COMMUNICATIONS IN SOIL SCIENCE AND PLANT ANALYSIS
2023, VOL. 54, NO. 15, 2102–2112
https://doi.org/10.1080/00103624.2023.2211604

The Effects of High C/N Ratio Plant Residues on Mineral Nitrogen Supplying Ratio of Soil

Hamza Negiş[a], Cevdet Şeker[a], and Ayşe Çetin[b]

[a]Department of Soil Science and Nutrition, Faculty of Agriculture, Selcuk University, Konya, Turkey; [b]Central Research and Application Laboratory, Kırşehir Ahi Evran University, Kırşehir, Turkey

ABSTRACT

The mineralization processes of plant residues in the soil vary depending not only on many factors such as climate and soil properties but also significantly on the C/N ratios. Increasing the surface area of these materials can also affect the mineralization process. This study increased the surface area of sunflower and maize harvest residues by fine grinding and applied 0.5%, 1%, 2%, and 4% doses by weight to soil with high clay content. After the application, the ammonium and nitrate nitrogen contents of the soils brought to the field capacity water content were measured on the 30th, 60th, 90th, and 180th days during the 180-day incubation period. The NH_4 and NO_3 nitrogen amounts of the starting soil were 12.76 and 13.99 mg kg^{-1}, respectively. The highest NH_4 and NO_3 nitrogen were observed as 28.29 mg kg^{-1} and 96.53 mg kg^{-1} in the M4 application on days 90, respectively. The lowest nitrogen contents were determined as 3.74 mg kg^{-1} in the M2 application on the 180th day and 8.65 mg kg^{-1} in the control application on the 90th day. Applications have remarkably increased the mineral nitrogen content of the soil and hence soil MNSR. As a result, it has been determined that establishing more controlled processes in stubble management, converting the nitrogen from stubble materials into a useful form for the plant, and reducing chemical fertilizer costs can contribute to the improvement of agricultural sustainability.

ARTICLE HISTORY
Received 7 October 2022
Accepted 27 April 2023

KEYWORDS
Ammonium nitrogen; maize straw; mineralization rate; nitrate nitrogen; sunflower straw

Introduction

One of the major issues of increasing maize and sunflower cultivation areas today is the management of harvest residues. Residues from agricultural practices to the soil as an organic carbon source is crucial for maintaining agricultural sustainability and increasing yield and quality (Babu et al. 2014). However, the direct use of plant residues can be limited by various factors. Plant residues (maize, sunflower, wheat stubble, etc.) with high cellulose and lignin content and high C/N ratio are very difficult and/or take a long time to decompose when applied directly to the soil, particularly in arid and semi-arid areas. In this process, microorganisms that decompose the residues can also compete with the plant by using the mineral nitrogen in the environment (Gentile et al. 2009; Ghadikolayi, Abdolreza Kazemeini, and Jafar Bahrani 2015; Torbert et al. 1999). In the studies, it has also been determined that the microbial nitrogen needed for the soil microorganisms during the decomposition of the stubble can be met from the nitrogen available in the agricultural soils and useful by the plants. (Christensen 1985; Harper and Jenkinson 1987; Henriksen and Breland 1999). The slow decomposition and decay of plant materials remaining after harvest in the soil is due to the limited nitrogen supply, as well as leaving them as coarse particles that are less susceptible to microbial interaction. Low nitrogen significantly slows down

CONTACT Hamza Negiş hnegis@selcuk.edu.tr Department of Soil Science and Nutrition, Faculty of Agriculture, Selcuk University, Konya, Turkey

the breakdown of materials containing high lignin (Corbeels, Hofman, and Van Cleemput 2000). However, increasing the surface area to accelerate the degradation of plant materials and promoting microbiological activity shortens the decomposition times of these materials (Chen, Jinggui, and Opoku-Kwanowaa 2020).

Plant materials remaining after maize and sunflower harvest are a significant source of soil organic matter and contain many valuable nutrients (Corbeels, Hofman, and Van Cleemput 2000). Although corn and sunflower straws have high potential in terms of both quantity and content, their use as soil conditioners in agricultural lands is low. (Brar et al. 2015). The most commonly used method of incorporating maize and sunflower stubble into the soil is by overturning the soil and burying the stubble underneath. In this case, since the stubble material does not decompose for a long time, it causes difficulties in the preparation of the next seed bed. Due to these difficulties, farmers burn these plant materials in the field. In fact, some inappropriate uses lead to the waste of these resources and environmental pollution (Zhu et al. 2022). Many studies have focused on the heating or energy efficiency of the carbon content of these high organic carbon-containing materials and have also carried out disposal studies for this. Sharma and Chetani (2017) these studies reported that the nutrient-rich residues of sunflower are mostly burned due to the high C/N ratio. However, in today's world, such destruction of carbon conversion and organic resources causes irreversible damage to the environment (Lin et al. 2022). As an alternative to low organic carbon in soils and high-cost nitrogen fertilization, it is crucial to make these plant residues more usable, both for sustainable agriculture and for making more profit from the unit area by using less agricultural inputs (Gao et al. 2020). Stubble application to the soil can reverse the reduction in soil organic matter and the disruption of the nutrient cycle caused by the intensification of agricultural practices (Arvanitoyannis and Tserkezou 2008). Therefore, returning nutrients to the soil is an important strategy to improve the environmental performance of organic residues and support the sustainability of agricultural production systems (Christensen 1985; Gümüş and Şeker 2017; Xie et al. 2020; Zhu et al. 2022). The conversion of organic nitrogen in the composition of these materials into inorganic nitrogen by accelerating the mineralization process will also make a significant contribution to reducing the cost of chemical fertilizer inputs. For these reasons, this study investigated the effects of finely grinding and mixing maize and sunflower stubble into the soil and the changes in the soil's mineral nitrogen cycle.

Materials and methods

For the incubation trial, Soil samples were taken from the field where corn will be planted from the maize and sunflower cultivation area in the Konya plain in April 2020. In order not to affect the pot experiment to be made, the mixture was obtained from 20 different points of the land with the least field traffic and without transfer points of the manure, straw and seed piles on the land. (37.674475; 32.781967). The soil was passed through a 4 mm sieve in the field, transported to the laboratory, and laid out to air dry. Before starting the trial experiment, the necessary characteristics of the soils were determined, and the methods applied at this stage are given in Table 1. Soil textures were found according to the Bouyoucos hydrometer method (Gee, Bauder, and Klute 1986); pH was measured with a glass electrode pH meter with digital display, in a 1:1 (w/v) mixture of soil/pure water (Gugino et al. 2009); Organic carbon (OC) and Total nitrogen (TN) were determined by the Dumas dry combustion method using a LECO CN-2000 device (Wright and Bailey 2001). Organic matter (OM) was calculated the 1.724 times OC. In order to determine the elemental content of the straw materials, the straw was weighed 0.3 g and were burned in the microwave oven (using nitric acid + hydrogen peroxide) and then read in the ICP-MS device to determine the element content of all samples. Information about the measured carbon and nitrogen amounts of the application materials, maize, and sunflower straw, is given in Table 2. Both straw materials had high carbon ratios, and therefore the calculated C/N ratios were high. Due to the low decomposition rates of both applications with a high carbon-nitrogen ratio in the literature, the incubation trial was started after grinding the materials to pass through a 4 mm sieve.

Table 1. Selected physical and chemical properties of experimental soil.

Parameters	Unit	Value	Methods
Sand	%	16.22 ± 1.25	Gee, Bauder, and Klute (1986)
Clay	%	49.50 ± 2.74	
Silt	%	34.28 ± 1.12	
pH (H_2O, 1:1)	-	7.96 ± 0.08	Gugino et al. (2009)
EC (H_2O, 1:1)	μmhos cm^{-1}	748 ± 12.00	
OC	%	1.17 ± 0.02	Wright and Bailey (2001)
TN	%	0.09 ± 0.01	
C/N	%	13.02 ± 0.01	
OM	%	2.02 ± 0.02	
NH_4-N	mg kg^{-1}	15.20 ± 1.23	Keeney (1982)
NO_3-N	mg kg^{-1}	7.58 ± 0.87	
$CaCO_3$	%	16.24 ± 2.54	Nelson (1982)

EC: Electrical conductivity; CaCO3: Lime; OM: Organic matter; NH4-N: Ammonium nitrogen; NO3-N: Nitrate nitrogen; OC: Organic carbon; TN: Total nitrogen.

Table 2. Carbon/Nitrogen content of corn and sunflower straw.

Parameters	Unit	SS	MS	Methods
Carbon	%	37.99 ± 1.23	42.47 ± 1.09	Wright and Bailey (2001)
Nitrogen	%	0.36 ± 0.02	0.38 ± 0.04	
C/N ratio	%	105 ± 1.11	118 ± 1.05	
pH	-	9.56 ± 0.32	6.03 ± 0.12	Moebius-Clune et al. (2011)
EC	μmhos	2003 ± 231	957 ± 50.00	
Ca	%	1.11 ± 0.03	0.23 ± 0.01	Ryan, Estefan, and Rashid, (2001)
Mg	%	0.74 ± 0.02	0.13 ± 0.02	
K	%	3.42 ± 0.58	1.08 ± 0.12	
P	%	0.31 ± 0.08	2.09 ± 0.21	
Cu	mg kg^{-1}	13.28 ± 0.59	14.76 ± 0.64	
Fe	mg kg^{-1}	657 ± 15.21	219 ± 2.98	
Mn	mg kg^{-1}	20.48 ± 4.36	60.17 ± 3.78	
Zn	mg kg^{-1}	35.49 ± 1.25	42.57 ± 2.76	

SS: Sunflower straw; MS: Maize straw.

Maize and sunflower harvest residues grounded at the beginning of the experiment were mixed with 0.5%, 1%, 2%, and 4% doses by weight and left for incubation after applying distilled water at field capacity. During the 180-day incubation period, samples were taken at days 30, 60, 90, and 180 and the changes in ammonium NH_4 (N) and nitrate NO_3 (N) nitrogen of these samples were measured for each period. Ammonium nitrogen and nitrate nitrogen contents of soil samples were determined by titration of H_2SO_4 in the solution obtained by distillation with 2 N KCL and distillation in a Kjeldahl device in the presence of MgO and devarda's alloy, respectively. Equation 1 was used to determine Ammonium nitrogen and nitrate nitrogen contents. Total nitrogen content was calculated from the sum of Ammonium nitrogen and nitrate nitrogen contents.

$$\text{Ammonium nitrogen and nitrate nitrogen}\left(mgkg^{-1}\right) = \frac{(A - B) * N * 14 * 100}{Weighed\ of\ soil(g)} \tag{1}$$

Determination of total mineral nitrogen ratios has an important place in the present study. Therefore, the mineral nitrogen supply ratio (MNSR) of the applications was determined for each incubation period by calculating the ratio of the total inorganic nitrogen of the control soil of that period to the inorganic nitrogen of the applications (Equation 2). Tukey test ($p < .05$) was used to compare periods and stubble applications.

$$MNSR(\%) = \frac{Total\ of\ NH4\ and\ NO3\ nitrogen\ of\ the\ control\ soil.}{Total\ of\ NH4\ and\ NO3\ nitrojen\ of\ the\ application} * 100 \tag{2}$$

Results and discussion

The sand, clay and silt ratios of the test soil were found to be 16.22%, 49.50% and 34.28%, respectively. The soil with a slightly alkaline pH level (7.96) had no salinity problems (748 µmhoscm^{-1}) and had a high lime content (16.24%) (Table 1). Before incubation, the NH_4 (N) level of the soil sample was 15.20 mg kg^{-1}, and the NO_3-N level was 7.58 mg kg^{-1} (Table 1). Stubble applications significantly increased the NH_4-N and NO_3-N contents of the soil during the incubation period ($p < .05$). The NH_4 (N) content of the C sample left for incubation was lower than the starting soil, especially on the 60th and 90th days.

On day 30, the highest NH_4 (N) content was measured as 26.39 mg kg^{-1} in M4 application, while the lowest NH_4 (N) content was measured as 12.76 mg kg^{-1} in C application (Figure 1). All of the application doses, higher NH_4 (N) contents were detected in M applications compared to S applications. The NO_3 (N) contents of all samples were higher during the incubation period compared to the starting soil. The applications and the incubation period accelerated the mineralization process in the soil and increased the NO_3 (N)contents of the samples. On day 30, the highest NO_3 (N) content was measured in M4 application with 24.49 mg kg^{-1}, while the lowest was measured in C sample with 13.99 mg kg^{-1}. Except for S0.5 and M0.5 applications, higher NO_3 (N) amounts were detected in M applications compared to S applications. In this period, the M4 application had the highest NH_4 and NO_3 nitrogen, and provided a 2-fold increase in nitrogen amounts compared to C.

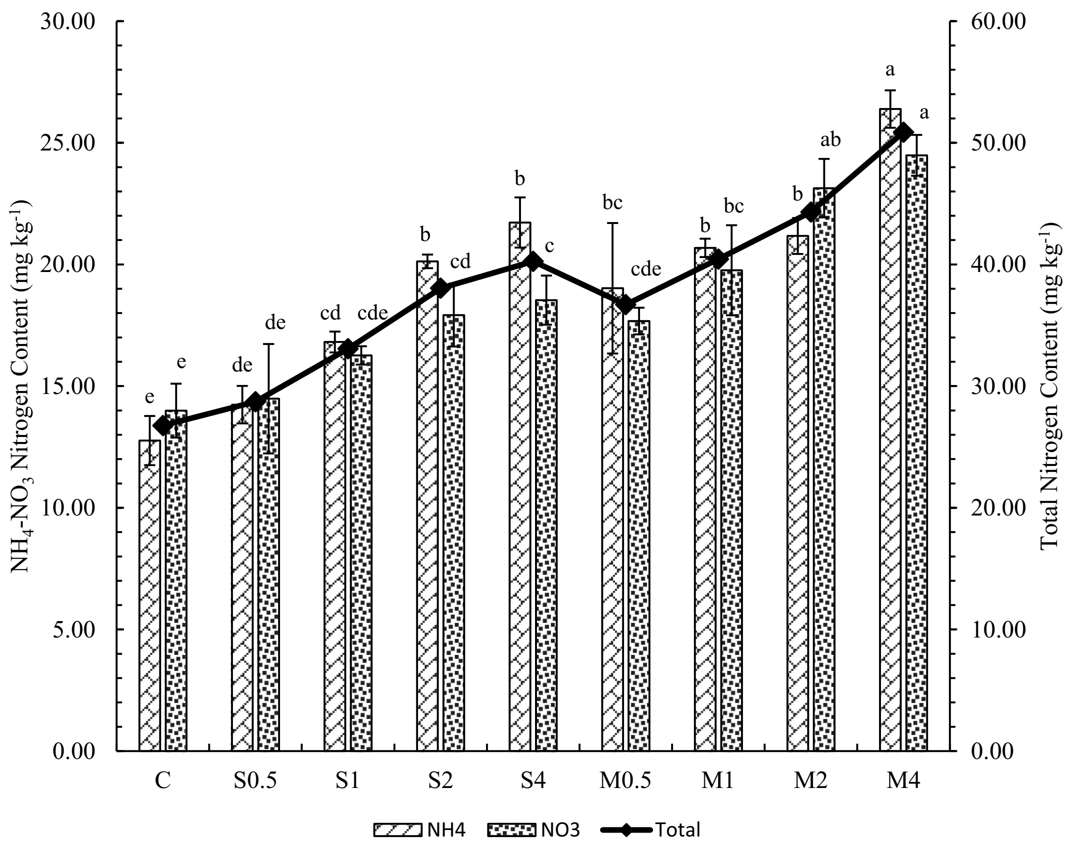

Figure 1. The change in the nitrogen content of the soils on the 30th day of incubation. Note: C: Control; S0.5: %0.5 Sunflower straw; S1: %1 Sunflower straw; S2: %2 Sunflower straw; S4: %4 Sunflower straw; M0.5: %0.5 Maize straw; M1: %1 Maize straw; M2: %2 Maize straw; M4: %2 Maize straw; NH_4-N: Ammonium nitrogen; NO_3-N: Nitrate nitrogen; The letters in the graphs show the significant difference between the different treatments in each row. P < 0.05.

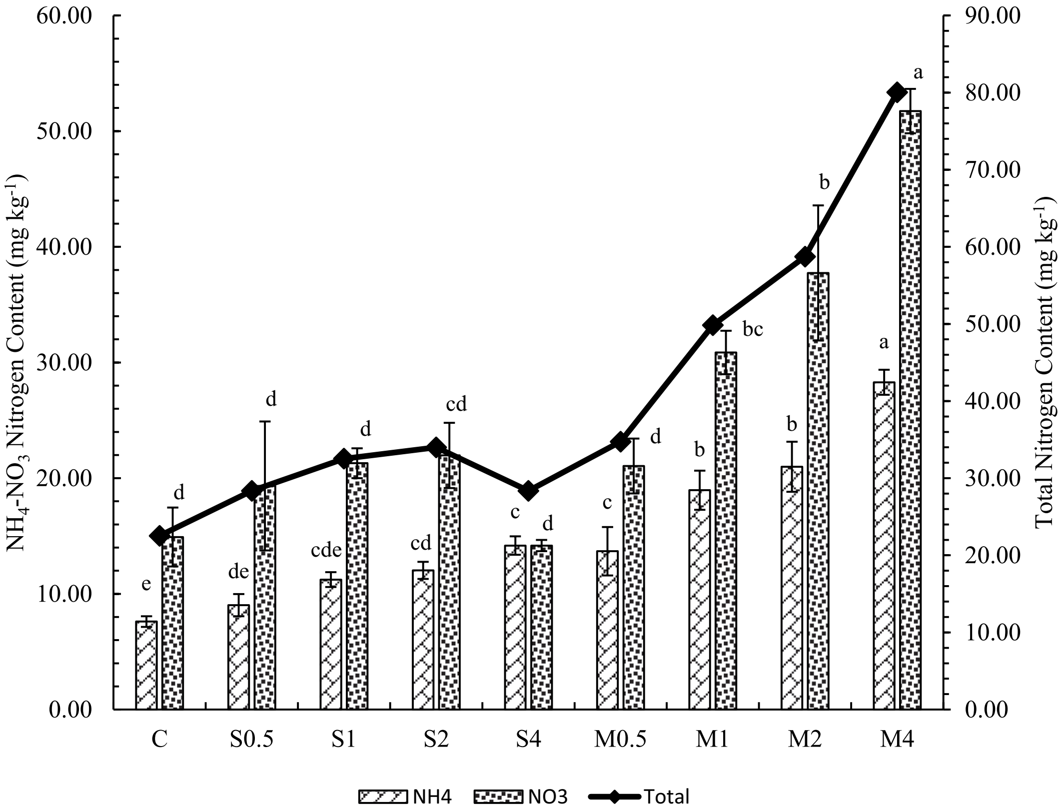

Figure 2. The change in the nitrogen content of the soils on the 60th day of incubation. Note: C: Control; S0.5: %0.5 Sunflower straw; S1: %1 Sunflower straw; S2: %2 Sunflower straw; S4: %4 Sunflower straw; M0.5: %0.5 Maize straw; M1: %1 Maize straw; M2: %2 Maize straw; M4: %2 Maize straw; NH_4-N: Ammonium nitrogen; NO_3-N: Nitrate nitrogen; The letters in the graphs show the significant difference between the different treatments in each row. $P < 0.05$.

Except for the M4 application, the amount of NH_4 (N) measured on the 60th day was lower than on the 30th day (Figure 2). In this period, the highest amount of NH_4 (N) was measured in M4 application with 28.29 mg kg^{-1}, while the difference between C, S0.5 and S1 applications was insignificant, and the lowest was measured in C application with 7.61 mg kg^{-1}. While C, S0.5 and M0.5 applications were in the same group, M1 and M2 applications with higher NH_4 (N) amount was in a different group. M applications have created a higher amount of NH_4 (N) than S applications. Except for the application of S4, the NO_3 (N) amounts of all samples were higher than on day 30. The highest amount of NO_3 (N) was again measured in M4 application with 51.73 mg kg^{-1}, while the lowest amount was found in S4 application with 14.18 mg kg^{-1}. However, the differences between S2, S4 and M0.5 applications were insignificant, and M1 and M2, M4 applications were in the upper group with a higher than other NO_3 (N) amount. Compared to the S applications, the increase in the NO_3 (N) became more pronounced with the increasing doses of M application. No significant change was observed in the nitrogen content of the control soil. Maize stubble applications exhibited a higher mineralization process than sunflower stubble applications and approximately a 2-fold increase was detected on the 30th day.

The amount of NH_4 (N) measured on the 90th day of the applications showed significant decreases compared to the beginning of incubation (Figure 3). In this period, the highest amount of NH_4 (N) was measured in the M4 application with 16.81 mg kg^{-1} the lowest was measured in C application with 7.98 mg kg^{-1}, and the differences between C, S0.5, and S1 applications were found to appear to be in the same letter groups. While the M4 application was in the upper group, the differences between the

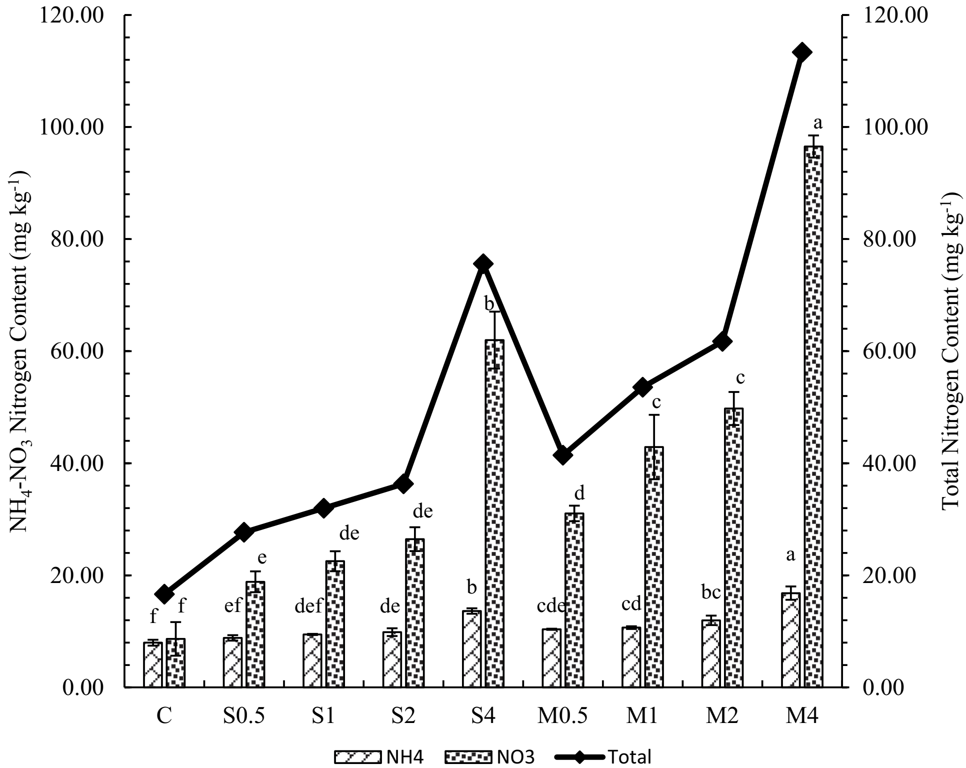

Figure 3. The change in the nitrogen content of the soils on the 90th day of incubation. Note: C: Control; S0.5: %0.5 Sunflower straw; S1: %1 Sunflower straw; S2: %2 Sunflower straw; S4: %4 Sunflower straw; M0.5: %0.5 Maize straw; M1: %1 Maize straw; M2: %2 Maize straw; M4: %2 Maize straw; NH_4-N: Ammonium nitrogen; NO_3-N: Nitrate nitrogen; The letters in the graphs show the significant difference between the different treatments in each row. $P < 0.05$.

M0.5, M1, and M2 applications were significant, and a slightly higher NH_4 (N) content was measured compared to C. On the 90th day, the NO_3 (N) concentration of the S4, M1, M2, and M3 applications increased to the highest level, whereas the NO_3 (N) concentration of the C sample decreased by 8.65 mg kg^{-1}. The highest NO_3 (N) concentration was measured in the M4 application with 96.53 mg kg^{-1} while 61.98 mg kg^{-1} was measured in the S4 application. This indicates a high level of nitrification on day 90 of incubation. The difference between S0.5, S1, and S2 applications was not statistically significant, and they were seen that they are in the same letter groups.

On the 180th day of incubation, the amount of NH_4 (N) decreased significantly compared to the beginning of the incubation, and the lowest amount of NH_4 (N) was measured in the M2 application with 3.74 mg kg^{-1} (Figure 4). The differences between C and S0.5andS4 applications were not statistically insignificant. In the last period, the highest amount of NH_4 (N) was measured in the S2 application with 11.17 mg kg^{-1} and it was in the same group as the S1 application. On the 180th day, the NO_3 (N) concentration of the S4 and M4 applications reached the highest level, while the NO_3 (N) concentration of the C sample was lower than the other applications of 13.19 mg kg^{-1}. The highest NO_3 (N) concentration was 50.93 mg kg^{-1} in the M4 application, and the differences between S4 and M2 applications were insignificant. This indicates significant denitrification losses on the 180th day, especially at the highest doses of S and M applications. The 180th-day measurements in the samples representing the last incubation period show that the mineralization processes of the organic materials have been completed to a large extent.

The NH_4 (N) contents of the applications were the lowest during the 90th and 180th days, and the maize straw applications even had lower NH_4 (N) content than the control. The NH_4 (N) amounts

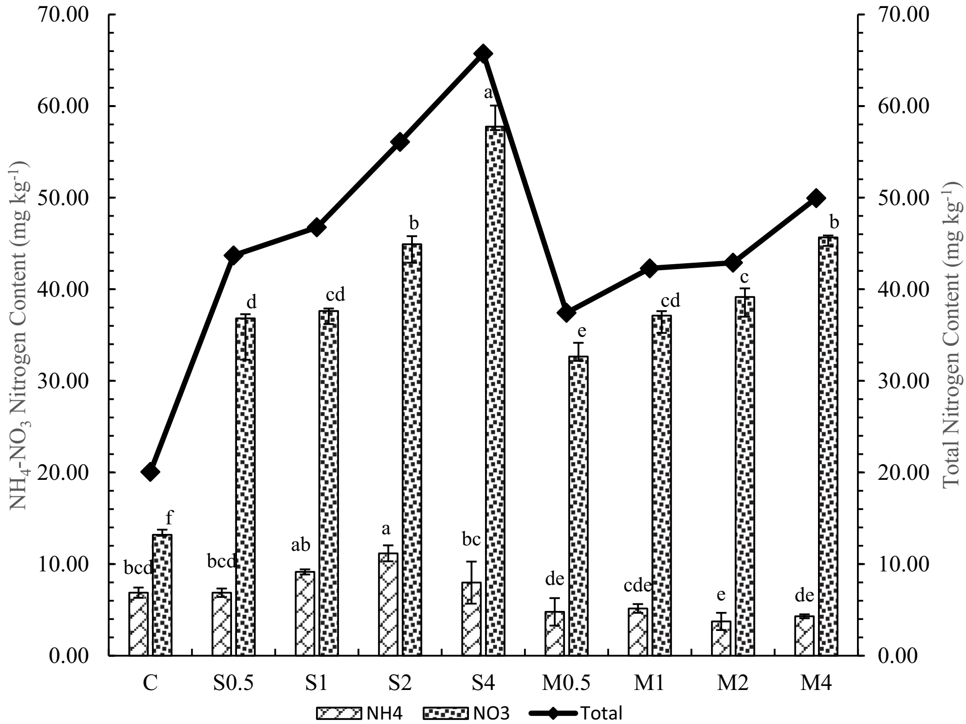

Figure 4. The change in the nitrogen content of the soils on the 180th day of incubation. Note: C: Control; S0.5: %0.5 Sunflower straw; S1: %1 Sunflower straw; S2: %2 Sunflower straw; S4: %4 Sunflower straw; M0.5: %0.5 Maize straw; M1: %1 Maize straw; M2: %2 Maize straw; M4: %2 Maize straw; NH_4-N: Ammonium nitrogen; NO_3-N: Nitrate nitrogen; The letters in the graphs show the significant difference between the different treatments in each row. P < 0.05.

were slightly higher than the control, with the late decomposition of the sunflower straw and incomplete mineralization. For application M4 with the highest NO_3 (N) at the end of the 90th day, the 180th-day results show that denitrification starts from this period to the 180th day period. At the highest dose of maize straw applications, the amount of NO_3 (N) decreased at a higher rate. In sunflower stubble, this decrease was seen only at the highest dose, while the increase continued at other doses. Maximum gross immobilization of soil inorganic nitrogen gave similar results for sunflower and maize straw. These data obtained are similar to figures reported by Nicolardot et al. (1991) and laboratory experiments obtained by Recous et al. (1995).

Organic matter content was found to be 4.51% higher in M4, treated soils over the initial value (96,94%) after 30 days of incubation (Figure 5). Throughout the incubation period, organic matter reached its peak at 30 days of incubation and decreased thereafter with time. After 180 days, organic matter content decreased significantly ($p < .05$) against 30 days samples treated soils. At 30 days of incubation, straw additions did not affect soil organic matter content, while a significant variation ($p < .05$) was found among treatment during other incubation periods. At the end of the incubation, the maximum decrease was observed when M4 was applied treated soils.

The effects of all straw applications on MNSR values during the incubation period are given in Figure 6. Accordingly, on the 30th day, the lowest MNSR value was 7.34% in the S0.5 application, while the highest was in the M4 application with 90.14%. On the 30th day of incubation, increases in both S and M application doses increased the MNSR values, but higher MNSR values were obtained in M applications. On the 60th day, the lowest MNSR was determined in the S0.5 and S4 applications, while the highest MNSR was calculated in the M4 application with 255.31%. Again, in this period, except for the S4 application, increases in both S and M application doses increased the MNSR values,

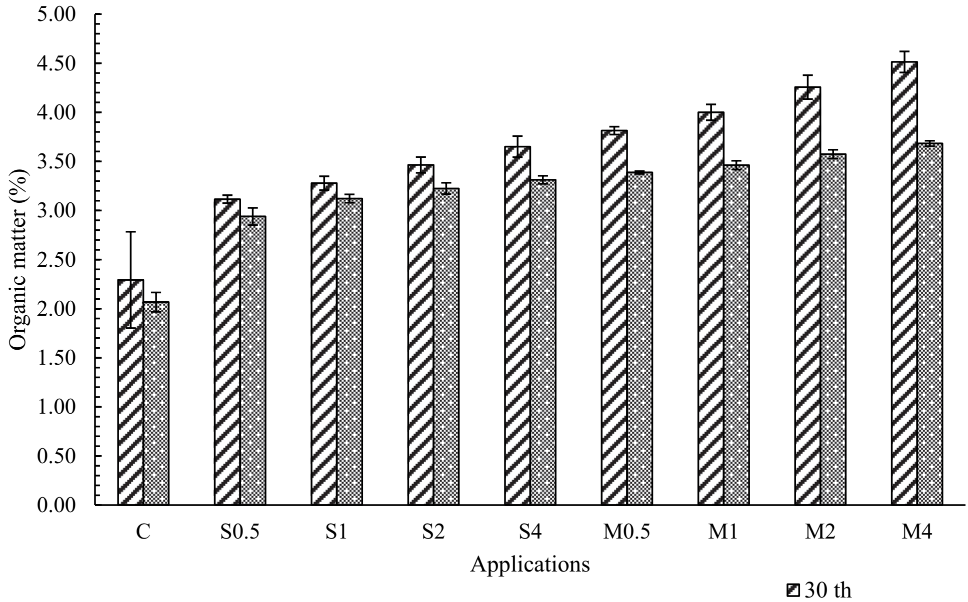

Figure 5. The change in the organic matter content of the soils on the 30-180th days of incubation. Note: C: Control; S0.5: %0.5 Sunflower straw; S1: %1 Sunflower straw; S2: %2 Sunflower straw; S4: %4 Sunflower straw; M0.5: %0.5 Maize straw; M1: %1 Maize straw; M2: %2 Maize straw; M4: %2 Maize straw; NH_4-N: Ammonium nitrogen; NO_3-N: Nitrate nitrogen; The letters in the graphs show the significant difference between the different treatments in each row. P < 0.05.

and the rate of increase was higher in M applications. This indicates that the M treatments were significantly mineralized and provided higher amounts of mineral nitrogen than the S treatments at the 30th and 60th days of incubation. On the 90th day of incubation, the lowest MNSR value was again determined in the S0.5 application with 66.42%, while the highest value was determined in the S4 application with 354.61%. During this period, as the doses of both stubble applications increased, the MNSR values also increased significantly and reached their high mineral nitrogen strength capacity. In the last period of incubation, the lowest MNSR value was found in the M0.5 application with 86.54%, while the highest value was determined in the S4 application with 227.52%. During this period, S applications at all doses yielded higher MNSR values than M applications. This indicates that sunflower stubble is more difficult and takes more time to decompose than maize stubble. In this case, fertilization doses and schedules should be adjusted in light of the data obtained from field studies, especially in meeting the mineral nitrogen needs of the plants to be grown in the periods following the stubble application.

Ammonium and nitrate nitrogen measured during the incubation period indicates that the stubble is converted to ammonium nitrogen at the beginning of the incubation period and then to nitrate nitrogen later in the period. Many studies have shown that when ammonium and nitrate ions are in the same environment, the ammonium ion is immobilized to nitrate ion (Gutser et al. 2005; Jansson, Hallam, and Bartholomew 1955; Recous et al. 1995; Recous, Mary, and Faurie 1990). Ammonium nitrogen started to decrease after the 30th day and completed its conversion to nitrate nitrogen on the 180th day. However, this does not apply to both stubbles. Figure 5 shows that this process is slower in sunflower stubble than in maize stubble. The longer decomposition time of sunflower stubble than corn stubble is due to its higher fiber structure (Jawson and Elliott 1986).

In stubble applications containing a certain amount of nitrogen, the immobilization of inorganic nitrogen after application to the soil is largely dependent on soil microorganisms (Kaleem Abbasi et al. 2007; Mary et al. 1996). Yet, crop amount, application time, soil type and climatic conditions, and rotation of plants planted in the soil affect the degradation time of crop residues by soil

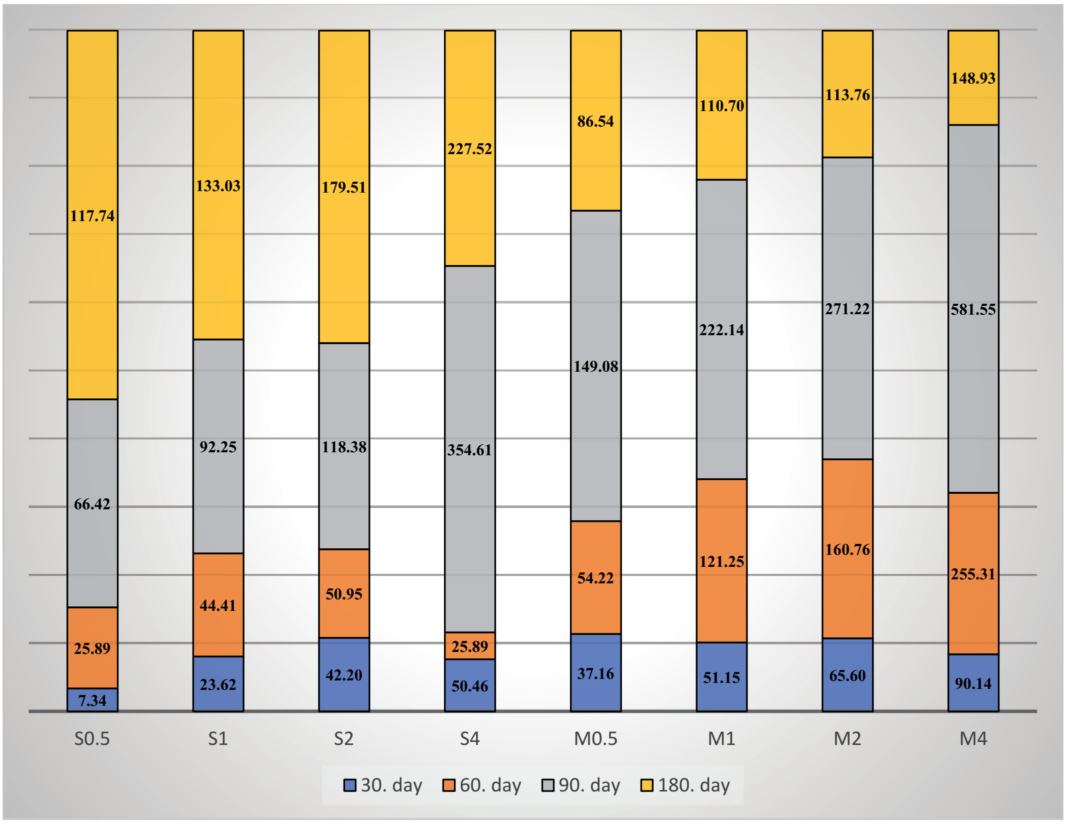

Figure 6. Percentage distribution of total fragmentation rates throughout incubation. Note: C: Control; A0.5: %0.5 Sunflower straw; A1: %1 Sunflower straw; A2: %2 Sunflower straw; A4: %4 Sunflower straw; M0.5: %0.5 Maize straw; M1: %1 Maize straw; M2: %2 Maize straw; M4: %2 Maize straw; NH_4-N: Ammonium nitrogen; NO_3-N: Nitrate nitrogen.

microorganisms (Cropping 2005; Ramesh et al. 2009). Therefore, it seems unnecessary to apply extra N in the fall to accelerate decomposition. The decomposition process of the applied stubble material may be limited by the temperature level and the availability of water, oxygen, and nutrients as well as the availability of stubble polysaccharides (Christensen 1985; Harper and Lynch 1981; Murayama 1984). In this context, it is noteworthy that despite the high C/N ratios of the applied stubble, the highest decomposition rate was reached at the end of 90 days after the stubble application. Other studies have revealed that straws are basically broken down by microbial decomposition (Jawson and Elliott 1986) and add nitrogen to the soils, but the decomposition does not become faster or more with more stubble applications (Recous et al. 1995; Zhang et al. 2012).

Conclusion

This incubation experiment, in which maize and sunflower stubble were mixed into the soil at different rates, revealed the period-dependent change of NH_4 (N) and NO_3 (N) nitrogen in the soil. The present study showed that the addition of straw to the soils after harvest and the current nitrogen potential of the soils in Turkey, where nitrogen fertilization is used for optimum crop yield, are sufficient for the decomposition of straw. It is seen that the necessity of providing additional nitrogen for the decomposition of stubble, which is a traditional view by scientists for the breakdown of stubble compositions with high carbon/nitrogen ratio, is eliminated by mixing the stubble into the soil without breaking it into smaller forms. Given the high mineral N concentration in the soil, stubble application after intensive grain cultivation (especially in autumn), where nitrogen is applied at recommended levels for optimum crop yield, will probably be sufficient to meet the needs of decomposed stubble. In this case, stubble applications should be made to cover 90-day periods, so that the plants can get the maximum benefit from the nitrogen content. In addition, these stubble materials should be examined in long-term field trials for soil sustainability and less input use in arid and semi-arid irrigable areas.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Hamza Negiş http://orcid.org/0000-0002-1880-9188

References

Arvanitoyannis, I. S., and P. Tserkezou. 2008. Corn and rice waste: A comparative and critical presentation of methods and current and potential uses of treated waste. *International Journal of Food Science & Technology* 43 (6):958–88. doi:10.1111/j.1365-2621.2007.01545.x.

Babu, S., D. S. Rana, G. S. Yadav, R. Singh, and S. K. Yadav. 2014. A review on recycling of sunflower residue for sustaining soil health. *International Journal of Agronomy* 2014:601049. doi:10.1155/2014/601049.

Brar, B. S., S. Jagdeep, G. Singh, and G. Kaur. 2015. Effects of long term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize–wheat rotation. *Agronomy* 5 (2):220–38. doi:10.3390/agronomy5020220.

Chen, X., W. Jinggui, and Y. Opoku-Kwanowaa. 2020. Effects of returning granular corn straw on soil humus composition and humic acid structure characteristics in saline-alkali soil. *Sustainability* 12 (3):1005. doi:10.3390/su12031005.

Christensen, B. T. 1985. Wheat and barley straw decomposition under field conditions: Effect of soil type and plant cover on weight loss, nitrogen and potassium content. *Soil Biology & Biochemistry* 17 (5):691–97. doi:10.1016/0038-0717(85)90047-1.

Corbeels, M., G. Hofman, and O. Van Cleemput. 2000. Nitrogen cycling associated with the decomposition of sunflower stalks and wheat straw in a vertisol. *Plant and Soil* 218/2 (1/2):71–82. doi:10.1023/A:1014904505716.

Cropping, P. I. R. B. 2005. Crop residue management for nutrient cycling and improving soil productivity in rice-based cropping systems in the tropics. *Advances in Agronomy* 85 (269):85006–5.

Gao, L., W. Li, U. Ashraf, L. Wenjia, L. Yuliang, L. Chunyan, L. Guangyu, L. Gaoke, and H. Jianguang. 2020. Nitrogen fertilizer management and maize straw return modulate yield and nitrogen balance in sweet corn. *Agronomy* 10 (3):362. doi:10.3390/agronomy10030362.

Gee, G. W., J. W. Bauder, and A. Klute. 1986. *Particle-Size Analysis, Methods of soil analysis, part 1, physical and mineralogical methods*. Madison, WIS, USA: Soil Science Society of America, American Society of Agronomy.

Gee, G. W., J. W. Bauder, and A. Klute. 1986. *Particle-Size Analysis, Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods*. Madison, WIS, USA: Soil Since Society of America, Inc.

Gentile, R., B. Vanlauwe, C. van Kessel, and J. Six. 2009. Managing N availability and losses by combining fertilizer-N with different quality residues in Kenya. *Agriculture, Ecosystems & Environment* 131 (3):308–14. doi:10.1016/j.agee.2009.02.003.

Ghadikolayi, A. K., S. Abdolreza Kazemeini, and M. Jafar Bahrani. 2015. Wheat yield and soil properties as influenced by crops residues and nitrogen rates. *Australian Journal of Crop Science* 9 (9):853–58.

Gugino, B. K., O. J. Idowu, R. R. Schindelbeck, H. M. van Es, D. W. Wolfe, B. N. Moebius- Clune, J. E. Thies, and G. S. Abawi. 2009. *Cornell soil health assessment training manual, Communications Services, NYSAES*, 44. 2nd ed. Ithaca, New York State: Cornell University.

Gümüş, İ., and C. Şeker. 2017. Effects of spent mushroom compost application on the physicochemical properties of a degraded soil. *Advances in Fission-Track Geochronology* 8 (6):1153–60. doi:10.5194/se-8-1153-2017.

Gutser, R., T. Ebertseder, A. Weber, M. Schraml, and U. Schmidhalter. 2005. Short-term and residual availability of nitrogen after long-term application of organic fertilizers on arable land. *Journal of Plant Nutrition & Soil Science* 168 (4):439–46. doi:10.1002/jpln.200520510.

Harper, S. H. T., and D. S. Jenkinson. 1987. Decomposition of crop residues and organic-matter in the soil. *Journal of the science of food and agriculture*, 40 (2):125–26.

Harper, S. H. T., and J. M. Lynch. 1981. The kinetics of straw decomposition in relation to its potential to produce the phytotoxin acetic acid. *Journal of Soil Science* 32 (4):627–38. doi:10.1111/j.1365-2389.1981.tb01735.x.

Henriksen, T. M., and T. A. Breland. 1999. Nitrogen availability effects on carbon mineralization, fungal and bacterial growth, and enzyme activities during decomposition of wheat straw in soil. *Soil Biology & Biochemistry* 31 (8):1121–34. doi:10.1016/S0038-0717(99)00030-9.

Jansson, S. L., M. J. Hallam, and W. V. Bartholomew. 1955. Preferential utilization of ammonium over nitrate by micro-organisms in the decomposition of oat straw. *Plant and Soil* 6 (4):382–90. doi:10.1007/BF01343647.

Jawson, M. D., and L. F. Elliott. 1986. Carbon and nitrogen transformations during wheat straw and root decomposition. *Soil Biology & Biochemistry* 18 (1):15–22. doi:10.1016/0038-0717(86)90097-0.

Kaleem Abbasi, M., M. Hina, A. Khalique, and S. Razaq Khan. 2007. Mineralization of three organic manures used as nitrogen source in a soil incubated under laboratory conditions. *Communications in Soil Science & Plant Analysis* 38 (13–14):1691–711. doi:10.1080/00103620701435464.

Keeney, D. R. 1982. Nitrogen—inorganic forms. *Methods of soil analysis part*, Vol. 21982: 672–78.Nelson, DW

Lin, H., H. Jin, L. Hongwen, Q. Wang, L. Caiyun, W. Yang, S. Huang, P. Liu, and Y. Chang. 2022. Design and experiment of a reciprocating intermittent chopping device for maize straw returning. *Agriculture* 12 (2):220. doi:10.3390/agriculture12020220.

Mary, B., S. Recous, D. Darwis, and D. Robin. 1996. Interactions between decomposition of plant residues and nitrogen cycling in soil. *Plant and Soil* 181 (1):71–82. doi:10.1007/BF00011294.

Moebius-Clune, B. N., O. J. Idowu, R. R. Schindelbeck, H. M. van Es, D. W. Wolfe, G. S. Abawi, and B. K. Gugino. 2011. Developing standard protocols for soil quality monitoring and assessment. In *Innovations as key to the green revolution in Africa*, ed. A. Bationo, B. Waswa, J. M. Okeyo, F. Maina, and J. M. Kihara, 833–42. Dordrecht: Springer Netherlands.

Murayama, S. 1984. Decomposition kinetics of straw saccharides and synthesis of microbial saccharides under field conditions. *Journal of Soil Science* 35 (2):231–42. doi:10.1111/j.1365-2389.1984.tb00279.x.

Nelson, R. E. 1983. Carbonate and gypsum. Methods of Soil Analysis: Part 2 Chemical and Microbiological Properties. 9:181–97.

Nicolardot, B., R. Chaussod, D. Cheneby, and M. Baugnet, 1991. "Effects of some factors on immobilization and mineralization of nitrogen in soils". In: *Stable Isotopes in Plant Nutrition, Soil Fertility and Environmental Studies: Proceedings of an International Symposium on the Use of Stable Isotopes in Plant Nutrition, Soil Fertility and Environmental Studies*. Vienna: IAEA, FAO: 327–30.

Ramesh, P., N. Raten Panwar, A. Bahadur Singh, S. Ramana, and A. Subba Rao. 2009. Impact of organic-manure combinations on the productivity and soil quality in different cropping systems in central India. *Journal of Plant Nutrition & Soil Science* 172 (4):577–85. doi:10.1002/jpln.200700281.

Recous, S., B. Mary, and G. Faurie. 1990. Microbial immobilization of ammonium and nitrate in cultivated soils. *Soil Biology & Biochemistry* 22 (7):913–22. doi:10.1016/0038-0717(90)90129-N.

Recous, S., D. Robin, D. Darwis, and B. Mary. 1995. Soil inorganic N availability: Effect on maize residue decomposition. *Soil Biology & Biochemistry* 27 (12):1529–38. doi:10.1016/0038-0717(95)00096-W.

Ryan, J., G. Estefan, and A. Rashid. 2001. *Soil and plant analysis laboratory manual Jointly published by the International Center for Agricultural Research in the Dry Areas (ICARDA) and the National Agricultural Research Centre (NARC).* 2nd ed. 46–48. Aleppo, Syria.

Sharma, A., and R. Chetani. 2017. A review on the effect of organic and chemical fertilizers on plants. *International Journal for Research in Applied Science and Engineering Technology* V (II):677–80. doi:10.22214/ijraset.2017.2103.

Torbert, H. A., K. N. Potter, D. W. Hoffman, T. J. Gerik, and C. W. Richardson. 1999. Surface residue and soil moisture affect fertilizer loss in simulated runoff on a heavy clay soil. *Agronomy Journal* 91 (4):606–12. doi:10.2134/agronj1999.914606x.

Wright, A. F., and J. S. Bailey. 2001. Organic carbon, total carbon, and total nitrogen determinations in soils of variable calcium carbonate contents using a Leco CN-2000 dry combustion analyzer. *Communications in Soil Science & Plant Analysis* 32 (19–20):3243–58. doi:10.1081/CSS-120001118.

Xie, W., Q. Chen, W. Lanfang, H. Yang, X. Jikun, and Y. Zhang. 2020. Coastal saline soil aggregate formation and salt distribution are affected by straw and nitrogen application: A 4-year field study. *Soil and Tillage Research* 198:104535. doi:10.1016/j.still.2019.104535.

Zhang, J. B., T. B. Zhu, Z. C. Cai, S. W. Qin, and C. Müller. 2012. Effects of long-term repeated mineral and organic fertilizer applications on soil nitrogen transformations. *European Journal of Soil Science* 63 (1):75–85. doi:10.1111/j.1365-2389.2011.01410.x.

Zhu, F., X. Lin, S. Guan, and S. Dou. 2022. Deep incorporation of corn straw benefits soil organic carbon and microbial community composition in a black soil of Northeast China. *Soil Use and Management* 38 (2):1266–79. doi:10.1111/sum.12793.