STE | 田间老化生物炭对肥料氮固持和 N2O 排放的影响（转）

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Effect of field-aged biochar on fertilizer N retention and N_2O emissions: A field microplot experiment with ^{15}N-labeled urea

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摘　要：施用生物炭被认为可以提高作物产量，减少氮素淋失和气体排放；然而，关于**田间老化生物炭如何影响肥料氮固持和 N_2O 排放**仍知之甚少。本文在华北平原玉米季进行了施用 ^{15}N 标记尿素的田间微区试验，在施用（Biochar 处理）和不施用（Control 处理）老化 3 年生物炭（施用量为 12 t ha^{-1}）的砂壤土上进行了田间微区试验。总体上，**25.6–26.2%的尿素氮被玉米地上生物量吸收，田间老化生物炭不影响产量或肥料氮回收率**。玉米收获后，对照和生物炭处理下土壤剖面（0–40 cm）中施用氮的残留率分别为 **21.6%和 20.3%**；施用老化生物炭后，表层土壤（0–20 cm）中施用氮的残留率**增加**了 **10.2%**，而亚表层土壤（20–40cm）中施用氮的残留率**减少**了 **37.2%**，这可能是由于**生物炭减少了 NO_3^- 淋失所致**。对照处理的累积 N_2O 排放量和尿素氮诱导的 N_2O 排放量分别为 **2.06 和 0.78 kg N ha^{-1}**，经生物炭处理后分别显著降低至 **1.89 和 0.74 kg N ha^{-1}**。施氮产生的 N_2O 排放量分别占对照和生物炭处理总 N_2O 排放量的 **38.0%和 39.4%**。在对照和生物炭处理下，**施氮激发效应引起的土壤有机氮分解产生的 N_2O 排放量分别为 0.69 和 0.56 kg N ha^{-1}，分别占总排放量的 33.7%和 29.7%**。总的来说，本研究结果表明，**田间老化生物炭通过减少 NO_3^- 淋失增加了肥料氮在表层土壤中的固持，同时有效地减少了砂壤土中肥料氮和有机氮矿化引发的 N_2O 排放**。

关键词：生物炭(Biochar)；^{15}N 标记尿素(^{15}N-urea)；氮素回收率(N recovery efficiency)；氮素固持(N retention)；N_2O(Nitrous oxide)

Graphical abstract:

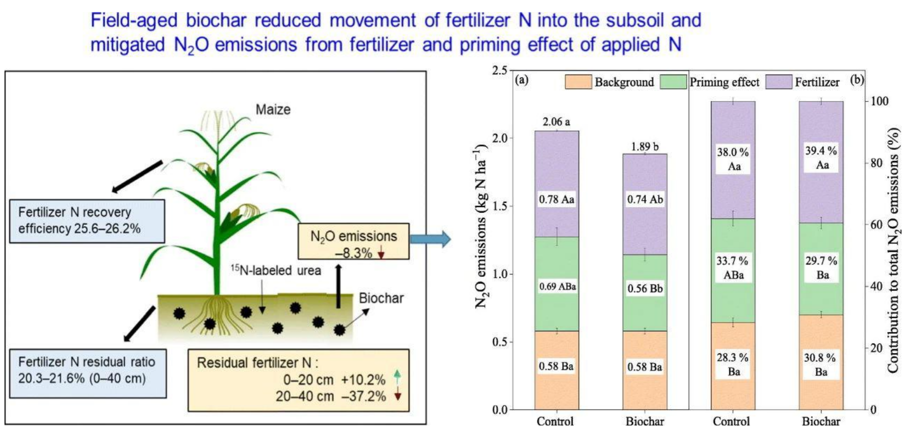

Table 1. Surface (0–20 cm) soil properties before fertilization and maize cropping.

Treatment	pH (H_2O)	BD (g cm^{-3})	SOC (g C kg^{-1})	TN (g N kg^{-1})	C/N	NH_4^+-N (mg N kg^{-1})	NO_3^--N (mg N kg^{-1})	DOC (mg C kg^{-1})
Control	8.09 ± 0.02a	1.47 ± 0.03a	7.75 ± 0.29b	0.78 ± 0.04a	9.92 ± 0.87a	1.70 ± 0.44b	10.55 ± 0.23a	40.09 ± 2.25a
Biochar	8.17 ± 0.05a	1.41 ± 0.02b	9.36 ± 0.39a	0.83 ± 0.06a	11.34 ± 0.72a	2.66 ± 0.54a	9.40 ± 0.14b	39.19 ± 2.19a

BD: bulk density, SOC: soil organic carbon, TN: total nitrogen, DOC: dissolved organic carbon. Values followed by different letters within the same column indicate significant differences at $P < 0.05$.

Table 2. Distribution of fertilizer N in the cropped maize under control (Control) and biochar (Biochar) treatment.

	Treatment	Grain	Straw	Aboveground	Belowground	Total
Yield	Control	10,479 ± 118a	9740 ± 408a	20,219 ± 433a	1537 ± 89a	21,756 ± 462a
(kg ha^{-1})	Biochar	10,583 ± 64a	9508 ± 242a	20,091 ± 306a	1499 ± 82a	21,590 ± 224a
N uptake	Control	154.59 ± 4.76a	89.56 ± 2.18a	244.14 ± 6.93a	14.07 ± 1.40a	258.21 ± 7.41a
(kg N ha^{-1})	Biochar	153.34 ± 2.41a	74.30 ± 3.82b	227.64 ± 1.43a	14.81 ± 0.65a	242.44 ± 1.99a
Fertilizer N uptake	Control	34.54 ± 2.01a	17.88 ± 0.59a	52.42 ± 2.43a	2.99 ± 0.31a	55.41 ± 2.39a
(kg N ha^{-1})	Biochar	36.14 ± 1.09a	15.12 ± 0.87b	51.26 ± 0.49a	3.02 ± 0.16a	54.28 ± 0.54a
Fertilizer N recovery efficiency	Control	17.27 ± 1.00a	8.94 ± 0.29a	26.21 ± 1.21a	1.50 ± 0.16a	27.70 ± 1.19a
(%)	Biochar	18.07 ± 0.54a	7.56 ± 0.44b	25.63 ± 0.25a	1.51 ± 0.08a	27.14 ± 0.27a

Values followed by different letters within the same column indicate significant differences at $P < 0.05$.

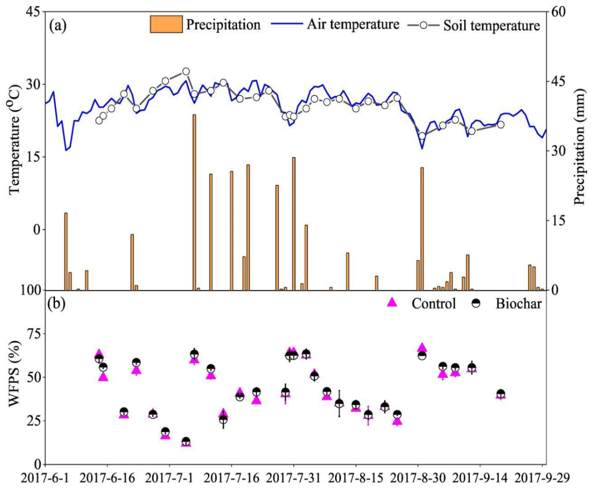

Fig. 1. Variations in (a) air temperature, soil temperature and precipitation, and (b) soil water-filled pore space (WFPS) values during the maize growing season.

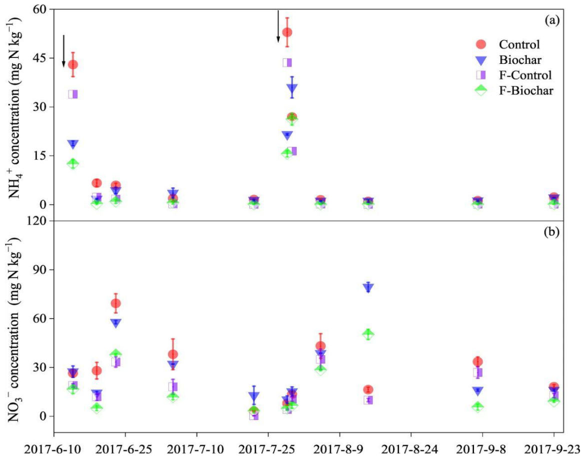

Fig. 2. Dynamic variations in the concentration of total soil NH_4^+-N and NO_3^--N (Control and Biochar) and NH_4^+-N and NO_3^--N derived from applied ^{15}N-urea (F-Control and F-Biochar) during the maize growing season. Vertical bars denote the standard errors of the mean (n = 3).

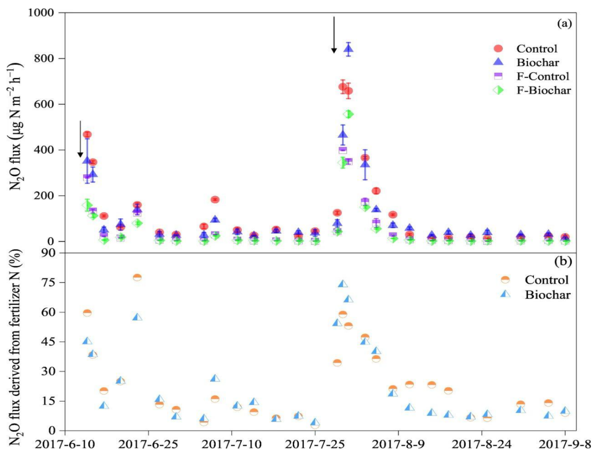

Fig. 3. Dynamic variations in the fluxes of total N_2O (Control and Biochar) and N_2O derived from applied ^{15}N-urea (F-Control and F-Biochar) during

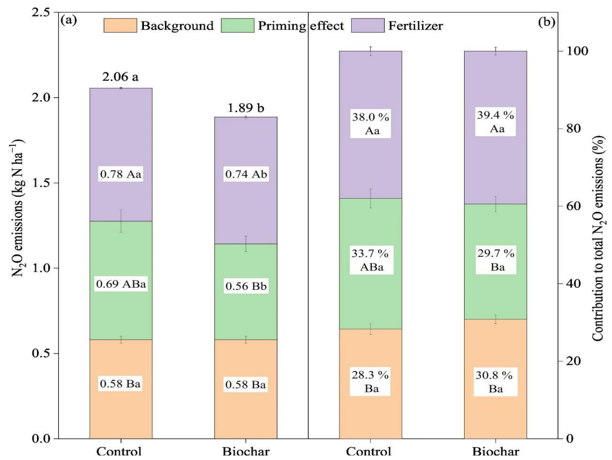

Fig. 4. Cumulative N_2O emissions and the contribution of soil background N_2O emissions, N_2O emissions derived from applied fertilizer N, and N_2O emissions resulting from the decomposition of organic N induced by the priming effect of applied fertilizer to total N_2O emissions under Control and Biochar treatment. .

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