Agronomy Research **11** (1), 103–110, 2013

Effect of crop residues on nitrous oxide flux in the controlled traffic farming system during the soil tillage by LEMKEN Rubin 9 disc harrow

T. Šima[1,*], L. Nozdrovický[2], M. Dubeňová[3], K. Krištof[4] and J. Krupička[5]

[1,2,4]Slovak University of Agriculture in Nitra, Faculty of Engineering, Department of Machines and Production Systems, Tr. A. Hlinku 2, 94976 Nitra, Slovak Republic; [*]Correspondence: tomasko.sima@gmail.com
[3]Slovak University of Agriculture in Nitra, Faculty of Engineering, Department of Production Engineering, Tr. A. Hlinku 2, 94976 Nitra, Slovak Republic
[5]Czech University of Life Sciences Prague, Faculty of Engineering, Department of Agricultural Machines, Kamýcká129, 16521 Prague, Czech Republic

Abstract. Nitrous oxide (N_2O) is one of the most important greenhouse gases. Agriculture, especially soil tillage and the use of fertilisers, significantly contributes to N_2O emissions from soil into the atmosphere. The aim of the paper was the comparison of the amount of nitrous oxide emissions released from the soil into the atmosphere depending on crop residues in conditions of a controlled traffic farming (CTF) system. Monitoring points were selected in parts of a field with/ without crop residues and in trafficked and non-trafficked areas. There were realised three variants of the experiment: before soil tillage, right after soil tillage and seven days after soil tillage. Soil tillage was carried out by a LEMKEN Rubin 9 disc harrow with a JOHN DEERE 8230 tractor on the loamy soil after the harvest of winter wheat. The used laboratory method of measuring N_2O emissions released from the soil into the atmosphere consists of collecting soil samples from the field and their subsequent analysis in the laboratory. There were used INNOVA devices which consist of a photo-acoustic field gas monitor INNOVA 1412 based on the infrared photo-acoustic detection method, a multipoint sampler INNOVA 1309 used for gas sampling transport to the gas analyser INNOVA 1412, and a notebook with operation software used for the control and setup of the analysis. There was discovered an effect of crop residues and soil compaction on the nitrous oxide flux.

Key words: nitrous oxide, soil tillage, soil compaction, crop residues, controlled traffic farming.

INTRODUCTION

Nitrous oxide (N_2O) is one of the most important greenhouse gases. Agriculture, especially soil tillage and the usage of fertilisers, contributes to N_2O emissions significantly. Nitrogen is an essential element for plant growth (Ambus et al., 2011) and is supplied to plants by fertilisers (Kajanovičováet al., 2011). Agriculture contributes to the increase in atmospheric N_2O, accounting for 24% of global annual emissions (IPCC 2007). Nitrous oxide directly affects the stratospheric ozone layer (Williams et al., 1992; Ravishankaraet al., 2009) and is one of the most important greenhouse gases, contributing 6% to global warming (Loubetet al., 2011; Ranucciet al., 2011). Emissions of N_2O from agriculture are from about 60% (IPCC 2007) to more than 75% (Abdalla et al., 2009[a]; Abdalla et al., 2009[b]; Jackson et al., 2009) of the total global anthropogenic emissions. The lifetime of N_2O in the atmosphere is about 150 years (Balashov et al., 2010). For a better comparison the emissions are commonly expressed as CO_2 equivalent of using the global warming potential (GWP), which is defined as the cumulative radiative forcing between the present and selected time in the future, caused by a unit mass of gas emitted now (Inselsbacher et al., 2011). The GWP (with a timespan of 100 years) of CO_2 and N_2O is 1 and 298, respectively (IPCC 2007). Nitrous oxide is produced in soil during nitrification and denitrification (Davidson, 1991; Ložek et al., 1997; Ambus et al., 2006) and chemo-denitrification at low pH < 5.5 (Van Cleemput & Samater, 1996). The most important factors affecting the N_2O released from the soil are soil organic matter content (Hayakawa et al., 2009), soil texture (Ruser et al., 2006; Beare et al., 2009), temperature (Kesik et al., 2006), pH (Mørkved et al., 2007) and fertilisation (Bouwman, 1996; Jones et al., 2007; He et al., 2009; Pang et al., 2009; Lin et al., 2010; Šima et al., 2012[c,d]). Emissions released from the arable soil into the atmosphere when compared with other sources are relatively small, but the total area of agricultural land is the source of a huge amount of emissions (Šima et al., 2011; Šima & Dubeňová, 2013). Intensification of agriculture, continued upward pressure on food production in sufficient quantity and adequate quality causes the removal and side-lining of environmental aspects (Šima et al., 2012[a,b]). The incorporation of crop residues into the soil has been widely accepted to maintain soil fertility and to enhance crop productivity (Šima & Dubeňová, 2013). The incorporation of residues supplies additional C and N into the soil (Zou et al., 2004). Controlled traffic farming (CTF) is the technology which minimises the compacted area of the field. All operations over the years are conducted in one direction using permanent tramlines (Galambošová et al., 2012). In traditional farming, there is more than 80% of the field trafficked (Kroulik, 2009). Soil compaction is one of the most important problems of current land management due to the size and weight of machinery and uncontrolled traffic on fields (Galambošová et al., 2012). The aim of the paper was the comparison of the amount of nitrous oxide emissions released from the soil into the atmosphere depending on controlled traffic farming (CTF) and crop residues.

MATERIALS AND METHODS

The Controlled Traffic Farming (CTF) system was implemented on a 16 ha field at the University farm in Kolíňany within the project ITEAPg (ITMS code 26220220014) by Department of Machines and Production Systems, Slovak University of Agriculture in Nitra (Galambošováet al., 2010; Galambošováet al., 2012). Measurements of nitrous oxide emissions released from the soil into the atmosphere were realised after the harvest of wheat. Soil tillage was carried out with a Lemken Rubin 9 and a John Deere 8230 tractor. The amount of crop residues was 0.897 kg m^{-2}. Loamy soil was studied and properties were analysed at the Department of Soil Science and Geology at the Slovak University of Agriculture in Nitra, Slovakia. Soil bulk density on trafficked and non-trafficked areas was 1.69 and 1.38 $g\,(cm^3)^{-1}$, respectively. The soil moisture content was measured by a gravimetric method and ranged from 11.54% to 12.31%, and pH in the trafficked area was 7.32 and 6.06 for

H_2O and KCl, respectively. Non-trafficked area pH reaction was 7.37 and 6.11 for H_2O and KCl, respectively.

There were three variants of the experiment:

- Taking soil samples before soil tillage,
- Taking soil samples right after soil tillage,
- Taking soil samples seven days after soil tillage.

Four monitoring points were selected:

- Non-trafficked area tracks with crop residues (nT-CR),
- Non-trafficked area tracks without crop residues (nT-noCR),
- Trafficked area with crop residues (T-CR),
- Trafficked area tracks without crop residues (T-noCR).

The laboratory method of measuring N_2O emissions released from the soil into the atmosphere was used. This method is possible to use for measuring carbon dioxide (Šima et al., 2012[a]; Šima & Dubeňová, 2013) and nitrous oxide emissions (Šima et al., 2012[b]). The laboratory method consists of collecting soil samples from the field and their subsequent analysis in the laboratory. Big sampling probes were inserted at a depth of 150 mm in the soil, the surrounding soil was removed and the sampling probes were closed up from the bottom (Fig. 1).

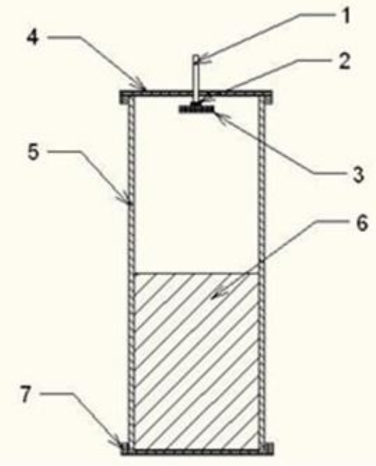

Figure 1. Sampling probe: 1 – suction teflon hose, 2 – fitting for air filter, 3 – air filter, 4 – top cap, 5 – sampling probe, 6 – soil, 7 – lower cap.

The amount of N_2O emission emitting from the soil was measured for 24 hours by INNOVA devices (Lumasense Technologies, Inc.) with measurement system based on the infrared photoacoustic detection method. The photoacoustic field gas monitor INNOVA 1412 and multipoint sampler INNOVA 1309 was used due to the possibility to analyse a number of samples simultaneously (Dubeňová et al., 2013). Detection of the gas samples is in the ppm (parts per million) with detection limit in the ppb (part per billion) region.

Data obtained were analysed by using the ANOVA test, after normality test by using the Kolmogorov-Smirnov test and the homogeneity of variance by using the

Levene's test. With ANOVA $P < 0.05$ or $P < 0.10$ we continued in the post-hoc LSD Test. We have used the software STATGRAPHICS Centurion XVI.I (Statpoint Technologies, Inc.; Warrenton, Virginia, USA).

RESULTS AND DISCUSSION

Results obtained when soil samples were taken before soil tillage

Data of summary statistics and Multiple Range test LSD at 95.0% confidence interval are shown in Table 1. Nitrous oxide emissions released from the soil into the atmosphere before soil tillage are affected by crop residues on the field surface and by soil compaction. Leaving crop residues on the field surface decreases nitrous oxide flux from soil to the atmosphere significantly for both monitoring points (trafficked and non-trafficked area). Nitrous oxide emissions from a non-trafficked area are higher in comparison with a trafficked area.

Table 1. Summary statistics of N_2O flux: before soil tillage, $n = 24$

Monitoring point	Average value, ppm	Median, ppm	Coefficient of variation, %	Minimum, ppm	Maximum, ppm	Range, ppm
nT-CR	0.5802*c*	0.5808	2.82%	0.5535	0.6056	0.0521
nT-noCR	0.6093*d*	0.6089	3.03%	0.5794	0.6392	0.0598
T-CR	0.5296*a*	0.5345	2.70%	0.4859	0.5429	0.0570
T-noCR	0.5589*b*	0.5619	2.37%	0.5274	0.5791	0.0517

Note: Different letters in the average value column (*a, b, c, d*) indicates that means are significantly different at $P < 0.05$ according to the LSD multiple-range test at the 95.0% confidence level.

Results obtained when soil samples were taken right after soil tillage

Effect of the incorporation of the crop residues was not shown. Data of summary statistics and Multiple Range test LSD at 90.0% confidence intervals are shown in Table 2. Right after soil tillage no effect were found of crop residues incorporated into the soil on nitrous oxide flux. There is no statistically significant difference between releasing N_2O emissions from monitoring points with and without crop residues incorporated into the soil. These were the found effects of the soil compaction. From the non-trafficked area of the field is released more emissions than from the trafficked area.

Table 2. Summary statistics of N_2O flux: right after soil tillage, $n = 24$

Monitoring point	Average value, ppm	Median, ppm	Coefficient of variation, %	Minimum, ppm	Maximum, ppm	Range, ppm
nT-CR	1.0630*b*	0.9734	29.07%	0.7270	1.6502	0.9232
nT-noCR	1.0731*b*	0.9558	29.56%	0.7244	1.6675	0.9431
T-CR	0.9285*a*	0.8758	21.61%	0.6678	1.3344	0.6666
T-noCR	0.9260*a*	0.8937	22.09%	0.6521	1.3210	0.6689

Different letters in the average value column (*a, b*) indicates that means are significantly different at $P < 0.10$ according to the LSD multiple-range test at the 90.0% confidence level.

Results obtained when soil samples were taken seven days after soil tillage

Nitrous oxide emissions released from the soil into the atmosphere before soil tillage are affected by crop residues on the field surface and soil compaction. Data of summary statistics and Multiple Range test LSD at 95.0% confidence intervals are shown in Table 3. The measurement conducted seven days after soil tillage showed a statistically significant difference in all monitoring points of the experiment. Crop residues incorporated into the soil have a negative effect on nitrous oxide flux. It may be caused by decomposition of organic matter. Soil compaction affects N_2O flux. There was a higher amount of N_2O in the non-trafficked area.

Table 3. Summary statistics of N_2O flux: seven days after soil tillage, $n = 24$

Monitoring point	Average value, ppm	Median, ppm	Coefficient of variation, %	Minimum, ppm	Maximum, ppm	Range, ppm
nT-CR	0.6146 *d*	0.6173	2.50%	0.5715	0.6364	0.0649
nT-noCR	0.5901 *c*	0.5895	1.81%	0.5730	0.6140	0.0410
T-CR	0.5509 *b*	0.5518	2.75%	0.5223	0.5825	0.0602
T-noCR	0.5193 *a*	0.5201	1.94%	0.4981	0.5385	0.0404

Different letters in the average value column (*a, b, c, d*) indicates that means are significantly different at $P < 0.05$ according to the LSD multiple-range test at the 95.0% confidence level.

Soil compaction by tractor wheels can also affect N_2O emission (Douglas & Crawford, 1993), in our study was found increasing compaction resulted in decreasing of the nitrous oxide emissions released from soil into the atmosphere. Those results are in agreement with results obtained by Ball et al. (1999) who found that heavy compaction reduced gas diffusivity. The same effect was observed in all three variants of our experiment (before soil tillage, right after soil tillage and seven days after soil tillage). Crop residues left on the soil surface before soil tillage decrease nitrous oxide flux what could be caused by the lower diffusivity mentioned above. Incorporation of crop residues into the soil increases the amount of organic matter in soil therefore increasing the decomposition of organic matter. Effect of incorporated crop residues into the soil right after soil tillage was not found. This effect was observed seven days after soil tillage that suggest the dependence of crop residues decomposition on the time scale. Incorporation of crop residues into soil caused increasing nitrous oxide emissions which is in agreement with results obtained by Velthof et al. (2002).

CONCLUSIONS

Crop residues and soil compaction can be considered as a factor which significantly effects the nitrous oxide flux from soil into the atmosphere. Emissions of N_2O from non-trafficked areas were higher than from trafficked areas in all three variants of the experiment: before soil tillage, right after soil tillage and seven days after soil tillage. Nitrous oxide emissions released from the soil into the atmosphere before soil tillage are effected by soil compaction and crop residues on the field surface. Leaving crop residues on the field surface significantly decreases nitrous oxide flux from soil into the atmosphere for both monitoring points (trafficked and non-trafficked area). Nitrous oxide emissions from non-trafficked areas are higher in comparison with trafficked areas. Incorporation of crop residues has no effect on N_2O flux during the first 24 hours after soil tillage. There is no statistically significant difference between releasing N_2O emissions from monitoring points with/without crop residues incorporated into the soil. There was found an effect of the soil compaction. From the non-trafficked area of the field there is released more emissions than from the trafficked area. The measurement conducted seven days after soil tillage showed a statistically significant difference in all monitoring points of the experiment. Crop residues incorporated into the soil has a negative effect on nitrous oxide flux. Seven days after soil tillage there were found an effect of crop residues incorporated into the soil which is caused by organic matter decomposition. Soil compaction affects N_2O flux. There was a higher amount of N_2O in the non-trafficked area with soil bulk density 1.69 g $(cm^3)^{-1}$ than in trafficked area with soil bulk density 1 g $(cm^3)^{-1}$. Results obtained during our experiments have confirmed the importance of soil conservation tillage technologies and controlled traffic system based on reduced soil manipulation and accurate machine passes on the field.

ACKNOWLEDGEMENTS. This work was supported by a research project funded from the European Union under the title: ITEPAg – Application of information technologies to increase the environmental and economical efficiency of production agro-system. ITMS 26220220014.

REFERENCES

Abdalla, M., Jones, M., Ambus, P. & Williams, M. 2009[a]. Emissions of nitrous oxide from Irish arable soils: effects of tillage and reduced N input. *Nutr. Cycling Agroecosyst.* **86**, 53–67.

Abdalla, M., Wattenbach, M., Smith, P., Ambus, P., Jones, M. & Williams, M. 2009[b]. Application of the DNDC model to predict emissions of N_2O from Irish agriculture. *Geoderma*. **151**, 327–337.

Ambus, P., Zechmeister-Boltenstern, S. & Butterbach-Bahl, K. 2006. Sources of nitrous oxide emitted from European forrest soils. *Biogeosciences*. **3**, 135–145.

Ambus, P., Skiba, U., Butterbach-Bahl, K. & Sutton, M. 2011. Reactive nitrogen and greenhouse gas flux interactions in terrestrial ecosystems. *Plant Soil*. **343**, 1–3.

Balashov, E.V., Horák, J., Šiška, B., Buchkina, N.P., Rizhiya, E. & Pavlik, S. 2010. N_2O fluxes from agricultural soils in Slovakia and Russia – direkt measurements and prediction using the DNDC model. *Folia Oecologica*. **37**, 8–15.

Ball, B.C., Parker, J.P. & Scott, A. 1999. Soil and residue management effects on cropping conditions and nitrous oxide fluxes under controlled traffic in Scotland. *Soil Tillage Res.*, **52**, 191–201.

Beare, M.H., Gregorich, E.G. & Georges, P.S. 2009. Compaction effects on CO_2 and N_2O production during drying and rewetting of soil. *Soil Biol. Biochem.*, **41**, 611–621.

Bouwman, A.F. 1996. Direct emissions of nitrous oxide from agricultural soils. *Nutrient Cycling in Agroecosys.*, **46**. 53–70.

Davidson, E.A., 1991. Fluxes of nitrous oxide and nitric oxide from terrestial ecosystems. In Rogers & Whitman (eds.): *Microbial production and comsumption of greenhouse gases: Methane, nitrogen oxides and halomethanes*. The American Society for Microbiology, pp. 219–235.

Douglas, J.T. & Crawford, C.E. 1993. The response of a ryegrass sward to wheel traffic and applied nitrogen. *Grass and Forage Sci.*, **48**, 91–100.

Dubeňová, M., Gálik, R., Mihina, Š. & Šima, T. 2013. Ammonia concentration in farrowing pens with permanent limited range of motion for lactating sows. *Res. Agr. Eng* .In press.

Galambošová, J., Rataj, V., Macák, M., Žitňák, M. & Nozdrovický, L. 2010. Controlled trafic farming and minimum tillage: results of initial ecperiments and layout of a long term experiment. In: *XVIIth World Congress of the International Commission of Agricultural and Biosystems Engineering (CIGR).* Canada, Canadian Society for Bioengineering, 2010.

Galambošová, J., Rataj, V. & Velčický, L. 2012. Three-year study on soil roughness under the controlled traffic system. *Acta technologica agriculturae*. **15**, 38–40.

Hayakawa, A., Akiyama, H., Sudo, S. & Yagi, K. 2009. N_2O and NO emissions from Andisol field as influenced by pelleted poultry manure. *Soil Biol. Biochem.*, **41**, 521–529.

He, F.F., Jiang, R.F., Chen, Q., Zhang, F.S. & Su, F. 2009. Nitrous oxide emissions from an intensively managed greenhouse vegetable cropping system in Northern China. *Environ. Pollut.* **157**, 1666–1672.

Inselsbacher, E., Wanek, W., Ripka, K., Hackl, E., Sessitsch, A., Strauss, J. & Zechmeister-Boltenstern, S., 2011. Greenhouse gas fluxes respond to different N fertilizer types due toaltered plant-soil-microbe interactions. *Plant Soil*, **343**, 17–35.

IPCC. 2007. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Eds.: Core Writing Team, Pachauri, R.K. and Reisinger, A. IPCC, 2007, Geneva, Switzerland, pp. 104.

Jackson, J., Choudrie, S., Thistlethwaite, G., Passant, N., Murrells, T., Watterson, J., Mobbs, D., Cardenas, L., Thomson, A. & Leech, A., 2009.UK greenhouse gas inventory 1990 to 2007. *Convention on Climate Change*. AEA Technology, 71.

Jones, S.K., Rees, R.M., Skiba, U.M. & Ball, B.C. 2007. Influence of organic and mineral N fertiliser on N_2O fluxes from a temperate grassland: a comparison of eddy covariance and statis chamber measurements. *Agric., Ecosyst. Environ*. **121**, 74–83.

Kajanovičová, I., Ložek, O., Slamka, P. & Várady, T. 2011. Bilancia dusíka v integrovanom a ekologickom systéme hospodárenia na pôde. *Agrochémia*, **51**, 7–11. (in Slovak, English abstract).

Kesik, M., Blagodatski, S., Papen, H. & Butterbach-Bahl, K. 2006. Effect of pH, temperature and substrate on N_2O, NO and CO_2 production by Alcaligenes faecalis p. *J. Appl. Microbiol.*, **101**, 655–667.

Kroulík, M. 2009. Hodnocení intensity zaťížení pudy pneumatikami zemědělských stroju. In: *GPS autopilot in agriculture*. Scientific conference, Prague, Czech University of Life Sciences.

Lin, S., Iqbal, J., Hu, R.G. & Feng, M.L. 2010. N_2O emissions from different land uses in mid-subtropical China. *Agric., Ecosyst. Environ*. **136**, 40–48.

Loubet, B. et al., 2011. Carbon, nitrogen and Greenhouse gases budgets over a four years crop rotation in northern France. *Plant and Soil*, **343**, 109–137.

Ložek, O., Bizík, J., Fecenko, J., Kováčik, P. & Vnuk, Ľ. 1997. *Výživa a hnojenie rastlín*. Nitra: SUA in Nitra. (in Slovak).

Mørkved, P.T., Dorsch, P. & Bakken, L.R. 2007. The N_2O product ratio of nitrification and its dependence on long-term changes in soil pH. *Soil Biol. Biochem.*, **39**, 2048–2057.

Pang, X.B., Mu, Y.J., Lee, X.Q., Fang, S.X., Yuan, J. & Huang, D.K. 2009. Nitric oxides and nitrous oxide fluxes from typical vegetables cropland in China: Effects of canopy, soil properties and field management. *Atmos. Environ.*, **43**, 2571–2578.

Ranucci, S. et al., 2011.The influence of management and environmental variables on soil N_2O emissions in a crop system in Southern Italy. *Plant and Soil*, **343**, 83–96.

Ravishankara, A.R., Daniel, J.S. & Portmann, R.W. 2009. Nitrous oxide (N_2O): the dominant ozone-depleting substance emitted in the 21st century. *Science*, **326**, 123–125.

Ruser, R., Flessa, H., Russow, R., Schmidt, G., Buegger, F. & Munch, J.C. 2006. Emission of N_2O, N_2 and CO_2 from soil fertilized with nitrate: Effect of compaction, soil moisture and rewetting. *Soil Biol. Biochem.*, 38, 263–274.

Šima, T., Nozdrovický, L. & Krištof, K. 2011. Analysis of the work quality of the VICON RS-L fertilizer spreader with regard to application attributes. *Poljoprivredna tehnika*. **36**, 1–11.

Šima, T., Nozdrovický, L., Krištof, K., Dubeňová, M. & Macák, M. 2012[a]. A comparison of the field and laboratory methods of measuring CO_2 emissions released from soil to the atmosphere. *Poljoprivrednatehnika*.**37**, 63–72.

Šima, T., Nozdrovický, L., Krištof, K., Dubeňová, M., Krupička, J. & Králik, S. 2012[b]. Method for measuring of N_2O emissions from fertilized soil after the using of fertilizer. *Poljoprivredna tehnika*.**38**, 51–60.

Šima, T., Nozdrovický, L., Dubeňová, M., Krištof, K. & Krupička, J. 2012[c]. Effect of satelite navigation on the quality of work of a fertiliser spreader Kuhn Axera 1102 H-EMC. *Acta technologica agriculturae*. **4**, 96–99.

Šima, T., Nozdrovický, L., Krištof, K., Jobbágy, J. & Fodora, M. 2012[d]. The work quality of fertilizer spreader Amazone ZA-M I 12-36 according of the precision agriculture requirements. *Acta facultatis technicae*. **17**, 99–108 (in Slovak, English abstract).

Šima, T. & Dubeňová, M. 2013. Effect of crop residues on CO_2 flux in the CTF system during soil tillage by a disc harrow Lemken Rubin 9. *Res. Agr. Eng.* In press.

Van Cleemput, O. & Samater, A.H. 1996. Nitrite in soils: accumulation and role in the formation of gaseous N compounds. *Fertilizer Research*, **45**, 81–89.

Velthof, G.L., Kuikman P.J. & Oenema, O. 2002. Nitrous oxide emission from soils amended with crop residues. *Nutr. Cycling Agroecosyst.*, **62**, 249–261.

Williams, E.J., Hutchinson, G.L. & Fehsenfeld, F.C. 1992. NO_x and N_2O emissions from soils. *Global Biogeochem.Cycles*.**6**, 351–388.

Zou, J., Huang, Y., Zong, L., Zheng, X. & Wang, Y. 2004. Carbon Dioxide, Methane and Nitrous Oxide Emissions from a Rice-Wheat Rotation as Affected by Crop Residue Incorporation and Temperature. *Adv. Atmos. Sci.*, **21**, 691–698.