**Journal of Agrometeorology**

*ISSN : 0972-1665 (print), 2583-2980 (online)*
*Vol. No. 25 (4) : 503-509 (December - 2023)*
*https://doi.org/10.54386/jam.v25i4.2337*
*https://journal.agrimetassociation.org/index.php/jam*

***Research Paper***

# Impact of tillage and residue management on greenhouse gases emissions and global warming potential of winter wheat in a semi-arid climate

**PRIYA BHATTACHARYA[1], K. K. BANDYOPADHYAY[2*], P. KRISHNAN[1], P. P. MAITY[1], T. J. PURAKAYASTHA[3], A. BHATIA[4], B. CHAKRABARTI[4], S. N. KUMAR[4], SUJAN ADAK[1], RITU TOMER[4] and MEENAKSHI[4]**

[1]*Division of Agricultural Physics, ICAR- Indian Agricultural Research Institute, New Delhi-110012,*
[2*]*ICAR- Indian Institute of Water Management, Bhubaneswar-751023*
[3]*Division of Soil Science and Agricultural Chemistry, ICAR- Indian Agricultural Research Institute, New Delhi-110012*
[4]*Division of Environment Science, ICAR- Indian Agricultural Research Institute, New Delhi-110012*
* Corresponding author email: kk.bandyopadhyay@gmail.com

## ABSTRACT

A two-year field study was carried out at the Indian Agricultural Research Institute New Delhi, from *rabi* 2020-21 to 2021-22, with the aim of examining the impacts of tillage and residue management on yield, greenhouse gases (GHGs) emissions, global warming potential (GWP) and carbon efficiency ratio (CER) of wheat in a split plot design. The results indicated that both tillage and residue management significantly influenced the grain and biomass yield of wheat. In comparison to conventional tillage (CT), no-tillage (NT) resulted in a substantial reduction of $CO_2$-C emissions by 19.9%, while it led to a notable increase of $N_2O$-N emissions by 11.6%. However, there was a notable and significant rise in GHG emissions with crop residue mulching, registering on an average 20.79% higher emissions compared to residue removal for both the years. The GWP was overall lower in case of NT as compared to CT plots. The highest CER was observed in NTR+ (3.07) during 2020-21 and in NTR0 (3.12) during 2021-22 due to lower $CO_2$ emissions and higher C fixation in both years. Therefore, it may be recommended that wheat can be cultivated in a semi-arid environment with no tillage and residue mulching to provide a comparable yield in addition to lower GHG emissions and GWP and higher CER compared to the farmers' practice of CT and residue removal.

***Key words*****:** Conventional tillage (CT), No tillage (NT), Yield, Greenhouse gas emissions, Global warming potential, Carbon Efficiency Ratio

The rice-wheat cropping system (RWCS) covers approximately 10.3 mha in the Indo-Gangetic plains (IGP), making it the dominant system in the region, accounting for about 40% of the wheat area (Gathala *et al*., 2013). The maize-wheat cropping system (MWCS) ranks third in popularity behind rice-wheat and rice-rice systems (Jat *et al*., 2014). Wheat (*Triticum aestivum* L.) plays a crucial role as a major cereal crop, particularly in semi-arid and arid regions of India during the low rainfall winter season. Traditional wheat cultivation in this area involves intensive tillage, substantial water, nutrient, and energy use (Kumar *et al*., 2013), contributing to greenhouse gas (GHG) emissions. Agriculture is responsible for approximately 10-12% of global GHG emissions, emitting around 6.2 ± 1.4 Gigatons (Gt) of carbon dioxide equivalent annually (IPCC, 2018). GHGs, including $CO_2$, $CH_4$, and $N_2O$ are consistently emitted from various agricultural activities, such as soil manipulation and fertilizer use (Bhattacharyya *et al*., 2018; Sapkota *et al*., 2021). Over the years, wheat production in India has seen an increase due to improved crop varieties, increased agrochemical and fertilizer use, and better access to irrigation and mechanization. In the agricultural year 2020–2021, India achieved a wheat production of 108.75 million tonnes, with an average national productivity of 3424 kg $ha^{-1}$ (Anonymous 2021). However, these intensive practices have also led to increased GHG emissions and subsequent climate change (FAO, 2020). The conversion of natural vegetation into farmland and extensive tillage practices can reduce soil organic carbon (SOC) levels and increase $CO_2$ emissions by exposing stored organic carbon to microbial decomposition. Conventional tillage, including deep ploughing and ridging, is

***Article info - DOI*****:** https://doi.org/10.54386/jam.v25i4.2337
*Received: 28 August 2023; Accepted: 6 November 2023; Published online : 30 November, 2023*

known to decrease SOC levels and negatively impact soil structure, leading to erosion. Sustainable farming practices, like conservation tillage, aim to enhance crop yield, conserve soil moisture, and reduce evaporation by returning crop residues to the soil and decreasing tillage intensity (Zhang *et al*., 2018). Conservation agriculture (CA) technologies, which encourage minimal or no tillage, crop residue retention, and suitable crop rotation, are recommended as alternatives to conventional systems Studies show that CA practices can increase grain productivity and decrease GHG emissions by reducing input usage and altering the soil environment (Aryal *et al*., 2015). However, research on the impact of CA practices on GHG emissions, especially in wheat-based systems like the maize-wheat cropping system, is limited and inconclusive. To address this knowledge gap, a study was conducted in 2020-21 and 2021-22 aimed to investigate the effects of tillage practices and residue management on GHG emissions, global warming potential (GWP), and crop yield in wheat cultivation.

## MATERIALS AND METHODS

### *Study area*

Field trials were conducted at the MB-4C experimental field located in ICAR-Indian Agricultural Research Institute, New Delhi. The site's coordinates are 28°35' N latitude, 77°12' E longitude, at an altitude of 228.6 m above sea level. The area experiences a semi-arid climate with hot, dry summers and short, harsh winters. The soil has an average bulk density of 1.57 Mg $m^{-3}$, a sandy loam texture (0–15 cm), a pH of 7.8, and an organic carbon content of 4.3 g $kg^{-1}$. Additionally, the soil contains 252 kg $ha^{-1}$ of available nitrogen (N), 7.3 kg $ha^{-1}$ of available phosphorus (P) (measured using the Olsen method), and 284 kg $ha^{-1}$ of available potassium (K).

### *Experimental details*

The study was conducted in long-term conservation agriculture (CA) field experiment on maize-wheat cropping system that had been running for the last six years. The experiment was carried out during the 2020-2021 and 2021-2022 seasons, and wheat was selected as the test crop. The assessment of different treatments was performed using a split plot design with three replications. The main plot factors consisted of two levels of tillage: conventional tillage (CT) and no-tillage (NT) and the sub-plot factors included two levels of crop residue mulching: crop residue mulch (R+) at a rate of 5 Mg $ha^{-1}$ and residue removal (R0). All the treatments were supplied with 100% of the recommended nitrogen dose. The crop was supplied with five irrigations (6 cm each irrigation) at critical growth stages.

### *Crop management*

Wheat (cv HD 2967) was sown with a tractor-driven no-till (NT) seed drill, spaced 22.5 cm apart, at a rate of 100 kg $ha^{-1}$ on November 26 in 2020 and November 23 in 2021. Harvesting occurred on April 13 in 2021 and April 11 in 2022. For conventional tillage (CT), the plot underwent two rounds of ploughing using a disc plough and a cultivator with duck-foot tines. After leveling, seeds were sown with a drill. In contrast, NT involved direct seeding with an "inverted T-type NT seed drill." In the R+ treatment, 5 t $ha^{-1}$ of maize straw mulch was added manually during the Crown Rooting Initiation (CRI) stage. Nitrogen was applied in three stages: 50% at sowing, 25% at CRI, and the remaining 25% at flowering as urea. All plots received five irrigations during key growth stages (CRI, tillering, jointing, flowering, and milk stages) at a rate of 6 cm per irrigation. In NT plots, weed control relied on herbicides, like Atrazine (0.75 kg ai/ha) and Pendimethalin (750 ml ai/ha). In CT plots, weed control involved herbicide spraying and manual weeding done 3-4 times at various crop growth stages.

### *Weather parameters*

Weather data were collected from the agro-meteorological observatory located near the field. Various weather parameters, includes maximum temperature (Tmax), minimum temperature (Tmin), maximum relative humidity (RHmax), minimum relative humidity (RHmin), sunshine hours (SSH), evaporation, and total monthly rainfall, were recorded daily. The monthly average weather data is presented in Table 1.

### *Grain and biomass yield*

During the second week of April, the crop was harvested when it reached physiological maturity. To ensure representative sampling, a 2 × 2 $m^2$ area was selected from every single plot, carefully avoiding boundary effects. Subsequently, appropriate conversions were applied to express the yield results.

### *Greenhouse gas emissions measurement and calculation*

Greenhouse gas samples ($CO_2$ and $N_2O$) were collected from the field during the growing seasons using the closed chamber method (Pathak *et al*., 2002). This method involved using a gas-tight syringe to collect gas samples from selected treatment plots, preferably before and after fertilization and irrigation events, within an acrylic chamber (50 cm × 30 cm × 30 cm). To create an airtight connection between the chamber and an 8 cm deep iron channel (8 cm × 25 cm × 25 cm inner lengths) inserted into the soil during seeding, the channel was filled with water. A battery-operated fan inside the chamber was briefly activated for gas mixing. A hypodermic needle connected to a two-way stopcock at the syringe's top was used to collect gas samples at 0, 30, and 60-minute intervals. Gas concentrations of $CO_2$ and $N_2O$ in the samples were measured using a gas chromatograph equipped with an electron capture detector (ECD) and a flame ionization detector (FID).

The gas emission flux was calculated as follows (Gao *et al*., 2019);

$$f = \frac{\Delta c}{\Delta t} \times \frac{V}{A} \times \rho \times \frac{273}{273+T} \tag{1}$$

Where $f$ is gas emission flux (mg $m^{-2}$ $h^{-1}$), $\boldsymbol{\Delta c/\Delta t}$ is variation in the gas concentration per unit time (mg $m^{-3}$), $V$ is volume of chamber ($m^{-3}$), $A$ is area ($m^{-2}$) of chamber, $\boldsymbol{\rho}$ is gas density under the standard condition (mg $cm^{-3}$), and $T$ is temperature of the chamber (°C).

The cumulative gas flux (Singh *et al*., 1999) during total growing period was calculated as follows;

$$F = \sum 0.5 \times (f_{i+1} + f_i) \times (t_{i+1} - t_i) \times 24 \quad (2)$$

Where $F$ is total emission flux of each gas (kg $hm^{-2}$), $f$ is gas emission flux (kg $ha^{-1}$ $h^{-1}$), $t$ is sampling time, $i$ is the $i^{th}$ sampling, and 24 is the conversion coefficient between hours and days.

The global warming potential (GWP) of different treatments was calculated by the formulae given below (Watson *et al*., 1996);

$$\text{GWP (in kg } CO_2 \text{ eq ha}^{-1}) = CO_2 + (N_2O \times 310) \quad (3)$$

The carbon equivalent emissions (CEE) and carbon efficiency ratios (CER) of the treatments were calculated using the following equations (Bhatia *et al*. 2005);

$$\text{CEE} = \text{GWP}*12/44 \quad (4)$$

$$\text{CER} = \text{GY (in terms of C kg ha}^{-1}) / \text{CEE} \quad (5)$$

### *Statistical analysis*

R software (4.3.1) was used to conduct an analysis of variance (ANOVA) for the split plot design. Least significant difference at 5% probability level was used to determine the significance of treatment effects and to examine the difference between the means.

## RESULT AND DISCUSSION

### *Weather parameters*

The monthly weather data presented in Table 1 for the wheat growing seasons in 2020–21 and 2021–22, shows that in 2021-22, the crop experienced decreased average maximum temperatures in December, January, and February, with reductions of 0.7°C, 0.6°C, and 3.3°C, respectively. However, November, March, and April saw an increase in maximum temperatures by 2.2°C, 0.2°C, and 3.6°C compared to 2020-21. Minimum temperatures ranged from 6.0°C to 17.4°C in 2020-21 and 7.1°C to 19.9°C in 2021-22. The growing period in 2021-22 received 181.5 mm of rainfall, while 2020-21 had 65.9 mm. Increased rainfall in 2021-22 led to a 12.5% higher average relative humidity. The increased evaporation in February, March, and April of 2021-22 was attributed to higher solar energy.

### *Grain and biomass yield of wheat*

The yield of wheat grain in 2020-21 and 2021-22, as influenced by tillage and residue management practices is depicted in Table 2. The grain yield varied from 4122 kg $ha^{-1}$ (CTR0) to 5273 kg $ha^{-1}$ (NTR+) with a mean value of 4698 kg $ha^{-1}$ for the year 2020-21 while for 2021-22 the grain yield varied from 4189 kg $ha^{-1}$ (CTR0) to 4879 kg $ha^{-1}$ (NTR+) with a mean value of 4584 kg $ha^{-1}$. So there was a slight decrease (2.43%) in average grain yield and a 2.89 % decrease in average biomass yields of wheat during the year 2020-21 compared to the year 2021-22. This could be due to the highest average maximum temperatures ever recorded in March. Since the temperature surge occurred at the period of grain development and filling, when the kernels were collecting starch and proteins, it had a negative impact on wheat grain filling in March 2022. By mid-March, maximum temperatures had risen beyond 35°C, cutting short the stage that affects the size and weight of the harvested grains. Large instances of rain had a negative impact on plant density, establishment, and yields. Similar impacts of rainfall on agricultural production were also documented by Adak *et al*., (2023). The grain yield under CT and NT were comparable for both the years while the biomass yield was significantly higher under NT than CT for the year 2020-21. This showed that NT can be practiced in wheat without significant yield penalty compared to CT and concomitantly saving energy in the form of fossil fuel combustion. Residue retention resulted in significantly higher grain yields (24.21% increase in 2020-21 and 7.41% increases in 2021-22) compared to residue removal. Similar pattern was observed for biomass yield also (Bag *et al*., 2020). The effect of residue retention could be observed during the comparatively drier year (2020-21) as it reduces evaporation (Acharya *et al*., 2005), increases infiltration (Verma and Acharya, 2004), and increases soil moisture storage (Granovsky *et al*., 1994). Nonetheless, according to Jat *et al.,* (2014), wheat yield exhibited enhancement from the second year onward in conservation agriculture compared to conventional tillage in a maize-wheat system. Reiger *et al*. (2008) reported a 3% decrease in wheat yield under no-tillage

### *Greenhouse gases emissions*

The seasonal $CO_2$-C and $N_2O$-N emissions as affected by tillage and residue management for the year 2020-21 and 2021-22 are presented in Table 3. The temporal variation in $CO_2$ and $N_2O$ emissions as affected by tillage and residue management for the year 2020-21 and 2021-22 are presented in Fig. 1. It was observed that $CO_2$-C emissions ranged from 519.1 kg $ha^{-1}$/season (NTR0) to 757.7 kg $ha^{-1}$/season (CTR+) with an average value of 608.7 kg $ha^{-1}$/season in the year 2020-21. The $N_2O$-N emissions in the same year ranged from 0.57 kg $ha^{-1}$/season (CTR0) to 0.75 kg $ha^{-1}$/season (NTR+). In the year 2021-22 the $CO_2$-C emissions ranged from 500.9 kg $ha^{-1}$/season (NTR0) to 778.0 kg $ha^{-1}$/season (CTR+) with an average value of 649.4 kg $ha^{-1}$/season while the range for $N_2O$-N emissions were 0.63 kg $ha^{-1}$/season (CTR0) to 0.74 kg $ha^{-1}$/season (NTR+). The year 2021-22 had 6.67% increase in $CO_2$-C emissions, which could be attributed to the heavy rainfall and increased maximum temperatures experienced during the crop growth season. The above conditions are favourable for faster decomposition of organic matter in soil and hence the increased $CO_2$ emissions. Considering the tillage practices, it was observed that NT showed significantly lower $CO_2$-C emissions as compared to CT. The $CO_2$-C emissions reduced in NT by 16.7% in year 2020-21 while in year 2021-22 the reduction was 23.0% when compared to CT. In the temporal variation in 2020-21 (Fig. 1) the $CO_2$ emissions ranged between 10226 g $ha^{-1}day^{-1}$ (NTR0 at 7DAS) to 29869 g $ha^{-1}day^{-1}$ (CTR+ at 8DAS) with a mean value of 16923 g $ha^{-1}day^{-1}$. The emissions were slightly higher at start of sowing owing to the pre sowing irrigation and fertilizer applications and gradually increased up to 10DAS and then again decreased. Emission peaks were observed at 23DAS and 87 DAS coinciding with the split application of urea at CRI and flowering stages and then gradual decrease was observed for all

**Table 1:** Monthly weather data during the crop growing period of the study area

| Month | Max. Temp (°C) | | Min. Temp (°C) | | Max. RH (%) | | Min. RH (%) | | Sunshine hours (h) | | Rainfall (mm) | | Evaporation (mm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2020-21 | 2021-22 | 2020-21 | 2021-22 | 2020-21 | 2021-22 | 2020-21 | 2021-22 | 2020-21 | 2021-22 | 2020-21 | 2021-22 | 2020-21 | 2021-22 |
| November | 24.9 | 27.1 | 10.2 | 10.6 | 77.6 | 91.6 | 34.6 | 52.0 | 6.3 | 4.5 | 0.1 | 0.0 | 2.7 | 2.5 |
| December | 22.4 | 21.7 | 6.2 | 7.1 | 89.3 | 90.6 | 48.1 | 65.2 | 5.4 | 3.8 | 0.6 | 9.6 | 2.0 | 1.7 |
| January | 18.0 | 17.4 | 6.0 | 7.4 | 88.5 | 92.3 | 60.7 | 75.7 | 2.9 | 2.4 | 65.7 | 141.9 | 1.5 | 1.6 |
| February | 26.4 | 23.1 | 8.7 | 8.7 | 88.6 | 89.6 | 38.8 | 51.6 | 6.9 | 6.5 | 7.0 | 30.0 | 3.2 | 2.8 |
| March | 32.2 | 32.4 | 14.6 | 15.3 | 78.3 | 80.2 | 35.5 | 39.0 | 6.5 | 8.2 | 2.0 | 0.0 | 4.2 | 4.6 |
| April | 36.6 | 40.2 | 17.4 | 19.9 | 67.5 | 65.1 | 27.4 | 15.0 | 9.1 | 8.7 | 5.4 | 0.0 | 6.1 | 6.8 |

**Table 2:** Grain and biomass yield of wheat as affected by tillage and residue

| Treatments | Grain yield (kg ha$^{-1}$) | | Biomass yield (kg ha$^{-1}$) | |
|---|---|---|---|---|
| | 2020-2021 | 2021-2022 | 2020-2021 | 2021-2022 |
| CT | $4631^{A}$ | $4403^{A}$ | $13135^{B}$ | $13718^{A}$ |
| NT | $4766^{A}$ | $4765^{A}$ | $13857^{A}$ | $14080^{A}$ |
| R0 | $4191^{B}$ | $4420^{B}$ | $13175^{B}$ | $12942^{B}$ |
| R+ | $5206^{A}$ | $4748^{A}$ | $13816^{A}$ | $14856^{A}$ |
| CT R0 | $4122^{B}$ | $4189^{B}$ | $12800^{B}$ | $12772^{C}$ |
| CT R+ | $5140^{A}$ | $4617^{AB}$ | $13470^{AB}$ | $14663^{AB}$ |
| NT R0 | $4260^{B}$ | $4651^{A}$ | $13551^{AB}$ | $13111^{BC}$ |
| NT R+ | $5273^{A}$ | $4880^{A}$ | $14162^{A}$ | $15048^{A}$ |
| LSD(*T*) | 523 | 852 | 429 | 1074 |
| LSD(*R*) | 466 | 309 | 538 | 1150 |
| LSD(*TXR*) | 660 | 437 | 761 | 1627 |

# Values in a column followed by same letters are not significantly different at p<0.05 as per DMRT

the treatments near the harvesting stage. During most of the part of growing season CTR+ was observed to have the highest emissions while NTR0 had lowest emissions. Similarly in the temporal variation in 2021-22 (Fig. 1) the $CO_2$ emissions ranged between 10394 g ha$^{-1}$day$^{-1}$ (NTR0 at 79 DAS) to 29735 g ha$^{-1}$day$^{-1}$ (CTR+ at 98DAS) with a mean value of 18225 g ha$^{-1}$day$^{-1}$. The emissions were slightly higher at start of sowing due to the pre sowing irrigation and fertilizer applications and gradually increased upto 18DAS and then again decreased. Emission peaks were observed at 25DAS and 98 DAS which coincided with the split application of urea at CRI and flowering stages and then gradual decrease was observed for all the treatments near the harvesting stage. In the year 2021-22 also, during most part of the growing season CTR+ was observed to have the highest emissions while NTR0 had lowest emissions.

In case of $N_2O$-N the emissions were 14.9% higher in NT as compared to CT for the year 2020-21 while for the year 2021-22 it was 8.3% higher. In the temporal variation in 2020-21 the $N_2O$ emissions ranged between 2.57 g ha$^{-1}$day$^{-1}$ (NTR+ at 58DAS) to 19.3 g ha$^{-1}$day$^{-1}$ (NTR+ at 23 DAS) with a mean value of 8.44 g ha$^{-1}$day$^{-1}$. The emissions were initially lower and then gradually increased up to 15DAS following which emission peaks were observed at 23DAS and 87 DAS coinciding with the split application of urea at CRI and flowering stages and then gradual decrease was observed for all the treatments near the harvesting stage. During most of the part of growing season NTR+ was observed to have the highest emissions while CTR0 had lowest emissions. Similarly in the temporal variation in 2021-22 (Fig. 2) the $N_2O$ emissions ranged between 1.67 g ha$^{-1}$day$^{-1}$ (CTR0 at 128 DAS) to 19.2 g ha$^{-1}$day$^{-1}$ (NTR+ at 36DAS) with a mean value of 7.89 g ha$^{-1}$day$^{-1}$. The emissions were lower at start of sowing and gradually increased up to 18DAS after which emission peaks were observed at 36DAS and 52 DAS which coincided with the split application of urea at CRI and flowering stages and then gradual decrease was observed for all the treatments near the harvesting stage. In the year 2021-22 (Fig. 2) also, during most part of the growing season NTR+ was observed to have the highest emissions while CTR0 had lowest emissions. However, there was a notable and significant rise with crop residue mulching, registering on an average 20.8% higher $CO_2$ emissions and 8.4% higher $N_2O$ emissions compared to residue removal for both the years. This was attributed to availability of a ready carbon source in the form of residues, which contributed to GHG emission upon decomposition. Tillage x residue interaction showed significant variations among all treatments in both the years. Consistent with other studies, Yeboah *et al*., (2016) reported that the rates of $CO_2$ emissions were significantly lower in NT and NT with residue (NTR+) compared to the tilled soils. These findings indicate that conservation tillage practices have the potential to significantly reduce $CO_2$ emissions. The CT system produced quantitatively more $CO_2$ emissions than NT, whereas the opposite is true for $N_2O$ emissions, but the difference was not very noticeable (Table 3). This was in accordance with earlier researches by Gupta *et al*., (2016) where NT emitted more $N_2O$ than CT. According to Al-Kaisi and Yin (2005), soil disturbance by traditional tillage may promote microbial growth and speed up the breakdown process, increasing $CO_2$ emissions. In addition to increasing soil aeration, soil disturbance may also boost oxidation of carbon into $CO_2$ (Jackson *et al*., 2003). On the other hand, NT causes less soil disturbance, which causes decomposition to proceed more slowly. Tillage releases organic material that has been physically stabilised in aggregates by breaking up the aggregates, and the stubble that is left on the field in CT is blended into the soil and instantly accessible as C substrate for microbes (Six *et al*., 2000). Crop residue is often left on the soil surface in CA, which promoted macrofauna activity, such as ants or earthworms, which is frequently impeded during the dry season and delays the crop residue breakdown (Dangerfield, 1997).

**Table 3:** GHG emissions, GWP and CER in wheat as affected by tillage and residue

| Treatments | $CO_2$-C (kg-C $ha^{-1}$/season) | | $N_2O$-N (kg-N $ha^{-1}$/season) | | GWP (kg $CO_2$-eq $ha^{1}$/season) | | CER | |
|---|---|---|---|---|---|---|---|---|
| | 2020-21 | 2021-22 | 2020-21 | 2021-22 | 2020-21 | 2021-22 | 2020-21 | 2021-22 |
| CT | 664.14$^{A}$ | 733.73$^{A}$ | 0.63$^{B}$ | 0.66$^{B}$ | 2740$^{A}$ | 3016$^{A}$ | 2.49$^{B}$ | 2.14$^{B}$ |
| NT | 553.22$^{B}$ | 564.83$^{B}$ | 0.74$^{A}$ | 0.72$^{A}$ | 2387$^{B}$ | 2426$^{B}$ | 2.92$^{A}$ | 2.90$^{A}$ |
| R0 | 544.86$^{B}$ | 595.18$^{B}$ | 0.65$^{B}$ | 0.67$^{B}$ | 2312$^{B}$ | 2511$^{B}$ | 2.66$^{A}$ | 2.64$^{A}$ |
| R+ | 672.50$^{A}$ | 703.38$^{A}$ | 0.71$^{A}$ | 0.72$^{A}$ | 2814$^{A}$ | 2932$^{A}$ | 2.75$^{A}$ | 2.40$^{B}$ |
| CT R0 | 570.60$^{C}$ | 689.43$^{B}$ | 0.57$^{D}$ | 0.63$^{D}$ | 2370$^{C}$ | 2837$^{B}$ | 2.55$^{B}$ | 2.17$^{C}$ |
| CT R+ | 757.69$^{A}$ | 778.03$^{A}$ | 0.68$^{C}$ | 0.70$^{C}$ | 3109$^{A}$ | 3196$^{A}$ | 2.42$^{B}$ | 2.12$^{C}$ |
| NT R0 | 519.13$^{D}$ | 500.93$^{D}$ | 0.72$^{B}$ | 0.71$^{B}$ | 2254$^{D}$ | 2184$^{D}$ | 2.77$^{AB}$ | 3.12$^{A}$ |
| NT R+ | 587.31$^{B}$ | 628.73$^{C}$ | 0.75$^{A}$ | 0.74$^{A}$ | 2519$^{B}$ | 2668$^{C}$ | 3.07$^{A}$ | 2.68$^{B}$ |
| LSD($T$) | 2.94 | 6.44 | 1.72 | 3.17 | 0.07 | 4.22 | 0.27 | 0.37 |
| LSD($R$) | 2.30 | 3.72 | 3.58 | 2.40 | 0.04 | 2.73 | 0.24 | 0.15 |
| LSD($TXR$) | 3.25 | 5.26 | 5.07 | 3.40 | 0.06 | 3.87 | 0.33 | 0.21 |

# Values in a column followed by same letters are not significantly different at $p<0.05$ as per DMRT

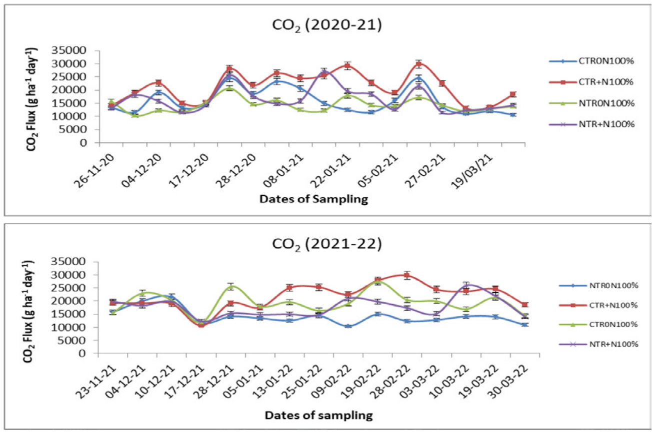

**Fig. 1:** Temporal variation of $CO_2$ flux as affected by tillage and residue in wheat

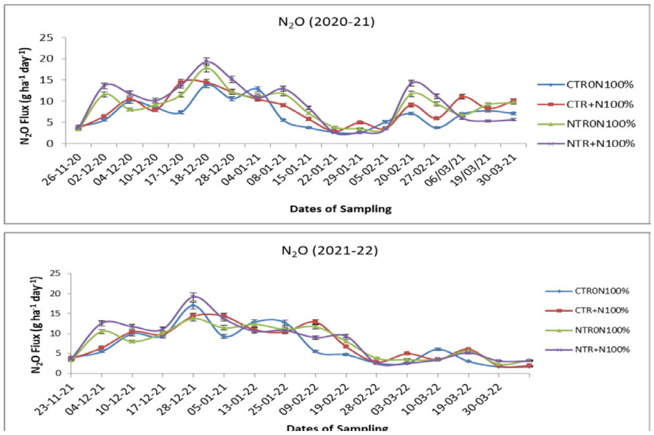

**Fig. 2:** Temporal variation of $N_2O$ flux as affected by tillage and residue in wheat

### *Global warming potential (GWP) and Carbon efficiency ratios (CER)*

The global warming potential (GWP) and carbon efficiency ratio (CER) of the treatments for two years 2020-21 and 2021-22 is presented in Table 3. It was observed that the GWP varied between 2184 kg $CO_2$-eq $ha^{-1}$/season (NTR0) to 3196 kg $CO_2$-eq $ha^{-1}$/season (CTR+). The GWP was 12.8% and 19.5% lower in NT than under CT for years 2020-21 and 2021-22 respectively. Residue retention increased the GWP by 16.01% on an average for both the years as compared to plots without residues. The CER, the amount of carbon fixed in grain by wheat per unit of carbon released, was highest (3.07) in NTR+ in the years 2020–21 and (3.12) NTR0 in the years 2021–22. Lowest CER was observed in CTR0 and CTR+ for both the years as these treatments had the largest $CO_2$ emissions and smaller amount of C fixed. This finding shows that conservation agriculture practices have potential to minimize the GWP.

## CONCLUSIONS

The findings from the present study indicate that tillage and residue management had a substantial influence on grain and biomass yield of wheat. The yield under tilled and no till plots were comparable whereas residue application showed significant increase in the wheat yield. The GHG emissions and GWP were significantly less under no tillage practices as compared to conventionally tilled soils. Though residue retention increased the emissions under both CT and NT still it was lower in NT with residue as compared to CT with residue. The NT with residue retention registered lower global warming potential and higher carbon efficiency ratio as compared to CT with residue retention. Thus, from the study it can be concluded that wheat can be grown under no tillage with residue to obtain comparable yield besides reduced GHG emissions and higher carbon efficiency ratio under a semi-arid climate.

## ACKNOWLEDGEMENT

The first author expresses gratitude for the support received from IARI in the form of a Senior Research Fellowship during the study period. Additionally, the logistical assistance provided by the Director of IARI throughout the study is acknowledged with thanks.

***Conflict of interest statement:*** The authors declare that there is no conflict of interest.

***Author's contributions*: P. Bhattacharya:** Conceptualization, Methodology, Writing-original draft; **K.K. Bandyopadhyay:** Methodology, Visualization, Writing-review and editing; **P. Krishnan:** Investigation, Writing-review and editing; **P.P. Maity:** Supervision and editing; **T.J. Purakayastha:** Supervision and editing; **A. Bhatia:** Writing-review and editing; **B.Chakrabarti:** Writing-review and editing; **Sujan Adak:** Writing-review and editing; **Ritu Tomer:** Writing-review and Editing; **Meenakshi:** Writing-review and Editing

***Disclaimer:*** The opinions, contents, and views expressed in the research article published in the Journal of Agrometeorology are the authors' own and do not necessarily reflect the position of the organizations they are affiliated with.

## REFERENCES

Acharya, C.L., Hati, K.M. and Bandyopadhyay, K.K. (2005). Mulches. In. (Hillel, D., Rosenzweig, C., Powlson, D.S., Scow, K.M., Singer, M.J., Sparks, D.L. and Hatfield, J. eds.) *Encyclopedia of Soils in the Environment,* pp. 521-532. Elsevier Publication.

Adak, S., Bandyopadhyay, K., Sahoo, R.N., Krishnan, P., Sehgal, V.K., Kumar, S.N., Datta, S.P., Sarangi, A., Bana, R.S., Mandal, N. and Bhattacharya, P. (2023). Interactive effect of tillage, residue, nitrogen, and irrigation management on yield, radiation productivity and water productivity of winter wheat in semi-arid climate. *J. Agrometeorol*., 25(3): 383-391. https://doi.org/10.54386/jam.v25i3.2240

Al-Kaisi, M.M. and Yin, X. (2005). Tillage and crop residue effects on soil carbon and carbon dioxide emission in corn-soybean rotations. *J. Environ. Qual*., 34(2):437-445

Anonymous (2021). All India Coordinated Research Project on Wheat and Barley. PROGRESS REPORT 2020–21. Retrieved from https://iiwbr.icar.gov.in/wp-content/uploads/2021/08/Social-Sciences-Progress-Report-2020-21.pdf

Aryal, J.P, Sapkota, T.B., Jat, M.L. and Bishnoi, D.K. (2015). On-farm economic and environmental impact of zero tillage wheat: a case of North-West India. *Exp Agric*. 51:1–16.

Bag, K., Bandyopadhyay, K.K., Sehgal, V.K., Sarangi, A. and Krishnan, P. (2020). Effect of tillage, residue and nitrogen management on radiation interception, radiation use efficiency and evapotranspiration partitioning. *J. Agrometeorol*., 22(3): 285–294. https://doi. org/10.54386/jam.v22i3.190

Bhattacharyya, R., Bhatia, A., Das, T.K., Lata, S., Kumar, A., Tomer, R., Singh, G., Kumar, S. and Biswas, A.K. (2018). Aggregate-associated N and global warming potential of conservation agriculture-based cropping of maize-wheat system in the north-western Indo-Gangetic Plains. *Soil Till Res.* 182:66-77.

Bhatia, A., Pathak, H., Jain, N., Singh, P. K. and Singh, A. K. (2005). Global warming potential of manure amended soils under rice–wheat system in the Indo-Gangetic plains. *Atmos. Environ.*, *39*(37): 6976-6984.

Dangerfield, JM. (1997). Abundance and diversity of soil macrofauna in northern Botswana. *J Trop. Ecol.,* 13:527–38.

FAO (2020). Global Forest Resources Assessment 2020: Main Report, FAO, Rome, http://www.fao.org/documents/card/en/c/ca9825en.

Gao, F., Li, B., Ren, B., Zhao, B., Liu, P. and Zhang, J. (2019). Effects of residue management strategies on greenhouse gases and yield under double cropping of winter wheat and summer maize. *Sci. Total Environ.*, 687:1138-1146.

Gathala, M.K., Kumar, V., Sharma, P.C., Saharawat, Y.S., Jat, H.S., Singh, M., Kumar, A., Jat, M.L., Humphreys, E., Sharma, D.K., and Sharma, S. (2013). Optimizing intensive cereal-based cropping systems addressing current and future drivers of agricultural change in the northwestern Indo-Gangetic Plains of India. *Agric. Ecosyst Environ*., 177:85–97.

Granovsky, A.V., McCoy, E.L., Dick, W.A., Slupitalo, M.J. and Edwards, W.M. (1994). Impacts of antecedent moisture and soil surface mulch coverage on water and chemical transport through a no-till soil. *Soil Till. Res.,* 36: 223-236.

Gupta, D.K., Bhatia, A., Kumar, A., Das, T.K., Jain, N., Tomer, R., Malyan, S.K., Fagodiya, R.K., Dubey, R., Pathak, H. (2016). Mitigation of greenhouse gas emission from rice–wheat system of the Indo-Gangetic plains: through tillage, irrigation and fertilizer management. *Agric Ecosys. Env*., 230:1–9.

IPCC (2018). Special Report: Global Warming of 1.5 C. Intergovernmental Panel on Climate Change.

Jackson, L.E., Calderon, F.J., Steenwerth, K.L., Scow, K.M., Rolston, D.E. (2003). Responses of soil microbial processes and community structure to tillage events and implications for soil quality. *Geoderma*., 114(3-4):305-317

Jat, M. L., Singh, B., and Gerard, B. (2014). Nutrient Management and Use Efficiency in Wheat Systems of South Asia. *Adv. Agron*., 129: 171–259.

Kumar, V., Saharawat, Y.S., Gathala, M.K., Jat, A.S., Singh, S.K., Chaudhary, N. and Jat, M.L. (2013). Effect of different tillage and seeding methods on energy use efficiency and productivity of wheat in the Indo-Gangetic Plains. *Field Crop Res*., 142:1–8.

Pathak, H., Bhatia, A., Prasad, S., Singh, S., Kumar, S., Jain, M.C. and Kumar, U. (2002). Emission of nitrous oxide from rice-wheat systems of Indo-Gangetic plains of India. *Environ. Monit. Assess.* 77:163-178.

Sapkota, T.B., Jat, M.L., Rana, D.S., Khatri-Chhetri, A., Jat, H.S., Bijarniya, D., Sutaliya, J.M., Kumar, M., Singh, L.K., Jat, R.K. and Kalvaniya, K. (2021). Crop nutrient management using Nutrient Expert improves yield, increases farmers' income and reduces greenhouse gas emissions. *Sci. Rep.,* 11(1): 1564.

Singh, S., Singh, J.S. and Kashyap, A.K. (1999). Methane flux from irrigated rice fields in relation to crop growth and N-fertilization. *Soil Biol. Biochem*., 31(9): 1219-1228.

Six, J., Elliott, E.T., Paustian, K. (2000). Soil macroaggregate turnover and microaggregate formation: a mechanism for C sequestration under no-tillage agriculture. *Soil Biol. Biochem*., 32:2099–103.

Verma, M.L. and Acharya, C.L. (2004). Soil moisture conservation, hydrothermal regime, nitrogen uptake and yield of rainfed wheat as affected by soil management practices and nitrogen levels. *J. Indian Soc. Soil Sci.,* 52: 69-73.

Watson, R.T., Zinyowera, M.C., Moss, R. H., Dokken, D.J. (1996). Climate change impacts, adaptations and mitigation of climate change. Scientific Technical Report Analyses Contribution of Working Group II to the Second Assessment Report of the *IPCC*. Cambridge, New York, p. 880.

Yeboah S, Zhang R, Cai L, Song M, Li L, Xie J, Luo Z, Wu J and Zhang J. (2016). Greenhouse gas emissions in a spring wheat field pea sequence under different tillage practices in semi-arid Northwest China. *Nutr. Cycl. Agroecosys.*, 106(1):77-91

Zhang, Y., Wang, S., Wang, H., Wang, R., Wang, X. and Li, J. (2018). Crop yield and soil properties of dryland winter wheat-spring maize rotation in response to 10-year fertilization and conservation tillage practices on the Loess Plateau. *Field Crops Res*., 225, 170-179.