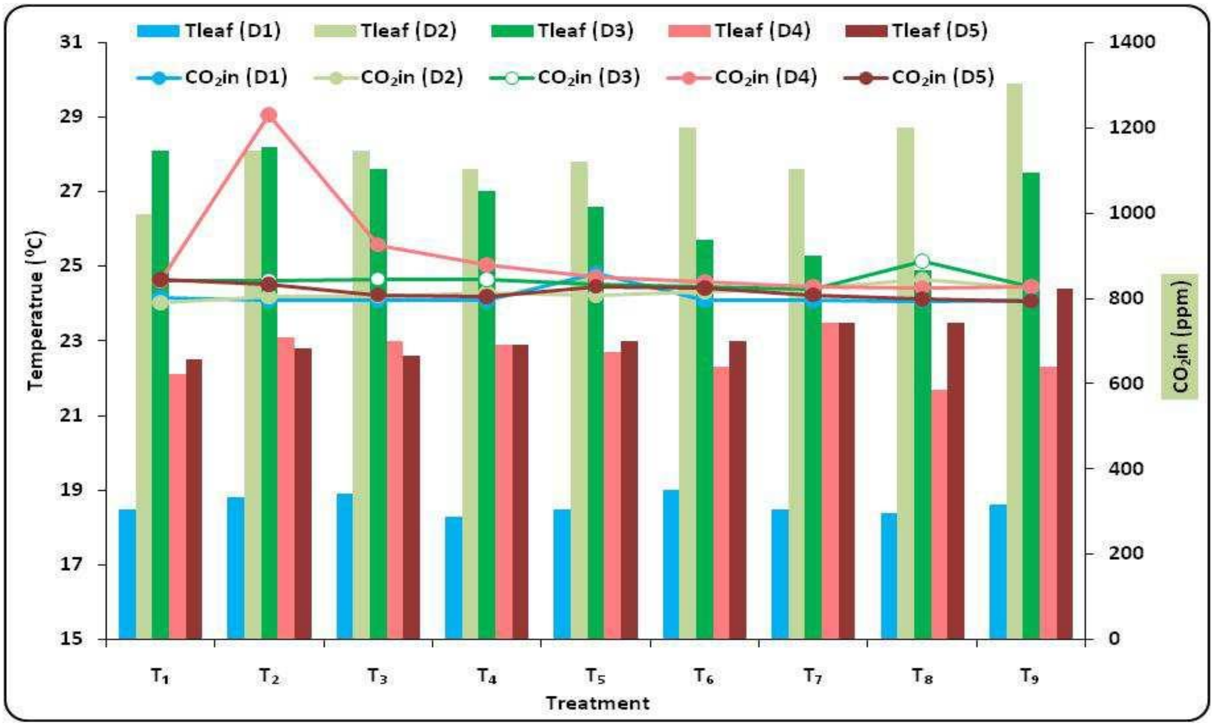


Fig.3 EffectsoftreatmentsonCO$_2$-outunderconventionaltillageoperations

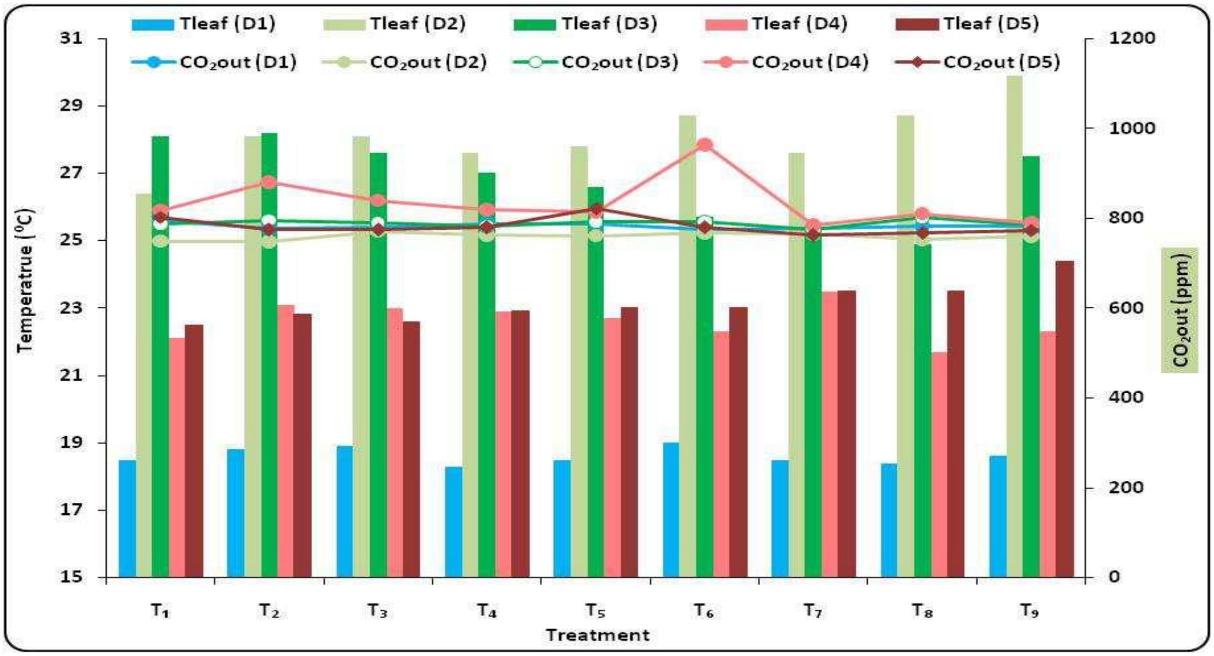


Fig.4 Effects of treatmentsonCO$_2$ –in under zero-tillage operations

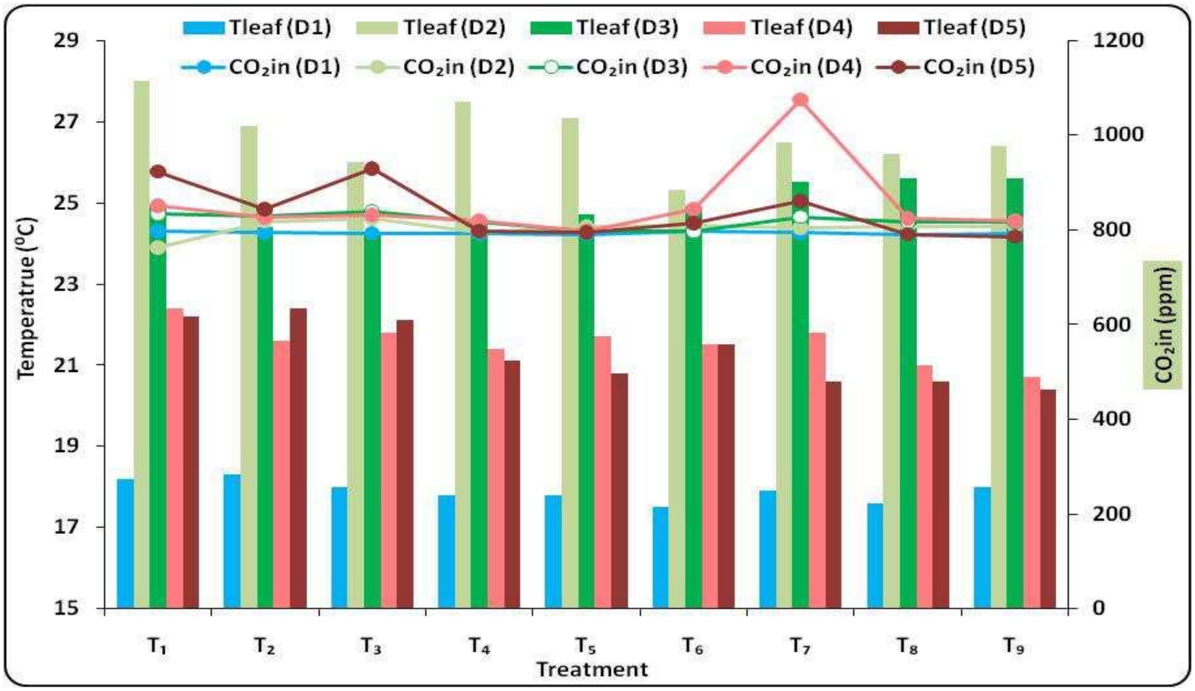


Fig.5 Effects of treatments on CO$_2$ out balance under zero-tillage operation

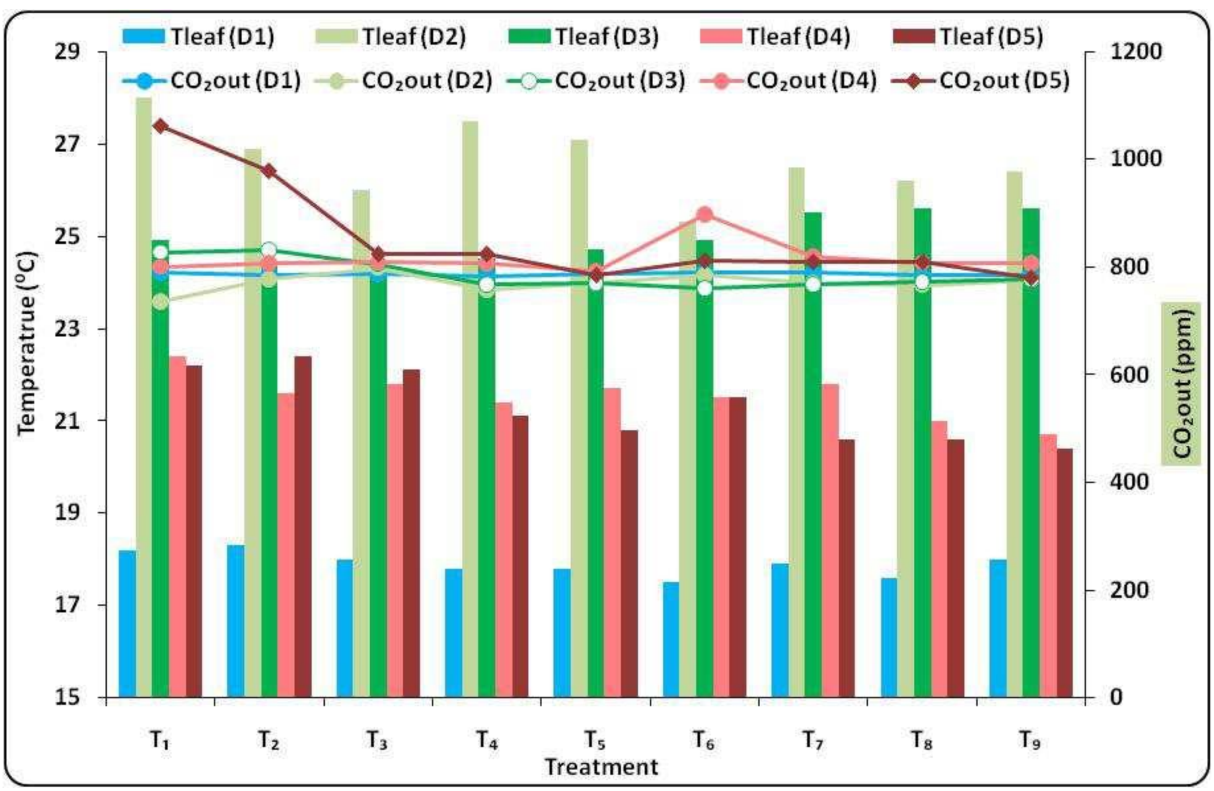
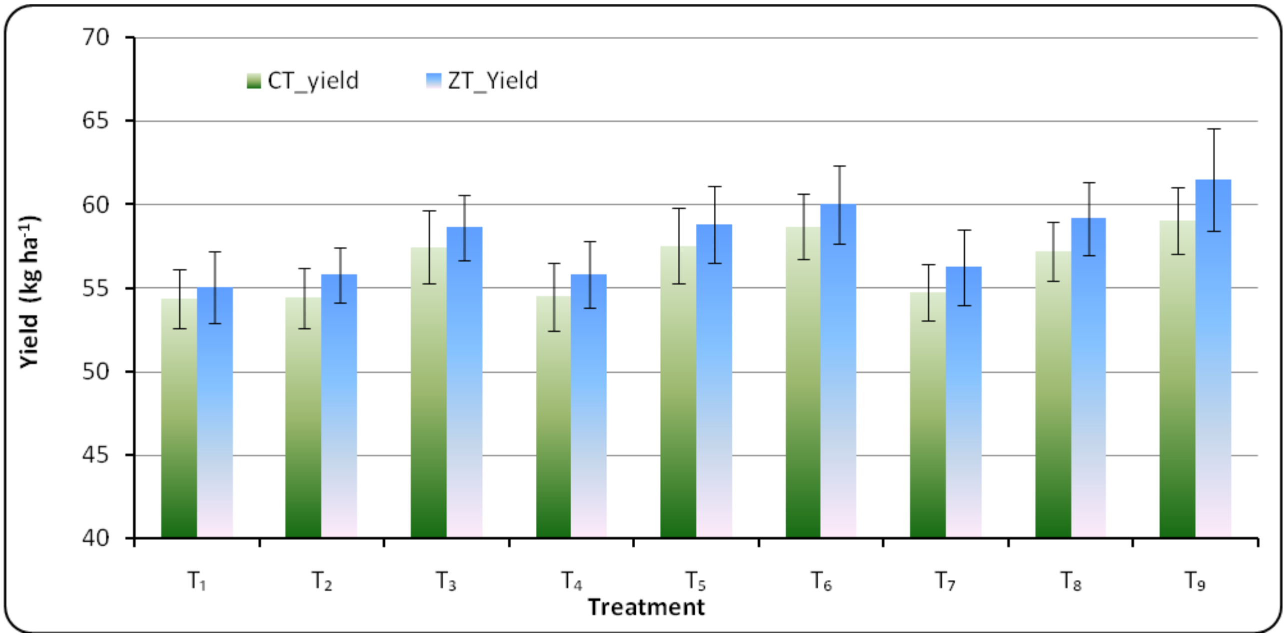


Fig.6 Effect of different treatments on yield of wheat



The temperature is a major determinant of microbial processes having a co-relation with leaf temperature during photosynthesis. The rates of organic matter decomposition along with CO_2-balance might have the significant effect on yield attributes (Schimel *et al.*, 1994) which in turn could have the effect on rate of decomposition by the atmospheric temperature (Waldrop and Firestone, 2004).

Thus, the CO_2-in and CO_2-out during the plant metabolic activity was governed by the different tillage operations which would regulate the 'C' sink in the soil for subsequent translocation to the plants. The yield of wheat was different due to the input of organic substances like FYM and paddy straw, which could have some effect on the CO_2-balance in the soil-atmosphere systems. The sequestered 'C' in soil might be a machinery to maintain the CO_2 balance affecting the ratio of starch/sucrose in wheat. The ambient atmospheric temperature also could play the role in CO_2-balance in the leaf environment, corresponding to different treatments.

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