Additional file for:

Fungi outcompete bacteria for straw and soil organic matter mineralization

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Table S1 Effects of incubation, fertilization, straw and nitrogen addition on soil carbon and microbial characteristics.

Items	Carbon turnover			Enzyme activities			PLFA		Abundance		Richness		Shannon diversity		Community composition	
	SOC-M	Straw-M	PE	BG	CBH	NAG	Bacteria	Fungi	Bacteria	Fungi	Bacteria	Fungi	Bacteria	Fungi	Bacteria	Fungi
T	61.9**	181**	519**	13.2**	1.70	14.8**	8.61**	3.26	19.0**	86.5**	57.4**	1.94	43.7**	1.11	56.2**	2.23
F	3.66*	21.0**	18.1**	3.67*	6.83*	8.40**	30.4**	17.2**	5.90*	0.01	1.72	0.05	3.62	0.34	12.4**	10.2**
SN	55.5**	303**	182**	46.4**	4.87*	22.2**	138**	167**	40.5**	60.5**	12.2**	107**	22.6**	76.6**	29.0**	19.4**
T×F	2.15	5.78*	6.73*	1.55	0.32	0.08	3.32	4.73*	4.91*	4.26*	3.03	0.73	2.92	0.03	2.66	1.08
T×SN	16.5**	86.3**	166**	12.0**	18.2**	20.9**	9.71**	0.16	4.14*	1.28	7.78**	2.97	8.92**	0.63	11.9**	0.16
F×SN	1.48	6.22*	4.48*	0.11	1.70	0.20	0.93	0.01	0.27	3.26	0.69	0.06	0.59	<0.01	0.41	0.81
T×F×SN	0.41	1.78	0.53	1.50	0.34	0.27	0.15	1.41	0.16	0.01	1.46	0.11	1.58	0.09	3.17	0.26

T: effect of incubation time; F: effect of fertilization levels; SN: effect of straw coupled with levels of added nitrogen; T × F: interaction effects of incubation time and fertilization levels; T × SN: interaction effects of incubation time and straw coupled with nitrogen level additions; F × SN: interaction effects of fertilization levels and straw coupled with levels of added nitrogen; T × F× SN: interaction effects of incubation time, fertilization levels, and straw coupled with levels of added nitrogen. PLFA, phospholipid fatty acids; SOC-M, soil organic carbon mineralization; Straw-M, straw mineralization; PE, priming effects; BG, β-D-glucosidase; CBH, cellobiohyrolase; NAG, β-N-acetylglucosaminidase. Data represent the value of F, and the "*" represent significant effects (* p <0.05, ** p < 0.01).

Table S2 Effects of incubation, fertilization, straw and nitrogen addition on bacterial community compositions.

Items	Acidobacteria	Actinobacteria	Armatimoadetes	Bacteroidetes	Chlamydiae	Chloroflexi	Cyanobacteria	Firmicutes	Gemmatimonadetes	Nitrospirae	Planctomycetes	Proteobacteria	Verrucomicrobia
T	11.4**	20.5**	52.9**	20.8**	42.4**	33.4**	127**	27.1**	44.1**	45.2**	30.6**	55.3**	49.4**
F	2.98	2.15	11.5**	0.02	<0.01	3.72	11.6**	5.07*	15.9**	5.75*	0.81	0.52	3.30
SN	38.7**	8.51**	11.7**	2.93	6.62*	37.1**	0.04	19.8**	48.4**	34.7**	27.6**	6.05*	38.5**
T×F	3.59	2.64	0.01	0.42	11.0**	5.91*	0.27	2.22	10.9**	7.56**	1.66	1.99	5.19*
T×SN	8.35**	5.75*	12.1**	1.67	0.21	10.1**	19.8**	5.77*	19.6**	20.9**	5.62*	5.01	8.48**
F×SN	0.57	0.15	0.38	0.01	0.13	0.99	0.03	0.14	0.29	0.01	0.66	0.02	0.66
T×F×SN	0.92	6.85*	1.15	0.69	4.35*	4.73*	6.37*	0.69	4.62*	5.82*	1.59	3.70	4.23*

T: effect of incubation time; F: effect of fertilization levels; SN: effect of straw coupled with levels of added nitrogen; T × F: interaction effects of incubation time and fertilization levels; T × SN: interaction effects of incubation time and straw coupled with nitrogen level additions; F × SN: interaction effects of fertilization levels and straw coupled with levels of added nitrogen; T × F× SN: interaction effects of incubation time, fertilization levels, and straw coupled with levels of added nitrogen. PLFA, phospholipid fatty acids; SOC-M, soil organic carbon mineralization; Straw-M, straw mineralization; PE, priming effects; BG, β-D-glucosidase; CBH, cellobiohyrolase; NAG, β-N-acetylglucosaminidase. Data represent the value of F, and the "*" represent significant effects (* p <0.05, ** p < 0.01).

Table S3 Effects of incubation, fertilization, straw and nitrogen addition on fungal community compositions.

Items	Asco-mycota	Basidio-mycota	Blastocladio-mycota	Chytridio-mycota	Crypto-mycota	Mucoro-mycota	Zoopago-mycota
T	3.91	1.02	0.92	11.5**	2.77	1.88	6.73*
F	3.48	0.46	7.49**	0.70	12.2**	2.63	4.40*
SN	15.8**	10.5**	25.5**	17.0**	6.07*	30.8**	11.6**
T×F	2.97	0.07	0.89	0.02	4.15*	1.15	9.18**
T×SN	0.18	<0.01	3.51	4.43*	1.98	0.09	14.6**
F×SN	<0.01	1.36	7.99**	4.16*	9.10**	0.40	7.73**
T×F×SN	0.29	0.99	0.76	1.30	2.96	0.27	22.5**

T: effect of incubation time; F: effect of fertilization levels; SN: effect of straw coupled with levels of added nitrogen; T × F: interaction effects of incubation time and fertilization levels; T × SN: interaction effects of incubation time and straw coupled with nitrogen level additions; F × SN: interaction effects of fertilization levels and straw coupled with levels of added nitrogen; T × F× SN: interaction effects of incubation time, fertilization levels, and straw coupled with levels of added nitrogen. PLFA, phospholipid fatty acids; SOC-M, soil organic carbon mineralization; Straw-M, straw mineralization; PE, priming effects; BG, β-D-glucosidase; CBH, cellobiohyrolase; NAG, β-N-acetylglucosaminidase. Data represent the value of F, and the "*" represent significant effects (* p <0.05, ** p < 0.01).

Table S4 Degree number for each bacterial and fungal taxa in the three feature modules of the integrated networks.

Degree number for each bacterial and fungal taxa in the three features modules of the integrated networks for soils without fertilization (Control), mineral fertilizers only (NPK), and mineral fertilizers plus maize and soybean straws (NPK+Straw).

		Control			NPK			NPK+Straw		
		M1	M2	M3	M1	M2	M3	M1	M2	M3
Bacteria	Acidobacteria	545	12	47	443	1	18	180	0	27
	Actinobacteria	**9772**	136	167	**8987**	28	31	**9656**	34	104
	Bacteroidetes	61	23	35	23	1	1	90	7	3
	Chloroflexi	70	3	51	119	0	1	84	2	11
	Firmicutes	**2177**	16	0	**2747**	0	0	**2626**	0	0
	Gemmatimonadetes	314	17	50	355	16	4	327	14	40
	Nitrospirae	34	5	0	116	0	0	60	0	0
	Planctomycetes	29	36	25	58	0	0	30	5	7
	Proteobacteria	**3111**	727	213	**4921**	4	53	**4695**	49	91
	Verrucomicrobia	50	38	27	11	6	0	33	0	10
Fungi	Ascomycota	**761**	**411**	**168**	**504**	**359**	**383**	**391**	**624**	**298**
	Basidiomycota	**208**	**319**	30	**218**	**236**	**122**	**142**	**187**	**237**
	Blastocladiomycota	0	26	0	43	0	0	0	0	30
	Mucoromycota	93	**245**	**139**	**220**	88	**184**	**140**	**312**	95
	Zoopagomycota	0	34	5	0	0	26	0	0	1

M1: module 1; M2: module 2; M3: module 3.

Bold fonts suggest the values that more than 2000 and 100 for bacteria and fungi, respectively;

Table S5 Integrated network properties of the bacteria in each treatment.

The integrated networks properties of bacteria in each soil without fertilization (Control), mineral fertilizers only (NPK), and mineral fertilizers plus maize and soybean straws (NPK+Straw). Only the 10000 main edges were included in the integrated network.

Bacteria	Nodes	Positive edges	Negative edges	Average betweenness
Control	880	9266 (92.7%)	734 (7.3%)	939.5
S0+N0	1404	7541 (75.4%)	2459 (24.6%)	2257.5
S+N0	1325	6892 (68.9%)	3108 (31.1%)	2133.1
S+N1	1107	8162 (81.6%)	1838 (18.4%)	1379.3
S+N2	1158	6927 (69.3%)	3073 (30.7%)	1994.6
NPK	485	9715 (97.2%)	285 (2.85%)	290.9
S0+N0	1139	9081 (90.8%)	919 (9.2%)	1754.8
S+N0	1133	8228 (82.3%)	1772 (17.7%)	1706.4
S+N1	976	8254 (82.5%)	1746 (17.5%)	373.5
S+N2	989	8525 (85.3%)	1475 (14.7%)	457.3
NPK+Straw	641	9354 (93.5%)	646 (6.5%)	650.9
S0+N0	1336	8546 (85.5%)	1454 (14.5%)	2261.9
S+N0	1158	8175 (81.8%)	1825 (18.2%)	2073.4
S+N1	1087	7974 (79.7%)	2026 (20.3%)	768.4
S+N2	1180	7183 (61.8%)	2817 (28.2%)	1913.1

Table S6 Integrated network properties of the fungi in each treatment.

The integrated networks properties of fungal in each soil without fertilization (Control), mineral fertilizers only (NPK), and mineral fertilizers plus maize and soybean straws (NPK+Straw). Only the 10000 main edges were included in the integrated network.

Fungi	Nodes	Positive edges	Negative edges	Average betweenness
Control	119	703 (54.1%)	597 (45.9%)	64.5
S0+N0	105	118 (59.0%)	82 (41.0%)	148.7
S+N0	80	124 (62.0%)	76 (38.0%)	91.4
S+N1	92	155 (77.5%)	45 (22.5%)	58.7
S+N2	92	102 (51.0%)	98 (49.0%)	42.6
NPK	113	716 (55.1%)	584 (44.9%)	54.0
S0+N0	88	99 (49.5%)	101 (50.5%)	97.6
S+N0	85	127 (63.5%)	73 (36.5%)	90.4
S+N1	91	123 (61.5%)	77 (38.5%)	138.9
S+N2	75	118 (59.0%)	82 (41%)	74.4
NPK+Straw	121	697 (53.6%)	603 (46.4%)	63.5
S0+N0	93	117 (58.5%)	83 (41.5%)	96.6
S+N0	81	151 (75.5%)	49 (24.5%)	95.7
S+N1	90	136 (68.0%)	64 (32.0%)	91.1
S+N2	75	142 (71.0%)	58 (29.0%)	79.6

Table S7 Relationships between soil organic carbon mineralization, straw decomposition, priming effects, soil properties and soil microbial characteristics.

Index	SOC-M	Straw-M	PE
BG	-0.19*	0.11	0.59***
CBH	-0.39***	-0.07	0.31***
NAG	-0.33***	-0.01	0.51***
MBC	0.67***	0.87***	-0.37***
MBN	0.16	0.37***	0.08
DOC	0.63***	0.66***	0.01
DON	0.13	0.47***	0.01
NH_4^+	0.47***	0.47***	-0.08
NO_3^-	-0.07	0.08	0.79***
Total PLFAs	0.28**	0.63***	0.31***
Bacterial PLFAs	0.39***	0.77***	0.14
Fungal PLFAs	0.49***	0.70***	0.23*
16S rRNA gene copies	0.06	0.37***	0.40***
18S rRNA gene copies	-0.20*	0.10	0.76***
Bacterial richness	-0.71***	-0.59***	0.40***
Fungal richness	-0.13	-0.36***	-0.44***
Bacterial Shannon index	-0.75***	-0.61***	0.36***
Fungal Shannon index	-0.37***	-0.42***	-0.28**
Bacterial NMDS1	0.78***	0.66***	-0.37***
Bacterial NMDS2	-0.08	0.14	0.22*
Fungal NMDS1	0.11	-0.04	-0.02
Fungal NMDS2	0.27**	0.46***	0.26*

MBC, microbial biomass carbon; MBN, microbial biomass nitrogen; DOC, dissolved organic carbon; DON, dissolved organic nitrogen; NH_4^+, ammonium nitrogen; NO_3^-, nitrate nitrogen; BG, β-D-glucosidase; CBH, cellobiohyrolase; NAG, β-N-acetylglucosaminidase; PE, priming effects; Straw-M, straw mineralization; SOC-M, soil organic carbon mineralization. Significant correlations are indicated by $p < 0.05$ (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

Table S8 Effects of environmental factors on soil organic carbon mineralization using a structural equation model (SEM).

	Effects	Observed outcomes (λ)					
		SF	SN	PLFAs	EA	SP	CP
SOC mineralization	Direct	-0.34	-0.13	0.19	-0.13	**0.50**	**0.52**
	Indirect	0.22	**0.43**	0	**-0.50**	0.07	0
	Total	-0.12	0.30	0.19	**-0.63**	**0.57**	**0.52**

SOC, soil organic carbon; FM, fertilization methods; SN, straw couple with N level addition; PLFAs, including total, bacterial, and fungal PLFAs; EA, Enzyme activities (BG, β-D-glucosidase; CBH, cellobiohyrolase; NAG, β-N-acetylglucosaminidase); SP, Soil property (MBC, microbial biomass carbon; MBN, microbial biomass nitrogen; DOC, dissolved organic carbon; DON, dissolved organic nitrogen; NH_4^+, ammonium nitrogen; NO_3^-, nitrate nitrogen); CP, Community compositions (including bacteria and fungi with NMDS1 and NMDS2).

Table S9 Basic physicochemical properties of the tested soils before our incubation experiment.

Types	pH	SOC (g/kg)	TN (g/kg)	TP (g/kg)	TK (g/kg)	DOC (mg/kg)	AN (mg/kg)	AP (mg/kg)	AK (mg/kg)	Ca (g/kg)	Mg (g/kg)
Control	7.04	23.20c	1.91	0.80b	1.17	8.28	121.90c	9.50c	84.69c	5.24	0.86
NPK	7.17	24.22b	2.05	1.12a	1.00	8.72	133.50b	22.4b	261.26a	5.47	0.80
NPK+Straw	7.18	26.09a	2.13	1.10a	0.94	9.20	157.30a	27.2a	172.02b	5.83	0.91

SOC, soil organic carbon; TN, total nitrogen; TP, total phosphorus; TK, total potassium; DOC, dissolved organic carbon; AN, available nitrogen; AP, available phosphorus; AK, available potassium; Ca, exchangeable calcium; Mg, magnesium. Different lowercase letters indicated significant differences under different soil types (soil without fertilization (Control), mineral fertilizers only (NPK), and mineral fertilizers plus maize and soybean straws (NPK+Straw)).

List of additional Figures

Figure S1 Soil properties for the control, inorganic fertilizer only, and inorganic and straw fertilizer. Control, soil without fertilization; NPK, mineral fertilizers only; NPK+Straw, mineral fertilizers plus maize and soybean straws. S0+N0, neither straw nor nitrogen fertilizer addition; S+N0, addition of ^{13}C-maize straw; S+N1, addition of ^{13}C-maize straw and low nitrogen; S+N2, addition of ^{13}C-maize straw and high nitrogen. MBC, microbial biomass carbon; MBN, microbial biomass nitrogen; DOC, dissolved organic carbon; DON, dissolved organic nitrogen; NH_4^+, ammonium nitrogen; NO_3^-, nitrate nitrogen. Values and bars are the mean ± standard errors (n = 3).

Figure S2 CO_2 flux measurements and priming effects from the different fertilizer treatments. Cumulative CO_2 fluxes (a), CO_2 fluxes (b), cumulative $^{13}CO_2$ fluxes (c), $^{13}CO_2$ fluxes (d), and priming effects for CO_2 emissions (e) during the 100-day incubation. Control, soil without fertilization; NPK, mineral fertilizers only; NPK+Straw, mineral fertilizers plus maize and soybean straws. S0+N0, neither straw nor nitrogen fertilizer addition; S+N0, addition of ^{13}C-maize straw; S+N1, addition of ^{13}C-maize straw and low nitrogen; S+N2, addition of ^{13}C-maize straw and high nitrogen. Values and bars are the mean ± standard errors (n = 3).

Figure S3 Changes in soil enzyme activities with straw and nitrogen addition. Change in β-D-glucosidase (BG, a), β-N-acetylglucosaminidase (NAG, b), and cellobiohyrolase (CBH, c) activities during incubation periods of 0, 1, 5, and 100 days. Control, soil without fertilization; NPK, mineral fertilizers only; NPK+Straw, mineral fertilizers plus maize and soybean straws. S0+N0, neither straw nor nitrogen fertilizer addition; S+N0, addition of ^{13}C-maize straw; S+N1, addition of ^{13}C-maize straw and low nitrogen; S+N2, addition of ^{13}C-maize straw and high nitrogen. Uppercase letters reflect significant differences among fertilization levels (Control, NPK and NPK+Straw) for the same nitrogen addition level and incubation time ($p < 0.05$); Lowercase letters represent significant differences among the straw and nitrogen additions (S0+N0, S+N0, S+N1, and S+N2) for the same fertilization level and incubation time ($p < 0.05$). Values and bars are the mean ± standard errors (n = 3).

Fig. S4 Microbial phospholipid fatty acids of bacteria and fungi in soil. Total microbial phospholipid fatty acids (PLFA) abundances (a), bacterial PLFA abundances (b), and fungal PLFA abundances (c) for soils during incubation periods of 0, 1, 5, and 100 days. Control, soil without fertilization; NPK, mineral fertilizers only; NPK+Straw, mineral fertilizers plus maize and soybean straws. S0+N0, neither straw nor nitrogen fertilizer addition; S+N0, addition of ^{13}C-maize straw; S+N1, addition of ^{13}C-maize straw and low nitrogen; S+N2, addition of ^{13}C-maize straw and high nitrogen. Uppercase letters reflect significant differences among fertilization levels (Control, NPK and NPK+Straw) for the same nitrogen addition level and incubation time ($p < 0.05$); Lowercase letters represent significant differences among the straw and nitrogen additions (S0+N0, S+N0, S+N1, and S+N2) for the same fertilization level and incubation time ($p < 0.05$). The insets show PLFAs abundance at day 0. Values and bars are the mean ± standard errors (n = 3).

Figure S5 Soil bacterial (a) and fungal (b) community compositions at the phylum level. Control, soil without fertilization; NPK, mineral fertilizers only; NPK+Straw, mineral fertilizers plus maize and soybean straws. S0+N0, neither straw nor nitrogen fertilizer addition; S+N0, addition of ^{13}C-

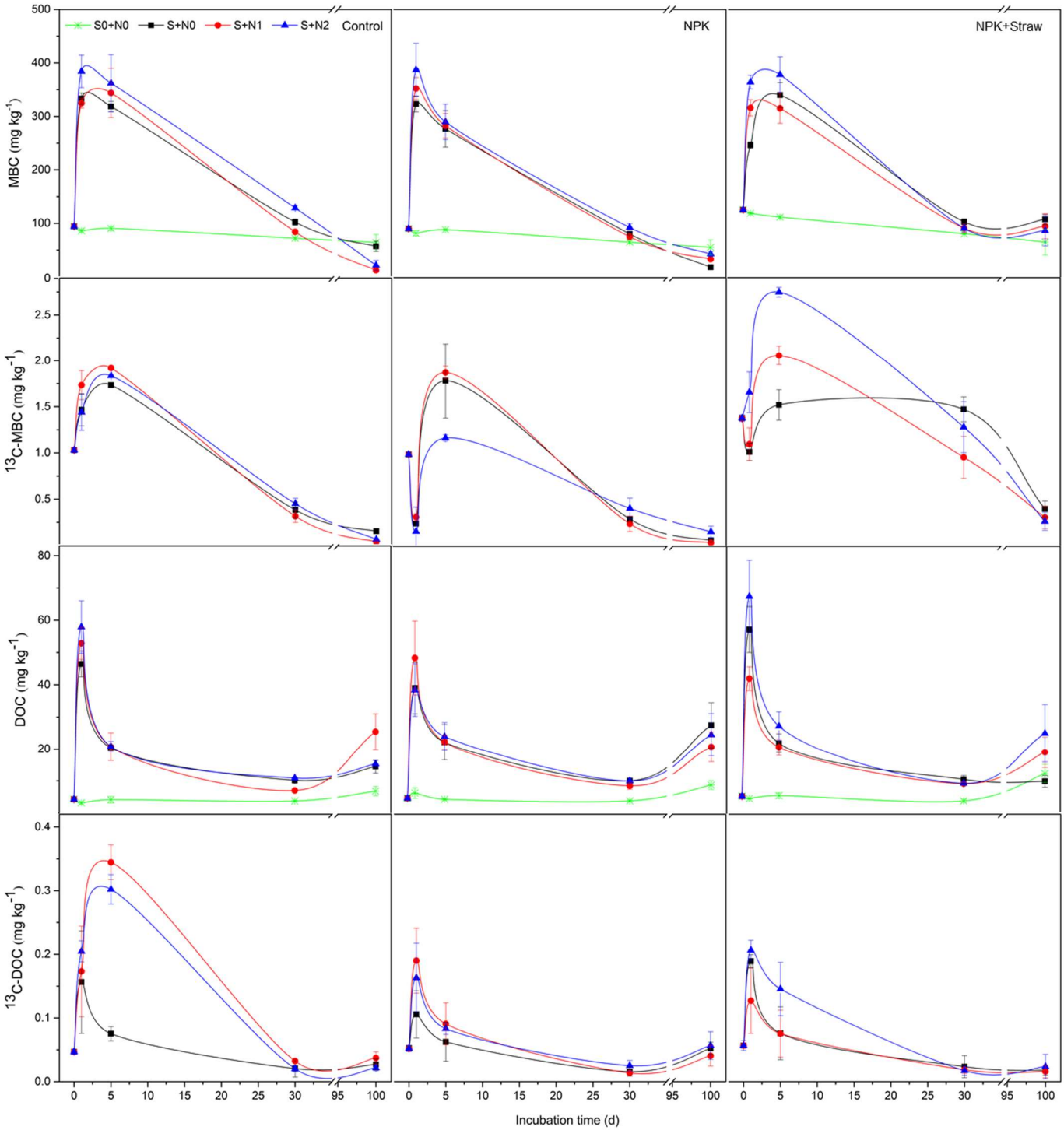
maize straw; S+N1, addition of ^{13}C-maize straw and low nitrogen; S+N2, addition of ^{13}C-maize straw and high nitrogen. Other: the sum of class occupying <0.5% of the total population.

Figure S6 Relative abundance of soil bacterial community compositions at the phylum level.
Control, soil without fertilization; NPK, mineral fertilizers only; NPK+Straw, mineral fertilizers plus maize and soybean straws. S0+N0, neither straw nor nitrogen fertilizer addition; S+N0, addition of ^{13}C-maize straw, S+N1, addition of ^{13}C-maize straw and low nitrogen; S+N2, addition of ^{13}C-maize straw and high nitrogen. Uppercase letters reflect significant differences among fertilization levels (Control, NPK and NPK+Straw) for the same nitrogen addition level and incubation time ($p < 0.05$); Lowercase letters represent significant differences among the straw and nitrogen additions (S0+N0, S+N0, S+N1, and S+N2) for the same fertilization level and incubation time ($p < 0.05$). Values and bars are the mean ± standard errors (n = 3).

Figure S7 Relative abundance of soil fungal community compositions at the phylum level.
Control, soil without fertilization; NPK, mineral fertilizers only; NPK+Straw, mineral fertilizers plus maize and soybean straws. S0+N0, neither straw nor nitrogen fertilizer addition; S+N0, addition of ^{13}C-maize straw, S+N1, addition of ^{13}C-maize straw and low nitrogen; S+N2, addition of ^{13}C-maize straw and high nitrogen. Uppercase letters reflect significant differences among fertilization levels (Control, NPK and NPK+Straw) for the same nitrogen addition level and incubation time ($p < 0.05$); Lowercase letters represent significant differences among the straw and nitrogen additions (S0+N0, S+N0, S+N1, and S+N2) for the same fertilization level and incubation time ($p < 0.05$). Values and bars are the mean ± standard errors (n = 3).

Figure S8 Relative abundance of three ecological clusters with bacterial and fungal taxa at the phylum level.
Relative abundance of the three ecological clusters (modules 1, 2, and 3) with bacterial (a, b, c) and fungal (d, e, f) taxa at phylum level for soil without fertilization (Control), mineral fertilizers only (NPK), and mineral fertilizers plus maize and soybean straws (NPK+Straw), according to the network analysis. S0+N0, neither straw nor nitrogen fertilizer addition; S+N0, addition of ^{13}C-maize straw; S+N1, addition of ^{13}C-maize straw and low nitrogen; S+N2, addition of ^{13}C-maize straw and high nitrogen.

Figure S9 Network of co-occurring analysis for bacterial and fungal abundant and rare taxa.
Network of co-occurring analysis of bacterial (top) and fungal (bottom) abundant taxa and rare taxa at amplicon sequence variant level, associated with environmental factors (MBC, MBN, DOC, DON, NH_4^+, NO_3^-, SOC mineralization, straw mineralization, and PE). A total of 10,000 and 1800 most correlations were used to construct co-occurring network for bacterial and fungi, respectively. A connection between two nodes represents strong (SparCC r > 0.3) and significant ($p < 0.05$) correlations. The size of each node for bacterial and fungal taxa based on ASVs or environmental factors is proportional to its degree with the number of connections among a node. Control, soil without fertilization; NPK, mineral fertilizers only; NPK+Straw, mineral fertilizers plus maize and soybean straws. MBC, microbial biomass carbon; MBN, microbial biomass nitrogen; DOC, dissolved organic carbon; DON, dissolved organic nitrogen; NH_4^+, ammonium nitrogen; NO_3^-, nitrate nitro gen; BG, β-D-glucosidase; CBH, cellobiohyrolase; NAG, β-N-acetylglucosaminidase; Straw-M, straw mineralization; SOC-M, soil organic carbon mineralization; PE, priming effects.


S0+N0
S+N0
S+N1
S+N2
Control
NPK
NPK+Straw
MBC (mg kg-1)
13C-MBC (mg kg-1)
DOC (mg kg-1)
13C-DOC (mg kg-1)
Incubation time (d)

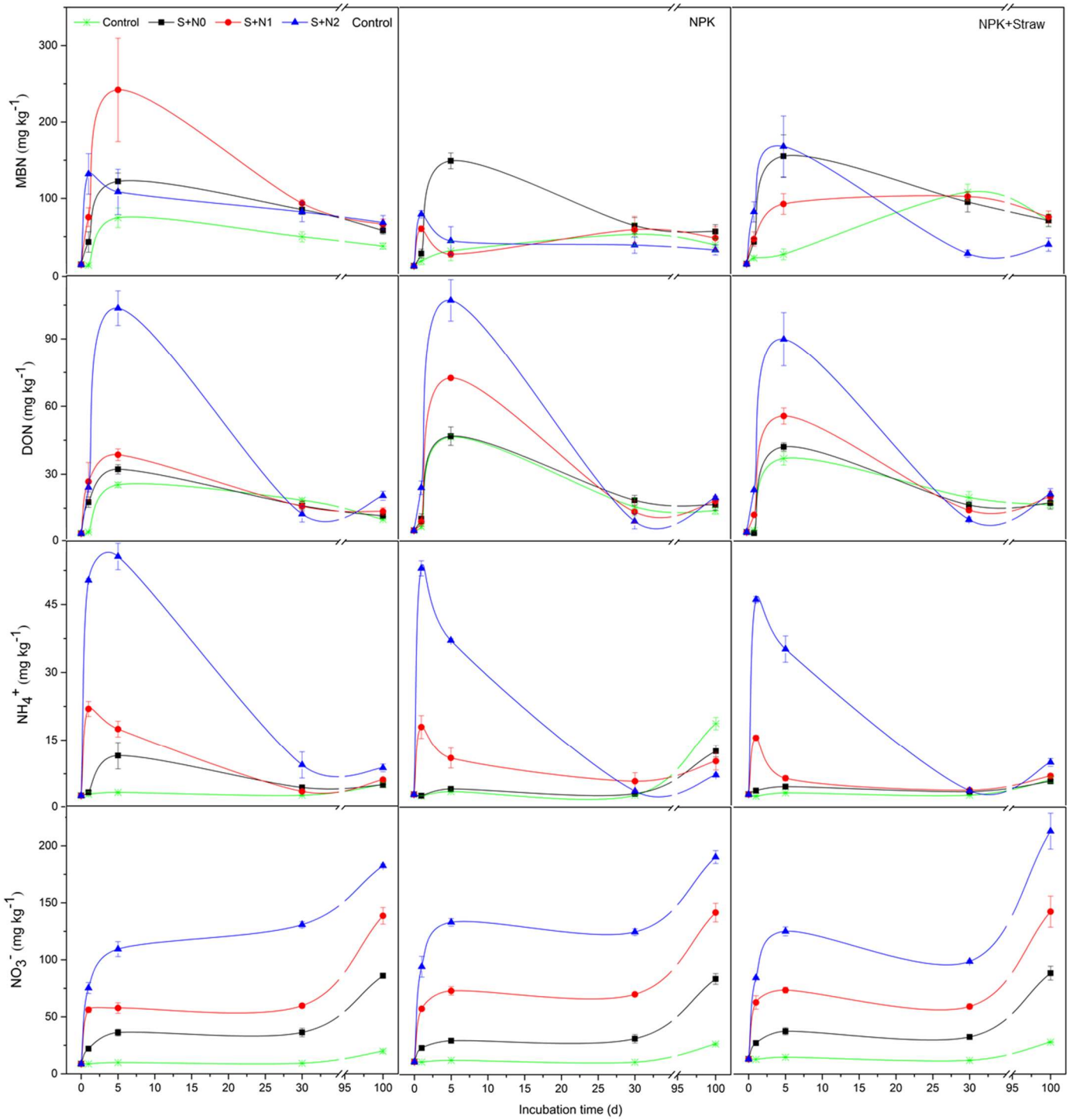


Figure S1 Soil properties for the control, inorganic fertilizer only, and inorganic and straw fertilizer. Control, soil without fertilization; NPK, mineral fertilizers only; NPK+Straw, mineral fertilizers plus maize and soybean straws. S0+N0, neither straw nor nitrogen fertilizer addition; S+N0, addition of ^{13}C-maize straw; S+N1, addition of ^{13}C-maize straw and low nitrogen; S+N2, addition of ^{13}C-maize straw and high nitrogen. MBC, microbial biomass carbon; MBN, microbial biomass nitrogen; DOC, dissolved organic carbon; DON, dissolved organic nitrogen; NH_4^+, ammonium nitrogen; NO_3^-, nitrate nitrogen. Values and bars are the mean ± standard errors (n = 3).

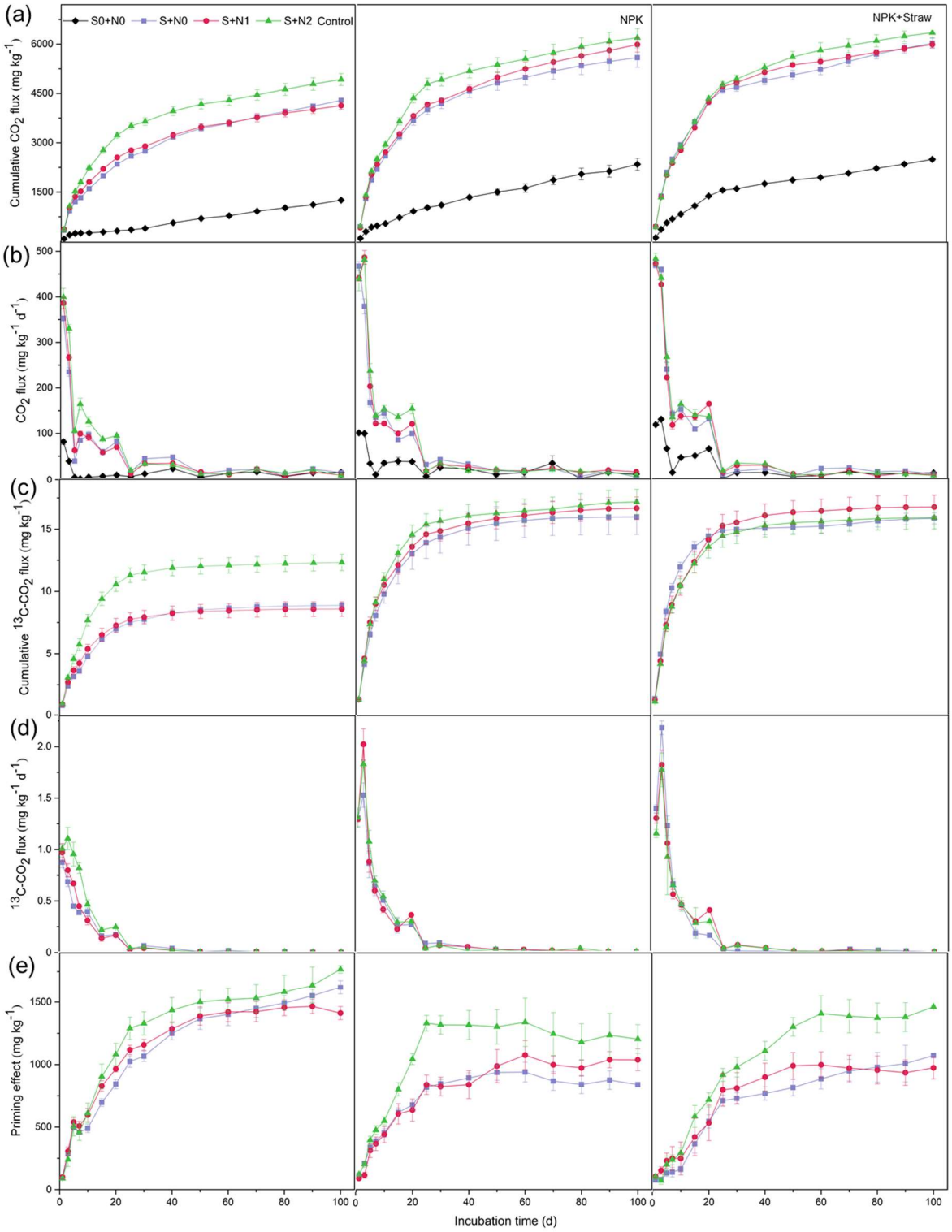


Figure S2 CO_2 flux measurements and priming effects from the different fertilizer treatments. Cumulative CO_2 fluxes (a), CO_2 fluxes (b), cumulative $^{13}CO_2$ fluxes (c), $^{13}CO_2$ fluxes (d), and priming effects for CO_2 emissions (e) during the 100-day incubation. Control, soil without fertilization; NPK, mineral fertilizers only; NPK+Straw, mineral fertilizers plus maize and soybean straws. S0+N0, neither straw nor nitrogen fertilizer addition; S+N0, addition of ^{13}C-maize straw; S+N1, addition of ^{13}C-maize straw and low nitrogen; S+N2, addition of ^{13}C-maize straw and high nitrogen. Values and bars are the mean ± standard errors (n = 3).

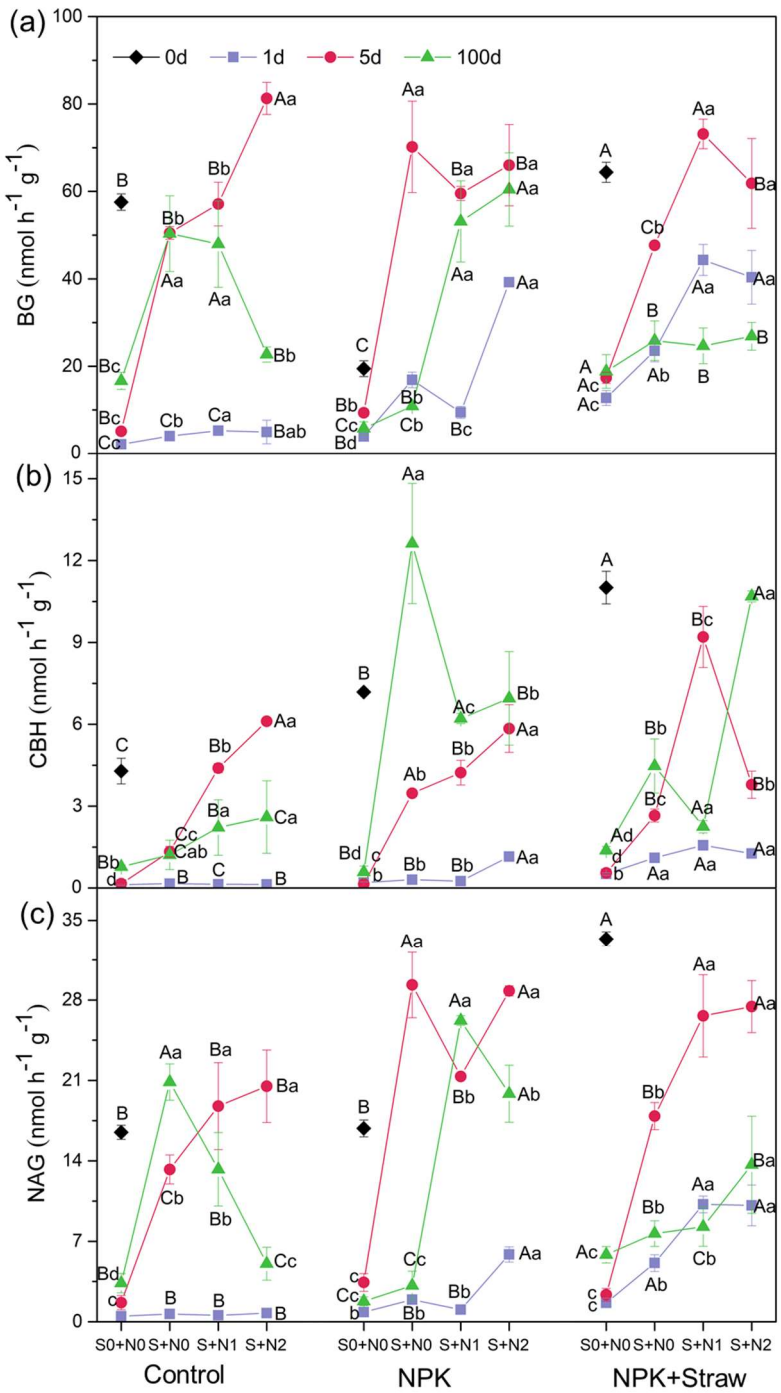


Figure S3 Changes in soil enzyme activities with straw and nitrogen addition.

Change in β-D-glucosidase (BG, a), β-N-acetylglucosaminidase (NAG, b), and cellobiohyrolase (CBH, c) activities during incubation periods of 0, 1, 5, and 100 days. Control, soil without fertilization; NPK, mineral fertilizers only; NPK+Straw, mineral fertilizers plus maize and soybean straws. S0+N0, neither straw nor nitrogen fertilizer addition; S+N0, addition of ^{13}C-maize straw; S+N1, addition of ^{13}C-maize straw and low nitrogen; S+N2, addition of ^{13}C-maize straw and high nitrogen. Uppercase letters reflect significant differences among fertilization levels (Control, NPK and NPK+Straw) for the same nitrogen addition level and incubation time ($p < 0.05$); Lowercase letters represent significant differences among the straw and nitrogen additions (S0+N0, S+N0, S+N1, and S+N2) for the same fertilization level and incubation time ($p < 0.05$). Values and bars are the mean ± standard errors (n = 3).

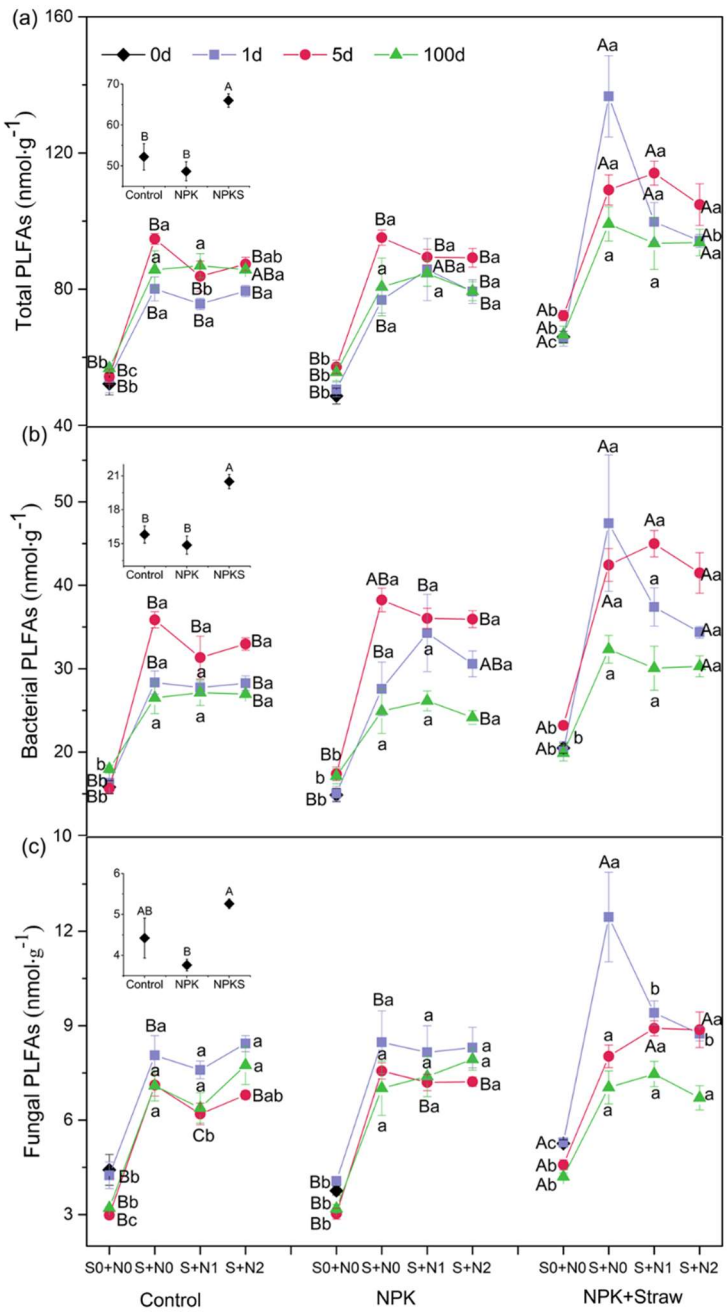


Fig. S4 Microbial phospholipid fatty acids of bacteria and fungi in soil.

Total microbial phospholipid fatty acids (PLFA) abundances (a), bacterial PLFA abundances (b), and fungal PLFA abundances (c) for soils during incubation periods of 0, 1, 5, and 100 days. Control, soil without fertilization; NPK, mineral fertilizers only; NPK+Straw, mineral fertilizers plus maize and soybean straws. S0+N0, neither straw nor nitrogen fertilizer addition; S+N0, addition of ^{13}C-maize straw; S+N1, addition of ^{13}C-maize straw and low nitrogen; S+N2, addition of ^{13}C-maize straw and high nitrogen. Uppercase letters reflect significant differences among fertilization levels (Control, NPK and NPK+Straw) for the same nitrogen addition level and incubation time ($p < 0.05$); Lowercase letters represent significant differences among the straw and nitrogen additions (S0+N0, S+N0, S+N1, and S+N2) for the same fertilization level and incubation time ($p < 0.05$). The insets show PLFAs abundance at day 0. Values and bars are the mean ± standard errors (n = 3).

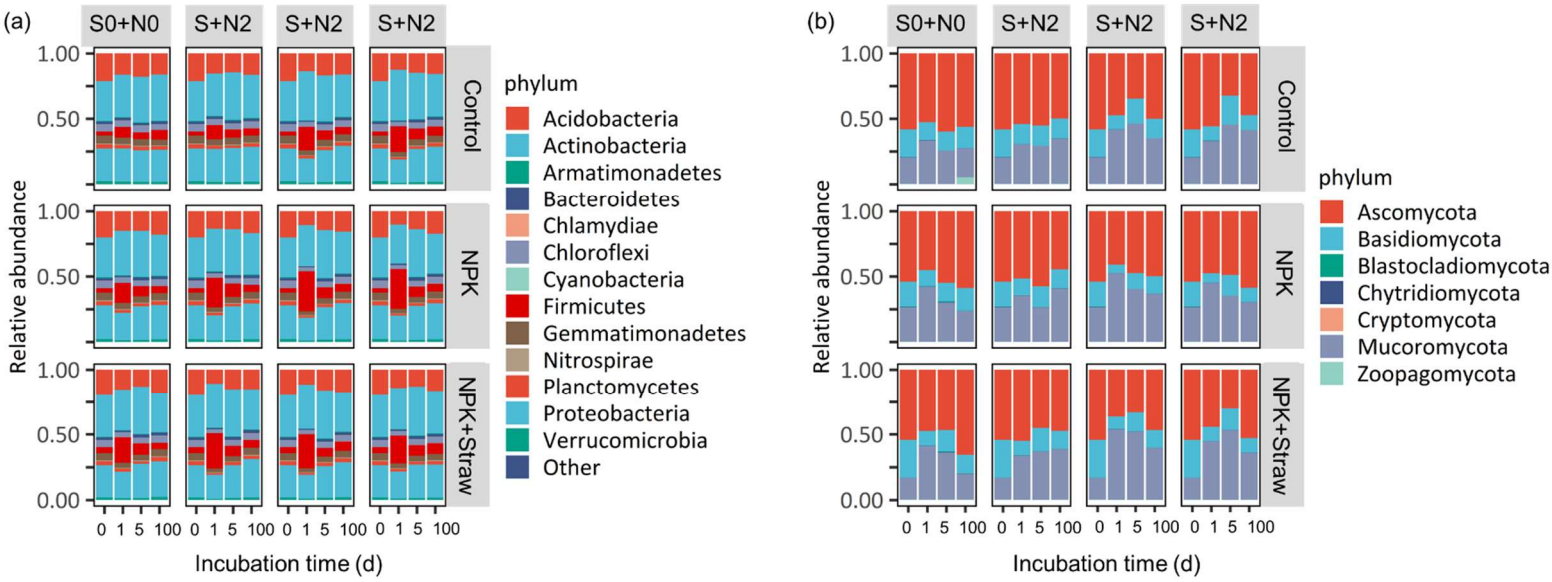
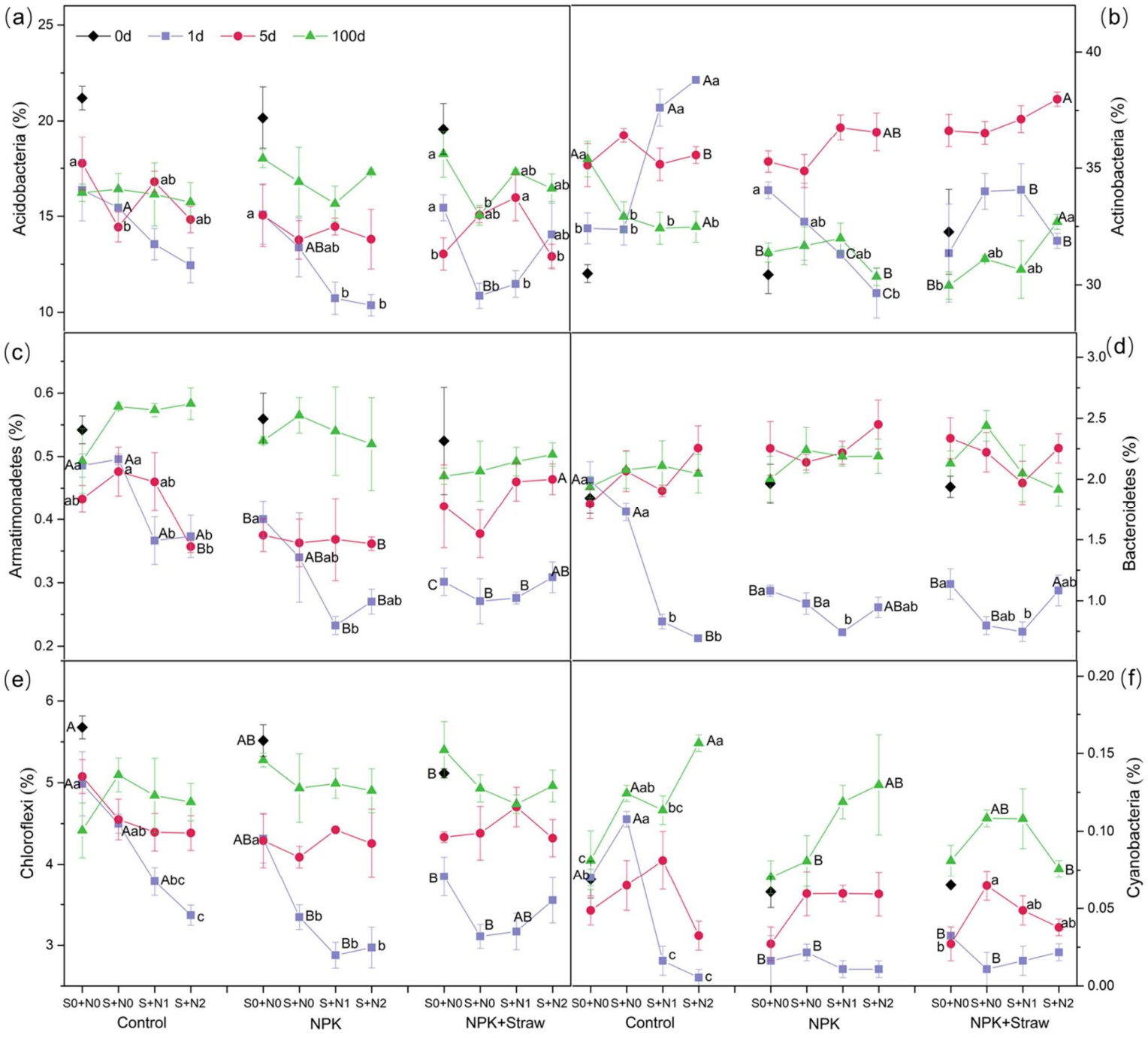


Figure S5 Soil bacterial (a) and fungal (b) community compositions at the phylum level.

Control, soil without fertilization; NPK, mineral fertilizers only; NPK+Straw, mineral fertilizers plus maize and soybean straws. S0+N0, neither straw nor nitrogen fertilizer addition; S+N0, addition of ^{13}C-maize straw; S+N1, addition of ^{13}C-maize straw and low nitrogen; S+N2, addition of ^{13}C-maize straw and high nitrogen. Other: the sum of class occupying <0.5% of the total population.


(a)
(b)
(c)
(d)
(e)
(f)
0d
1d
5d
100d
Acidobacteria (%)
Actinobacteria (%)
Armatimonadetes (%)
Bacteroidetes (%)
Chloroflexi (%)
Cyanobacteria (%)
S0+N0
S+N0
S+N1
S+N2
Control
NPK
NPK+Straw

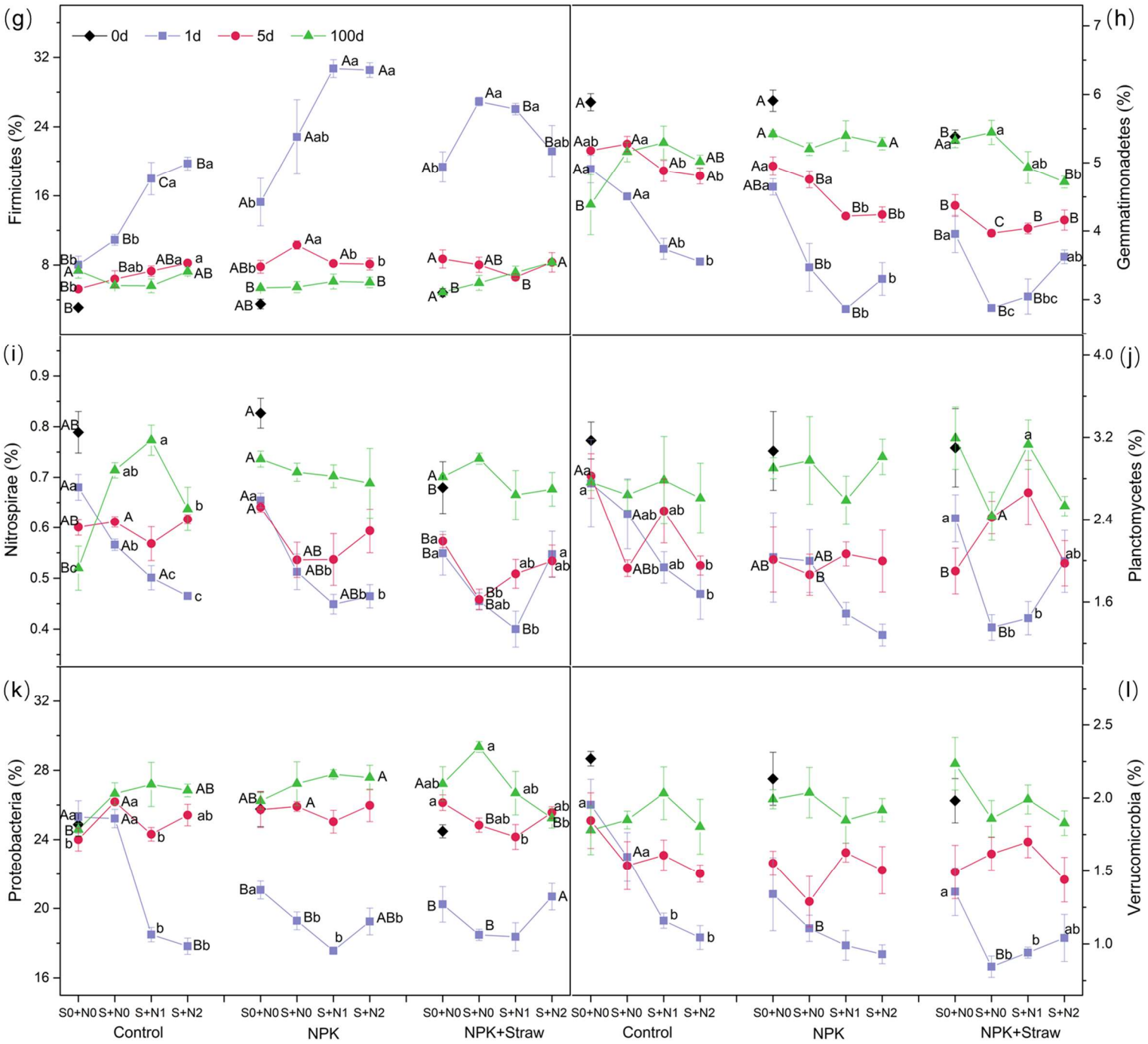


Figure S6 Relative abundance of soil bacterial community compositions at the phylum level. Control, soil without fertilization; NPK, mineral fertilizers only; NPK+Straw, mineral fertilizers plus maize and soybean straws. S0+N0, neither straw nor nitrogen fertilizer addition; S+N0, addition of ^{13}C-maize straw; S+N1, addition of ^{13}C-maize straw and low nitrogen; S+N2, addition of ^{13}C-maize straw and high nitrogen. Uppercase letters reflect significant differences among fertilization levels (Control, NPK and NPK+Straw) for the same nitrogen addition level and incubation time ($p < 0.05$); Lowercase letters represent significant differences among the straw and nitrogen additions (S0+N0, S+N0, S+N1, and S+N2) for the same fertilization level and incubation time ($p < 0.05$). Values and bars are the mean ± standard errors (n = 3).

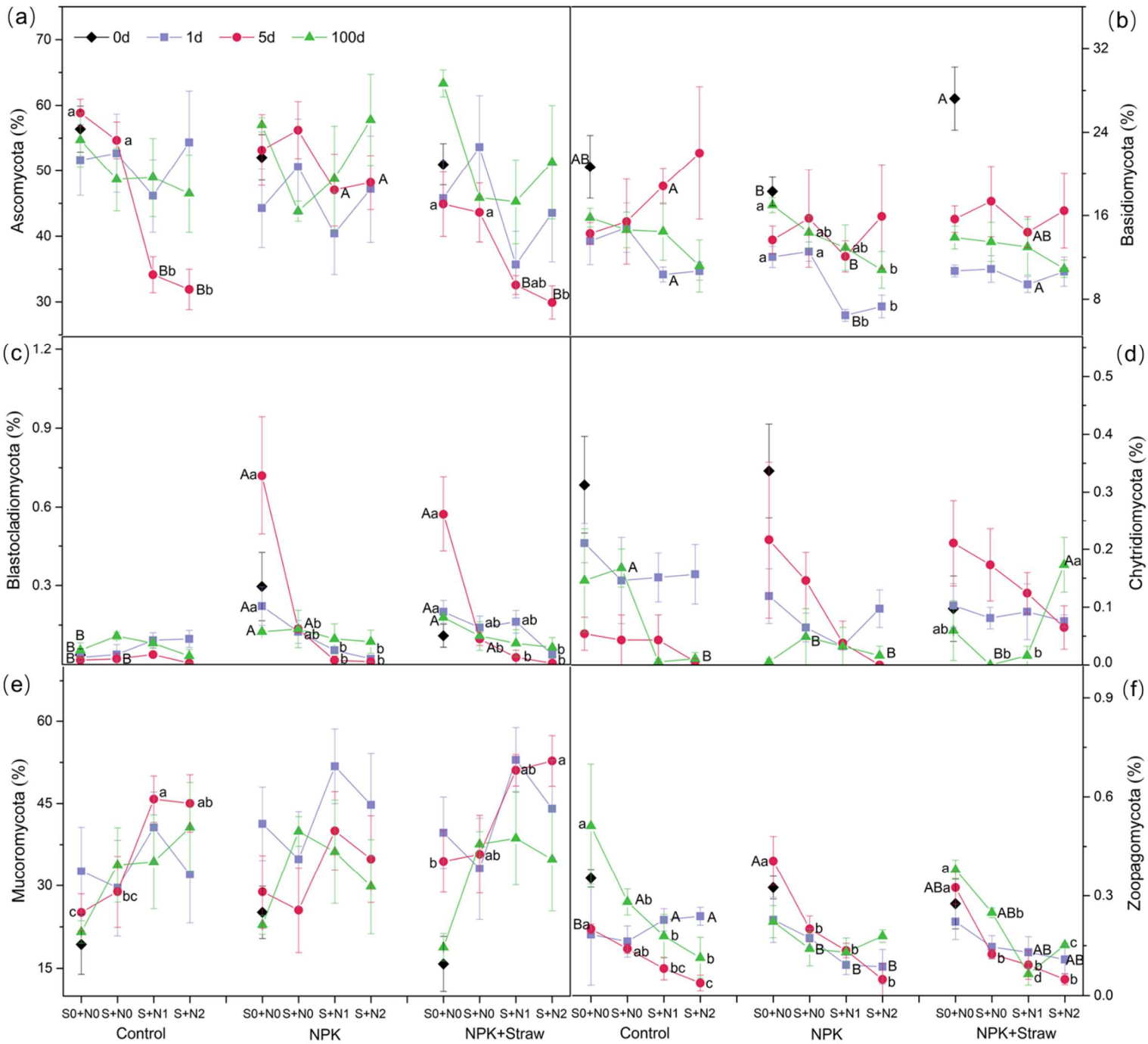


Figure S7 Relative abundance of soil fungal community compositions at the phylum level.

Control, soil without fertilization; NPK, mineral fertilizers only; NPK+Straw, mineral fertilizers plus maize and soybean straws. S0+N0, neither straw nor nitrogen fertilizer addition; S+N0, addition of ^{13}C-maize straw; S+N1, addition of ^{13}C-maize straw and low nitrogen; S+N2, addition of ^{13}C-maize straw and high nitrogen. Uppercase letters reflect significant differences among fertilization levels (Control, NPK and NPK+Straw) for the same nitrogen addition level and incubation time ($p < 0.05$); Lowercase letters represent significant differences among the straw and nitrogen additions (S0+N0, S+N0, S+N1, and S+N2) for the same fertilization level and incubation time ($p < 0.05$). Values and bars are the mean ± standard errors (n = 3).

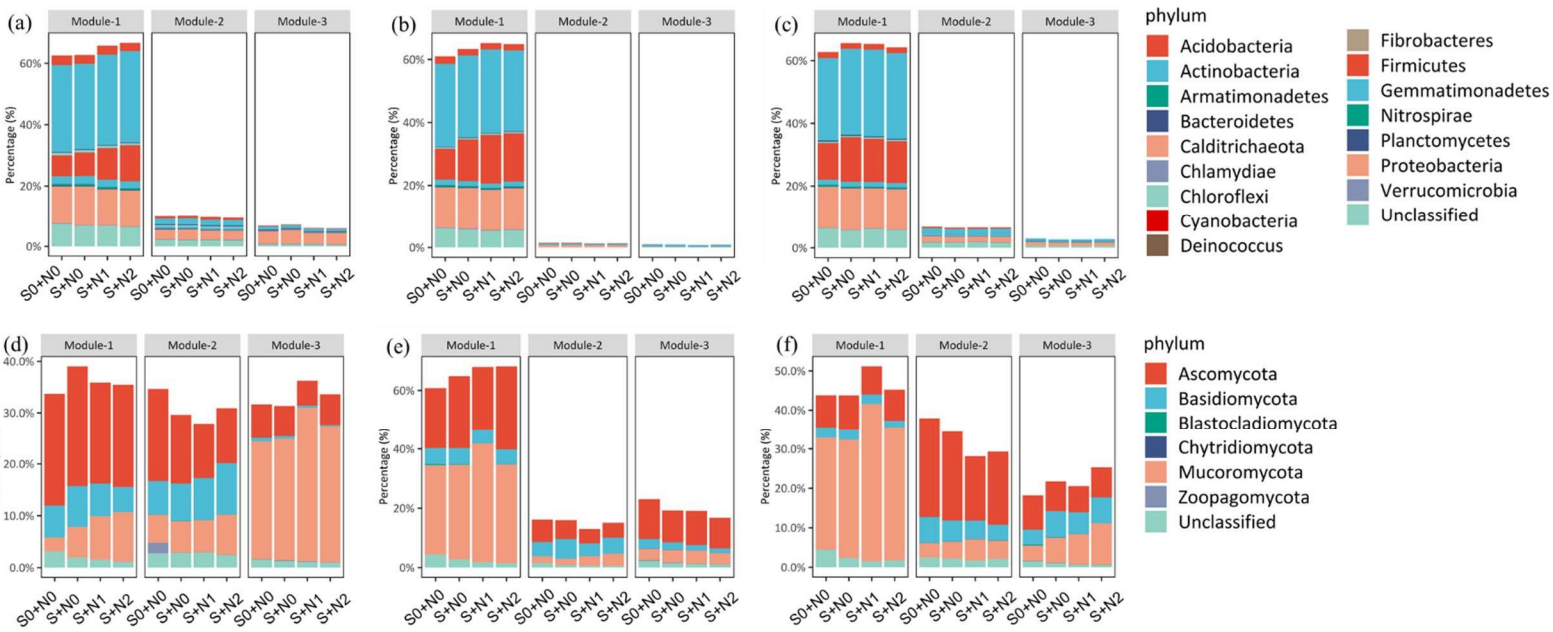


Figure S8 Relative abundance of three ecological clusters with bacterial and fungal taxa at the phylum level.

Relative abundance of the three ecological clusters (modules 1, 2, and 3) with bacterial (a, b, c) and fungal (d, e, f) taxa at phylum level for soil without fertilization (Control), mineral fertilizers only (NPK), and mineral fertilizers plus maize and soybean straws (NPK+Straw), according to the network analysis. S0+N0, neither straw nor nitrogen fertilizer addition; S+N0, addition of ^{13}C-maize straw; S+N1, addition of ^{13}C-maize straw and low nitrogen; S+N2, addition of ^{13}C-maize straw and high nitrogen.

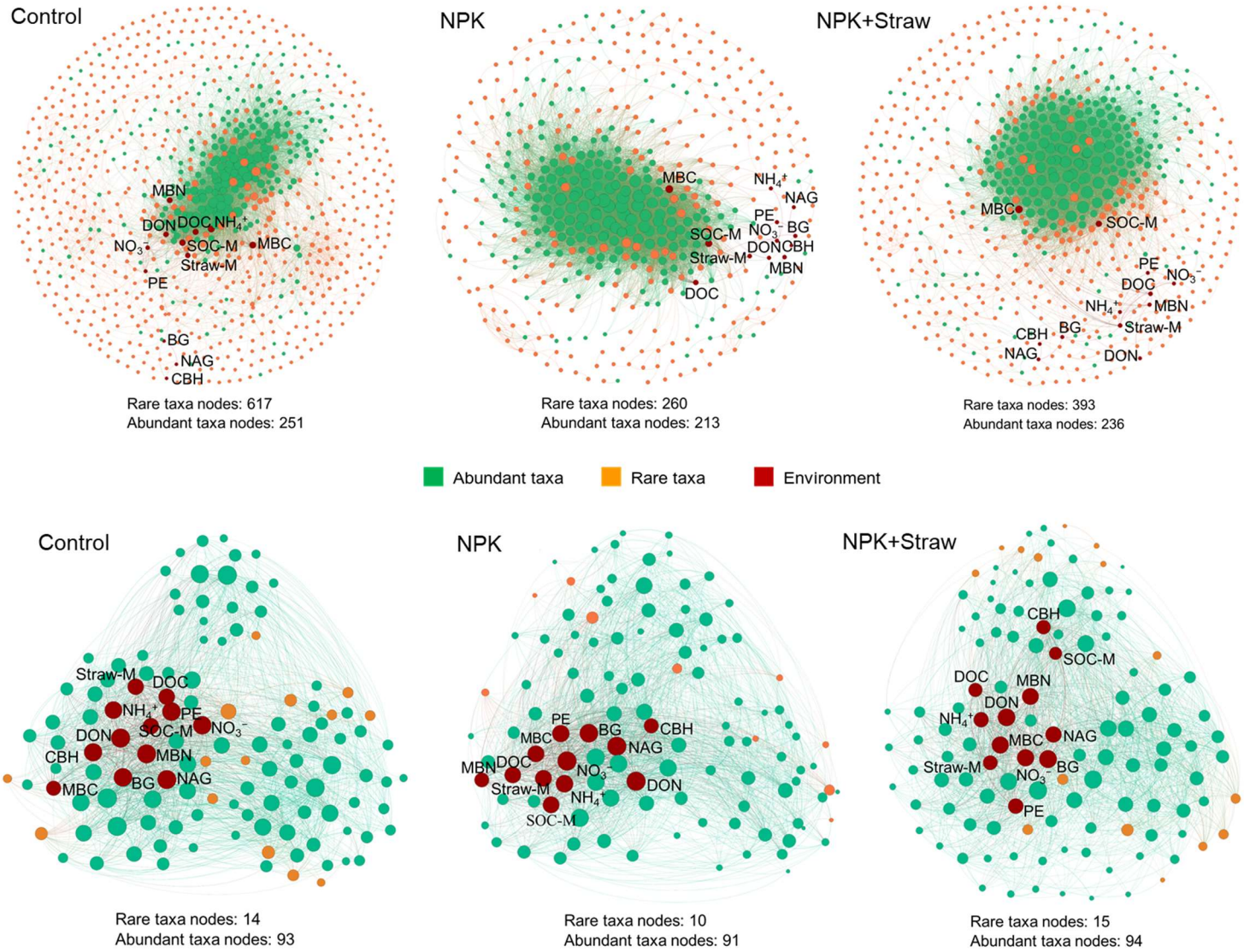


Figure S9 Network of co-occurring analysis for bacterial and fungal abundant and rare taxa. Network of co-occurring analysis of bacterial (top) and fungal (bottom) abundant taxa and rare taxa at amplicon sequence variant level, associated with environmental factors (MBC, MBN, DOC, DON, NH_4^+, NO_3^-, SOC mineralization, straw mineralization, and PE). A total of 10,000 and 1800 most correlations were used to construct co-occurring network for bacterial and fungi, respectively. A connection between two nodes represents strong (SparCC r > 0.3) and significant ($p < 0.05$) correlations. The size of each node for bacterial and fungal taxa based on ASVs or environmental factors is proportional to its degree with the number of connections among a node. Control, soil without fertilization; NPK, mineral fertilizers only; NPK+Straw, mineral fertilizers plus maize and soybean straws. MBC, microbial biomass carbon; MBN, microbial biomass nitrogen; DOC, dissolved organic carbon; DON, dissolved organic nitrogen; NH_4^+, ammonium nitrogen; NO_3^-, nitrate nitro gen; BG, β-D-glucosidase; CBH, cellobiohyrolase; NAG, β-N-acetylglucosaminidase; Straw-M, straw mineralization; SOC-M, soil organic carbon mineralization; PE, priming effects.