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Full Length Article

Effect of Corn Residue Mulch and N Fertilizer Application on Nitrous Oxide (N_2O) Emission and Wheat Crop Productivity under Rain-fed Condition of Loess Plateau China

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Abstract

With the continuous use of N fertilizers for crop production, the emission of N_2O is consistently increasing in the atmosphere. A field study was conducted to assess the effects of corn crop residue mulch and different N fertilizer levels i.e., 0, 80, 160, 240 and 320 kg N ha^{-1} respectively on the emissions of N_2O and wheat crop productivity under the rain-fed condition of Loess Plateau China. Factorial experiment with three replications was used for this study. Maximum grain yield was recorded for 160, 240 and 320 kg N ha^{-1}, fertilizer level. Maximum emission of N_2O was recorded during the first three weeks of planting wheat crop. Except for N fertilizer level of 240 kg N ha^{-1}, applications of mulch reduced the emission of N_2O for 0, 80, 160 and 320 kg N ha^{-1}, N fertilizer levels. On cumulative basis, minimum emission of N_2O was recorded in case of 80 kg N ha^{-1} N fertilizer level. Application of mulch increased the number of tillers and biological yields which ultimately resulted in more grain yields in all other N fertilizer treatments except for 240 kg N ha^{-1}. It can be concluded that the application of crop residue mulch along with the application of N fertilizer level from 80-160 kg N ha^{-1} has many environmental and economic benefits, because it reduces the emissions of N_2O, increases crop production by increasing the soil moisture and similarly its use increases the soil fertility by increasing the soil organic carbon. © 2014 Friends Science Publishers

Keywords: Fertilizer; Corn residue mulch; Tillage; Wheat yield; Rain-fed; N_2O emission

Introduction

Globally the use of nitrogenous fertilizers is increasing very rapidly to fulfill the ever increasing demands of human population for food, fiber and fuel. Nitrous oxide (N_2O) is one of the major greenhouse gases, mainly produced by the application of N fertilizers for the production of different crops. Nitric oxide (NO) is produced from N_2O, which after combination with O_2, reacts with the ozone. The Global Warming Potential (GWP) of N_2O is 298 times more than of CO_2 and it has an important role in global warming, because it is destructive for the stratospheric ozone (O_3) layer (IPCC, 2007). Animal wastes are also considered another important source of its emissions. In the atmosphere annually about 5.7 Tg N_2O-N y^{-1}, N_2O is produced. Agricultural soils provide about 3.5 Tg N_2O-N per year, produced from the soils by the process of nitrification and de-nitrification. Main soil factors responsible for its emissions include organic matter, moisture, temperature, pH, and N fertilizer levels (Maag and Vinther, 1999). Similarly tillage methods, crop residues and application of N fertilizer affect nitrate N concentration, soil aeration and gaseous N loss (MacKenzie *et al*., 1997; Baggs *et al*., 2000).

Different agricultural management practices along with natural environmental conditions play a fundamental role in the production of N_2O (Snyder *et al.,* 2009). Bouwman (1996) reported more emissions of N_2O with higher rates of N fertilizer. Studies regarding the emissions of N_2O from the use of crop residues in the agricultural fields are not clear. Seneviratne and Van Holm (1998) reported less emissions of N_2O by the application of surface mulch from the wet land soil. Similarly Hao *et al.* (2001) reported less emissions of N_2O from the crop residues retained plots, especially from those plots, which were tilled in autumn after harvest, while Cochran *et al*. (1997) and Lemke *et al*. (1999) reported more emissions of N_2O from the incorporated crop residues. Improved N fertilization not only increases the crop production, but also the some soil quality parameters (Malhi and Lemake, 2007). They further reported that improved fertilization also increased the leaching of NO_3-N and emissions of N_2O-N.

According to an estimate, about 90% of N_2O and 20% CO_2 in the atmosphere result from agricultural production (Bouwman, 1990). According to FAOSTAT (2008), during 2008 to 2012 the demand for N fertilizers on annual basis will increase at the rate of 1.4% and about 69% of this increase will take place in Asia.

As the government of China has banned the burning of maize and wheat crops straws and now the use of these crops straws in soils has become a popular practice. The application of crop straws in combination with fertilizers is considered helpful in improvement of soil fertility. Use of

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crops residues as a mulch, can be helpful in reducing the soil erosion and support in improving the soil water status. Crops residues mulch can be helpful in reduction of weeds infestation (Teasdale, 1996) and will reduce the use of herbicides resulting in healthy environment. It will also lessen the economic burden of farming community.

The main objective of this study was to find out the effects of different levels of N fertilizer and corn residue mulch on the emissions of N_2O and wheat crop productivity under the rain-fed condition of Loess Plateau China. The results of study will be helpful for the better management of soils not only in this region but also in other areas of the world having similar soil and environmental conditions.

Materials and Methods

Experimental Site

The field experiment was conducted during the cropping year, 2011-2012 at the experimental area of Northwest A & F University, Shaanxi Province, northwestern China (latitude of 34˚ 20˚, N and longitude of 108˚ 04˚E and elevation of 466.7 m above sea level) on the Eum-Orthrosols (Chinese soil Taxonomy) soil, with the mean bulk density of about 1.29 g cm^3. The soil in the top 40 cm had soil organic carbon (SOC) about 14.26 g kg^{-1}, total nitrogen was 0.74 g kg^{-1} and pH of 7.85. This area is under the corn-wheat rotation system. Wheat crop was planted after harvesting of corn crop. The total rainfall during the wheat crop growing season (2011-2012) was 242.7 mm (Fig. 1).

Experimental Design and Treatments

The experiment was conducted in an area previously under ongoing tillage experiment started in 2009. Within on-going experiment, the experiment involving different mulch kinds and different N fertilizer levels was started during the year, 2010-2011, but the results for only 2011-2012 have been presented. The experiment was planted by using the factorial arrangements with split plot arrangement, with corn residue mulch in the main plots and nitrogen fertilizer levels in the sub plots. Soil was prepared by using the rotary tillage, the commonly used method for soil preparation in this area. Seed-bed was prepared by using the rotavator up to the depth of 15-20 cm. Two levels of corn residue mulch i.e., No mulch and corn reside mulch and five levels of nitrogen fertilizer i.e., 0, 80,160, 240 and 320 kg N ha^{-1} were used for this study. The treatments were completely randomized and each treatment had an area of 3 m x 25 m. Urea fertilizer having N ≥ 46%, was used as the source of the nitrogen and 750 kg ha^{-1}, phosphorous (P) fertilizer in the form of calcium phosphate ($Ca_2(PO_4)_3$ having 16% P was applied to all the treatments at the time of soil preparation.

Previously harvested corn crops straw/residues were used as source of corn residue mulch and when the wheat crop was at the 3-4 leaf stage, corn residue mulch was applied at the rate of 0.75 kg m^{-2}. For this purpose instead of chopping the corn, whole corn dried plants were flattened between the wheat crop rows. The field was flat in surface with uniform topography. No irrigation was applied to the both crops.

Winter wheat (*cv.* Shaan mai-139) was planted on 18 October 2011, by using the wheat drill with about 16 cm apart rows. The seed had 13% moisture contents and 85% germination rate. Seed rate was used at the rate of 205-210 kg ha^{-1}. Different treatments were separated from each other by making the boundaries. Both years' Carfentrazone- Ethyl ($C_{15}H_{14}C_{12}F_3N_3O_3$), herbicide was used to control the weeds at the required time. At physiological maturity on June 10, 2012 wheat crop was harvested by using the combine harvester.

N_2O emission data were recorded every week and the schedule for data collection are given in Table 1. For this purpose in each treatment glass funnels having 72 mm diameter were permanently fixed for the whole wheat crop growing season. These funnels were fixed in soil up to 5 cm depth. At the time of data collections, funnels were completely closed for 1 h by using the plastic tubes. Then from each glass funnel, 2 mL gas sample was collected by using the plastic syringe. Every week samples were collected between 09:00 A.M to 10:00 A.M. These gas samples were collected in air tight syringes through the rubber septum. The gas samples were immediately shifted to the laboratory for further analysis. N_2O samples were analyzed by using the Hitachi GC 663-30. N_2 was used as a carry gas with the flow rate of 30 ml/min. INJ was used at 150^{o}C, while column was used at 80^{o}C. Similarly Pora pak Q, used was 3 m X 3 mm, while ECD was used at 150^{o}C, ^{63}Ni. N_2O emissions data was recorded every week through-out the crop growing season (Fig. 2). The data recorded during the whole crop growing season (On one hour basis) was summed up for statistical analysis (Tables 2, 3). This N_2O data (on one hour basis) was further converted into g ha^{-1}, and is given in Fig. 7.

The environmental data i.e. rainfall, temperature, wind speed and relative humidity etc. of the experimental area during the study period were taken from the nearby Meteorological office Xian (Fig. 1). Along with the collection of N_2O samples, every week soil temperatures from the top 5 cm soil depths and soil moisture contents from the top 30 cm soil depths were also recorded. Soil samples were collected in aluminum boxes and these samples were immediately shifted to the laboratory. After recording the fresh weight, these samples were dried in oven at least for 48 h at 105ºC. The soil moisture contents were finally converted into moisture %, by using the following equation:

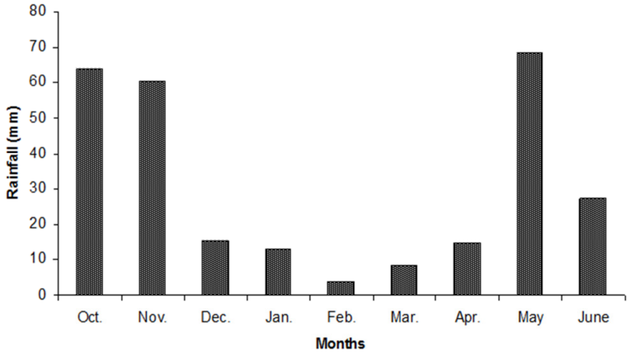

Fig. 1: Total monthly rainfall (mm) of the experimental area during the wheat crop growing season

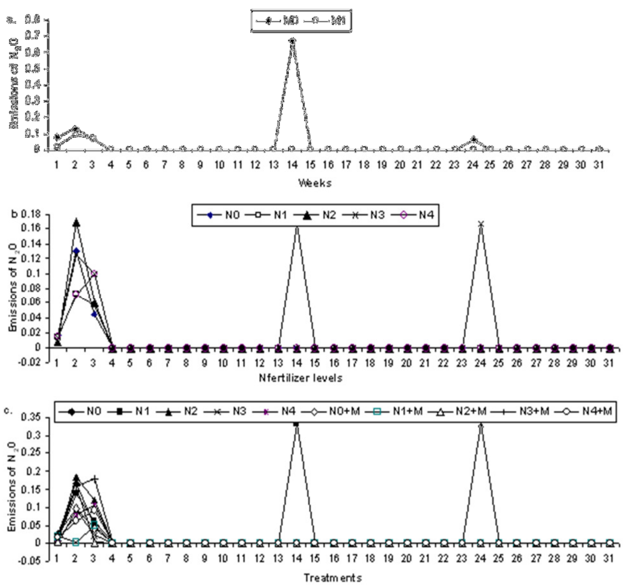

Fig. 2: Weekly changes in the emissions of N_2O (mol of N_2O/mol of air) under the different crop management practices during the wheat crop growing season. (*).M_0, application of no corn residue mulch., M_1, application of corn residue mulch., N_0, 0 kg N ha^{-1} fertilizer., N_1, 80 kg N ha^{-1}., N_2, 160 kg N ha^{-1}., N_3, 240 kg N ha^{-1} and N_4, 320 kg N ha^{-1}., N_0+M, o kg N ha^{-1} fertilizer + corn residue mulch., N_1+M, 80 kg N ha^{-1} + corn residue mulch., N_2+M, 160 kg N ha^{-1} + corn residue mulch., N_3+M, 240 kg N ha^{-1} + corn residue mulch., N_4+M, 320 kg N ha^{-1}+ corn residue mulch

$$\text{Soil water content }(\%) = \frac{\text{fresh weight of soil} - \text{dry weight of soil}}{\text{dry weight of soil}} \times 100$$

While total soil water contents from the top 30 cm soil depths were calculated by using the equation i.e., soil water x BD x thickness of soil layer. Soil bulk densities were measured by using the core method. The average bulk density (B.D) from 0-30 cm soil depth recorded for the non-residue mulch treatments was about 1.48 g cm^{-3}, while the average bulk density recorded for the maize residue mulch treatments was about 1.43 g cm^{-3}. Soil organic carbon (SOC) was recorded at the crop harvesting stage. For this purpose, soil samples of 0-10 cm soil depths were randomly collected from two points from each plot by using the hand augur. The samples of each treatment were then mixed together to make a composite sample of each treatment. These samples were then air dried at room temperature, crushed gently and passed through a 2-mm sieve for further chemical analysis. Soil organic carbon was determined by oxidation method with K_2 Cr_2 O_7.-H_2SO_4. For chemical analysis, 0.5 g soil was digested with 5 mL 1 M K_2 Cr_2 O_7 and 5 mL concentrated H_2SO_4 was heated at 175˚C for 5 min. followed by titration of digests with $FeSO_4$ as described by Lu (1999). Samples for biomass and grain yields were randomly selected from each treatment at crop maturity stage.

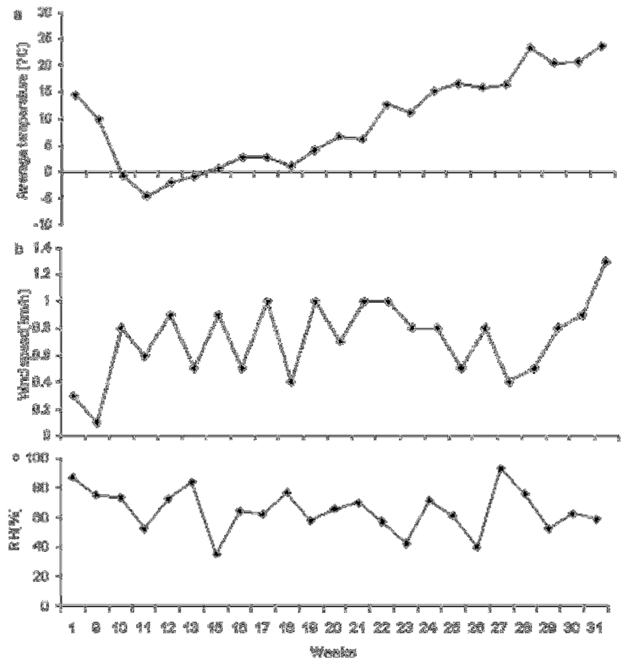

Fig. 3a: Changes in weekly aerial temperatures of the study area during the wheat crop growing season (2011-2012), (**b**) Changes in weekly wind speeds of the study area during the wheat crop growing season (2011-2012) (**c**) Changes in weekly relative humidity's of the study area during the wheat crop growing season (2011-2012). (*) Series 1-31 represents the number of data recording weeks

Statistics

Data collected over the whole period were subjected to Analysis of variance (ANOVA). The SAS analytical software package GLM (8.01) was used for the statistical analyses. ANOVA was used to assess the treatment effects on the measured variables. Means were declared statistically significant by using the DUNCAN test (DMRT) at the 0.05 probability level.

Results

Effects of Different Treatments on the Weekly Emissions of N_2O

Weekly N_2O emission indicates that during the first week of planting wheat crop about 309.6% more emissions of N_2O was recorded from the non-residue mulched treatments as compared with the corn residue mulched treatments (Fig. 2). Data recorded on different twenty two weeks from 2^{nd} to 31^{st} week after planting (i.e., 2^{nd}, 3^{rd}, 5^{th}, 6^{th}, 8^{th}, 10^{th}, 11^{th}, 12^{th}, 13^{th}, 14^{th}, 15^{th}, 16^{th}, 20^{th}, 21^{st}, 22^{nd}, 23^{rd}, 24^{th}, 25^{th}, 28^{th}, 29^{th}, 30^{th} and the week 31^{st}) revealed non-significant differences in the emissions of N_2O from both corn residue mulched or non-mulched treatments (Fig. 2).

However, the significant differences were in the

Table 1: Schedule for recording of N_2O emissions during the wheat crop growing season (2011-2012)

S.NO	Date	Days after sowing of wheat crop	Week number	S.NO	Date	Days after sowing of wheat crop	Week number
1	Oct.20-2011	2	W-1	16	Feb.14-2012	119	W-16
2	Oct.27-2011	9	W-2	17	Feb.21.2012	126	W-17
3	Nov. 8- 2011	21	W-3	18	Feb.28-2012	133	W-18
4	Nov.15-2011	28	W-4	19	Mar.6-2012	139	W-19
5	Nov.22-2011	35	W-5	20	Mar.13-2012	146	W-20
6	Nov.30-2011	43	W-6	21	Mar.20-2012	153	W-21
7	Dec.6-2011	49	W-7	22	Mar.27-2012	159	W-22
8	Dec.13-2011	56	W-8	23	Apr.3-2012	165	W-23
9	Dec.20-2011	63	W-9	24	Apr.10-2012	172	W-24
10	Dec.27-2011	70	W-10	25	Apr.17-2012	179	W-25
11	Jan.4-2012	78	W-11	26	Apr.25-2012	187	W-26
12	Jan.11-2012	85	W-12	27	May.2-2012	194	W-27
13	Jan.17-2012	91	W-13	28	May-9-2012	201	W-28
14	Jan.31-2012	105	W-14	29	May.16-2012	208	W-29
15	Feb.7-2012	112	W-15	30	May.29-2012	220	W-30
				31	June.6-2012	228	W-31

Table 2: Mean Square Values of total emissions of N_2O, SOC and wheat crop grain yields and some yield components under the different mulch and N fertilizer treatments

Source		Emissions of N_2O	SOC	Tillers/m^2	1000 grain weight (g)	Biological yield (t/ha)	Grain yield (t/ha)
	D.F	Mean Square values	Mean Square values	Mean Square values	Mean Square values	Mean Square values	Mean Square values
Mulch	1	0.73998678*	3.97936937*	6541.63333*	0.23267213	3945813.33	922253.333
Fertilizer	4	0.52039718**	2.50292112***	2697.41667	8.02721200	3505205.00	1220641.667***
Mulch x Fertilizer	4	1.94405357***	2.49075393*	3578.38333	7.97996880	1075688.33	368161.667

* Significant at 0.05 probability levels; ** Significant at 0.01 probability levels; *** Significant at 0.001 probability levels

Table 3: Total emissions of N_2O, grain yields and % changes (+ or -) under the different mulches and N fertilizer levels

Source	Emissions of N_2O (ml/ml)	% Changes (+ or -)	Tillers/m^2	% Changes (+ or -)	B.Y (t/ha)	% Changes (+ or -)	Grain yield (t/ha)	% Changes (+ or -)	1000 grain wt (g)	% Changes (+ or -)
Mulch										
M_0 (No mulch)	1.52 a	-	533.7 b	-	13.5	-	6.9 a	-	40.60	-
M_1 (corn residue mulch)	1.21 b	-25.6	563.3 a	+5.5	14.2	+5.2	7.2 a	+5.09	40.64	+1.1
N fertilizer levels										
N_0 (0 kg N/ha)	1.30 bc	+7.4	558.2	-3.7	12.9	-14.7	6.4 c	-18.8	42.0	+2.2
N_1(80 kg N/ha)	0.99 c	-21.2	522.7	-10.7	13.3	-11.3	6.8b c	-11.8	39.8	-3.3
N_2 (160 kg N/ha)	1.70 a	+40.5	538.5	-7.5	13.9	-6.5	7.2 ab	-5.6	40.6	-1.2
N_3 (240 kg N/ha)	1.62 ab	+33.9	544.3	5.3	14.3	-3.5	7.3 ab	-4.1	39.1	-5.1
N_4(320 kg N/ha)	1.2 1c	-	578.8	-	14.8	-	7.6 a	-	41.1	-
Mulch x Fertilizer										
N_0	1.61 c	-	524.7	-	12.3	-	6.2 a	-	44.1	-
N_1	1.59 c	-	489.0	-	12.6	-	6.4 a	-	39.8	-
N_2	2.27 b	-	533.3	-	13.2	-	6.8 a	-	40.1	-
N_3	0.82 d	-	568.0	-	14.6	-	7.5 a	-	38.2	-
N_4	1.31 cd	-	553.7	-	14.6	-	7.5 a	-	40.8	-
N_0+ M	0.99 d	-62.6	591.7	+12.8	15.5	+26.0	6.7 a	+8.1	40.0	-10.3
N_1+M	0.40 d	-297.5	556.3	+13.8	14.0	+11.6	7.2 a	+12.5	39.8	-1.1
N_2+M	1.13 cd	-100.9	543.7	+1.95	14.5	+9.32	7.6 a	+11.8	41.2	+2.8
N_3+M	2.41 a	+193.9	520.7	-9.1	14.2	-4.20	7.1 a	-5.6	39.9	+4.3
N_4+M	1.10 d	-19.1	604.0	+9.1	15.0	+2.3	7.6 a	+1.3	41.4	+1.5

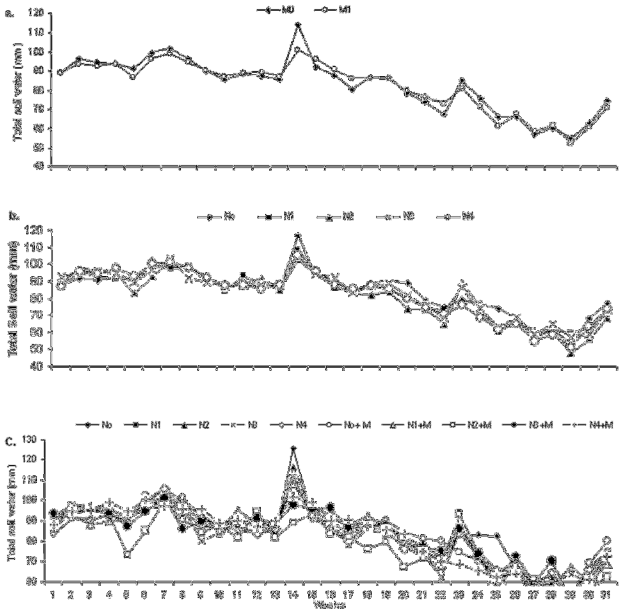

Fig. 5: Weekly changes in total soil moisture (from 0-30 cm soil depth) of the different treatments during the whole wheat crop growing season., (*) Series 1-31, Weeks numbers.,M_0, No corn residue mulch., M_1, application of corn residue mulch., N_0, 0 kg N ha^{-1} fertilizer., N_1, 80 kg N ha^{-1}., N_2, 160 kg N ha^{-1}., N_3, 240 kg N ha^{-1} and N_4, 320 kg N ha^{-1}., N_0+M, o kg N ha^{-1}/ha fertilizer + corn residue mulch., N_1+M, 80 kg N ha^{-1} + corn residue mulch., N_2+M, 160 kg N ha^{-1} + corn residue mulch., N_3+M, 240 kg N ha^{-1} + corn residue mulch., N_4+M, 320 kg N ha^{-1} + corn residue mulch

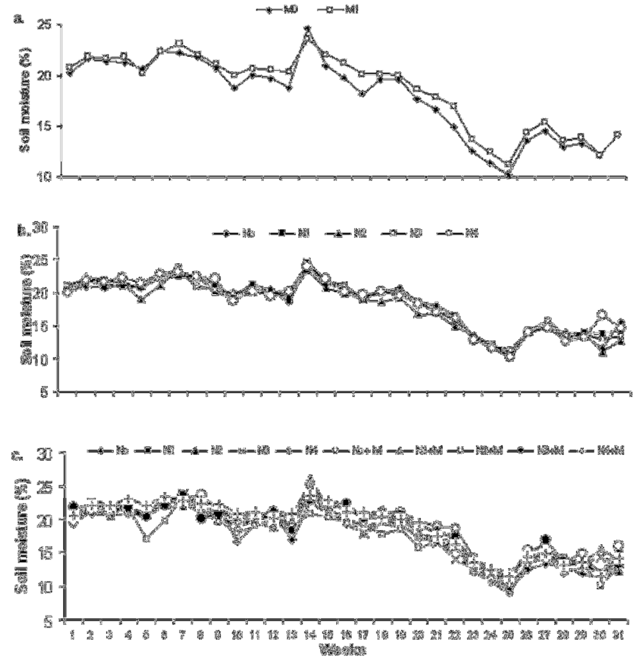

Fig. 6: Weekly changes in the total soil water % (0-30 cm soil depth) of the different treatments during the whole wheat crop growing season (2011-2012). (*).Series 1-31., Weeks numbers., M_0, No corn residue mulch., M_1, application of corn residue mulch., N_0, 0 kg N ha^{-1} fertilizer., N_1, 80 kg N ha^{-1}., N_2, 160 kg N ha^{-1}., N_3, 240 kg N ha^{-1} and N_4, 320 kg N ha^{-1}, N_0+M, 0 kg N ha^{-1} fertilizer + corn residue mulch., N_1+M, 80 kg N ha^{-1} + corn residue mulch., N_2+M, 160 kg N ha^{-1} + corn residue mulch., N_3+M, 240 kg N ha^{-1} + corn residue mulch., N_4+M, 320 kg N ha^{-1} + corn residue mulch

emissions of N_2O on 4th, 7th, 9th, 17th, 18th, 19th, 26th and the week 27th, respectively (Fig. 2).

During the week 4th, 9th, 18th, 19th and week 27th less emission of N_2O was recorded from the corn residue mulched treatments as compared with the non-residue mulched and the reductions during these weeks by using the corn residue mulch were 27.5%, 66.8%, 11.3%, 17.7% and 601.0%, respectively. While on week 7th, 17th and 26th more emissions of N_2O i.e., 74.4%, 75.7% and 153.3% were recorded from the corn residue mulched treatments as compared with non-residue mulched treatments (Fig. 2).

Different N fertilizer treatments significantly affected the emissions of N_2O on the different weeks including, 3rd, 4th, 9th, 17th, 18th, 19th, 22nd and 26th week, respectively. During the week-3rd, about 120.8% more emissions of N_2O were recorded in case of both 320 and 240 kg N ha^{-1} N fertilizer levels, as compared with the minimum emission, in case of 0 kg N ha^{-1} fertilizer level. During the week-4th, maximum emission of N_2O was recorded in case of 80 kg N ha^{-1} followed by 160 kg N ha^{-1} fertilizer level. As compared with the 80 kg N ha^{-1} about 426.1% less emission of N_2O was recorded in case of 0 kg N ha^{-1} fertilizer level (Fig. 2).

On week-9th and 18th, maximum emissions of N_2O was recorded in case of 320 kg N ha^{-1} while on week-17th, and week-19th, maximum emissions of N_2O were recorded in case of 240 kg N ha^{-1} fertilizer level. On the week-22nd, maximum emission of N_2O was recorded in case of 80 kg N ha^{-1}, while on the week-26th highest emission of N_2O was recorded for 320 kg N ha^{-1} (Fig. 2).

Cumulative Emissions of N_2O

About 26.0% less N_2O emission was recorded from the corn residue mulched treatments as compared with the non-residue mulched treatments (Tables 2, 3, Fig. 7). Similarly in case of N fertilizer levels, minimum emission of N_2O was recorded for 80 kg N ha^{-1}. Among mulch x N fertilizer interactions, except for 240 kg N ha^{-1} N fertilizer level, application of corn residue mulch reduced the emissions of N_2O for all other N fertilizer levels.

As compared with the non-mulched treatments, application of corn residue mulch reduced the emissions of

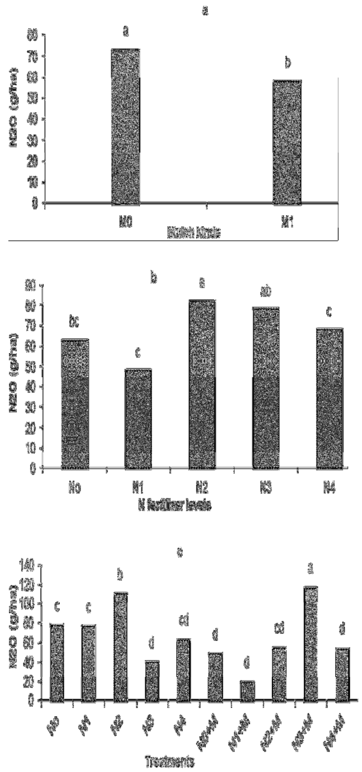

Fig. 7: Cumulative emission of N_2O grams/ha under the different crop management practices during the wheat crop growing season (2011-2012). (*). M_0, application of no corn residue mulch., M_1, application of corn residue mulch., N_0, 0 kg N ha^{-1} fertilizer., N_1, 80 kg N ha^{-1}., N_2, 160 kg N ha^{-1}., N_3, 240 kg N ha^{-1} and N_4, 320 kg N ha^{-1}., N_0+M, 0 kg N ha^{-1} fertilizer + corn residue mulch., N_1+M, 80 kg N/ha + corn residue mulch., N_2+M, 160 kg N ha^{-1} + corn residue mulch., N_3+M, 240 kg N ha^{-1} + corn residue mulch., N_4+M, 320 kg N ha^{-1} + corn residue mulch

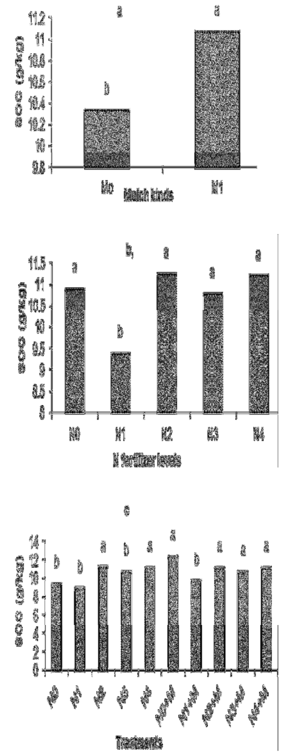

Fig. 8: Changes in SOC (g/kg) under the different crop management practices during the wheat crop growing season (2011-2012). (*).M_0, application of no corn residue mulch., M_1, application of corn residue mulch., N_0, o kg N ha^{-1} fertilizer., N_1, 80 kg N ha^{-1}., N_2, 160 kg N ha^{-1}., N_3, 240 kg N ha^{-1} and N_4, 320 kg N ha^{-1}., N_0+M, 0 kg N ha^{-1} fertilizer + corn residue mulch., N_1+M, 80 kg N ha^{-1} + corn residue mulch., N_2+M, 160 kg N ha^{-1} + corn residue mulch., N_3+M, 240 kg N ha^{-1} + corn residue mulch., N_4+M, 320 kg N ha^{-1}+ corn residue mulch

N_2O at different levels of N fertilizer levels. The reductions in N_2O emissions for 0, 80, 160 and 320 kg N ha^{-1} were about, 63.9, 300.8, 100.9 and 18.6%, respectively.

Yield

About 5.5% more tillers were recorded for corn residue mulched treatment as compared with the non-mulched treatments, while non-significant differences were recorded for different levels of N fertilizers and for their interactions. Application of corn residue mulch produced up to 12.8, 13.8, 1.9 and 9.1% more tillers for 0 kg N ha^{-1}, 80 kg N ha^{-1}, 160 kg N ha^{-1} and 320 kg N ha^{-1}, N fertilizer levels respectively than produced from the same N fertilizer treatments for non-mulched treatments. But in case of 240 kg N ha^{-1}, application of mulch reduced the number of tillers up to 9.1% as compared with the non-mulched treatments (Table 3). Non-significant difference in biological yields was recorded by application of different treatments but the application of mulch increased the biological yield up to 5.4% as compared with non-mulched treatments. Application of higher levels of N fertilizer increased the biological yields by 2.9, 7.3, 10.9, and 14.7% as compared with control. Similarly except for 240 kg N ha^{-1}, N fertilizer level, in which mulch application decreased the biological yield up to 4.2%, while corn residue mulch increased the biological yields up to 9.7, 11.6, 9.3 and 2.3%, respectively for 0 kg N ha^{-1}, 80 kg N ha^{-1}, 160 kg N ha^{-1} and 320 kg N ha^{-1} N fertilizer treatments (Table 3). Although statistically non-significant differences in 1000-grain weight were recorded by the application of corn residue mulch and different N fertilizer levels, but the application of mulch increased the 1000 grain weight up to 1.1% as compared to non-mulched treatment. Variations in 1000 - grain weights were recorded by the use of different N fertilizer levels and application of mulch increased the 1000 - grain weight in 160, 240 and 320 kg N ha^{-1}, while its application reduced the 1000 grain weight in 0, and 80 kg N ha^{-1} (Tables 2 and 3).

However, the application of mulch increased the grain yield up to 5.1% as compared with the non-residue mulched treatments (Table 2 and 3). Higher N fertilizer levels increased the grain yield as compared with the control treatment (Table 2 and 3). Similarly for interactions, except for 240 kg N ha^{-1}, application of residue mulch increased the grain yield as compared with the non-residue mulched treatments (Table 2 and 3).

Discussion

Except for 240 kg N ha^{-1}, N fertilizer level, the increases in the number of tillers and biological yields from corn residue mulched treatments, might be due to moisture conservation as compared with the non-residue mulched treatments (Figs. 5 and 6). Variations in the emissions of N_2O and grain yield recorded by the application of different N fertilizer levels (Table 2, 3 and Fig. 7). McSwiney and Robertson (2005) earlier reported that yield varied from 5-9 t ha^{-1}, but the maximum grain yields were recorded with 101 kg N ha^{-1}. This N rate also resulted in moderately less emissions of N_2O. With higher N rates, sharp increases in N_2O emissions were recorded, and then declined. Maximum loss of N_2O (7%) was found in case of 134 kg N ha^{-1} and above 134 kg N ha^{-1}, the loss of N as N_2O dropped to 2-4%. It was concluded that this threshold N_2O response to N fertilization suggests that agricultural N_2O fluxes could be reduced with no or little yield penalty by reducing N fertilizer inputs to levels that just satisfy crop needs.

In present study, increased grain yields by application of corn residue mulch and N fertilizer levels. It might be due to more moisture conservation by the application of corn residue mulch as compared to the non-mulched treatments (Figs. 5 and 6) (Malhi and Lemake, 2007). Higher barley crop yields when straw were used as compared with the removed straw treatments (Wani *et al*. (1994).

Emissions of N_2O increased substantially with the increase of temperature and total nitrogen input, but overall application of corn residue mulch reduced the emissions of N_2O as compared with non- mulched treatments. No-till, application of higher crop residues and less rates of N fertilization efficiently reduced the emission of greenhouse gases (Li *et al.,* 2010). Different factors including different management practices, rainfall and temperature etc significantly affected the emission of N_2O (e.g., Fig. 7). Previous studies also showed that the most effective ways to reduce the emission of N_2O are the applications of improved management practices (Smith *et al.,* 2001; Lal, 2003). In our experiment, emission of N_2O was less from the corn residue mulched treatments as compared with the non-residue mulched treatments. According to Li *et al.* (2010), the addition of organic carbon can reduce the oxygen supply, which reduces the activities of autotrophic nitrification bacteria and ultimately impacts the emission of N_2O. Other reasons might be the presence of decayed crop residues resulting from previous year applied corn residue mulch, which might helped in the reduction of emissions of N_2O from the treatments of corn residue mulched treatments. Some previously conducted studies also reveals that decayed crops straws can produce some chemical compounds, which can significantly result in reduced emissions of N_2O from the soils (Zhou and Huang, 2002). Reductions in the emissions of N_2O in the rice crop, by the applications of wheat straw have also been reported (Zou *et al*., 2004). The application of crops straw also improves the soil fertility. Rainfall timings had significant effect on the emissions of N_2O. The results showed that except two weeks i.e., week 10th and 18th, significant differences in the emissions of N_2O were recorded on the other different weeks (i.e., 4th, 19th, 20th, 21st, 22nd, 23rd, 26th, 27th, 28th, 29th and week 31st). According to rainfall data, during all weeks rains occurred, which might affected the emissions of N_2O. In addition, during these weeks increasing trends in soil temperatures were recorded (Figs. 3 and 4), which in combination with soil moisture affected the emissions of N_2O. Except for 240 kg N ha^{-1}, N fertilizer level, application of corn residue mulch reduced the emissions of N_2O. It might be due to the increase of SOC in the corn residue mulched treatments as compared with the non-mulched treatments (Fig. 8), which would have reduced activities of autotrophic bacteria by reducing the oxygen supply (Li *et al.,* 2010). However, no clear reason has been reported regarding the emissions of N_2O by the application of crop straws. For example Malhi and Lemake (2007) reported no significant influence of straw management on the cumulative emissions of N_2O. According to IPCC (1997), application of crop residues may increase the emissions of N_2O as have been reported by other researchers that increased emissions of N_2O with the application of straw (Baggs *et al*., 2000; Huang *et al.,* 2004). In our experiment, in case of 0 kg N ha^{-1}, N fertilizer level, higher emissions of N_2O, might be due to residual effect of N fertilizer applied to the previous crop. These variations in the emissions of N_2O due to the crop residues/mulch might be due to many other factors such as timings of fertilizer applications and quantity of fertilizer application etc. (Hao *et al.,* 2001).

In conclusion, maximum emissions of N_2O were recorded with in the first few weeks, after the planting of wheat crop and over all maximum emissions of N_2O were recorded from the higher doses of N fertilizer levels. Except for 240 kg N ha^{-1}, N fertilizer level, as compared with the non-mulched treatments, application of corn residues mulch along with other N fertilizer levels reduced the emissions of N_2O. Rainfall along with rising temperatures resulted in higher emissions of N_2O. Emissions of N_2O by applications of different levels of N fertilizer are not clear, which need further clarifications. Application of corn residue mulch also increased the grain yields in case of all other treatments of N fertilizer levels as compared with the non-residue mulched treatments. Further studies are needed in future with focus to enhance nutrient use efficiency and help in achieving the higher grain yields and mitigate the emission of N_2O by increasing the storage of soil C.

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