

Supplementary tables

Trade-off between microbial carbon use efficiency and specific carbon-, nitrogen- and phosphorus-acquiring extracellular enzyme activities under reduced oxygen

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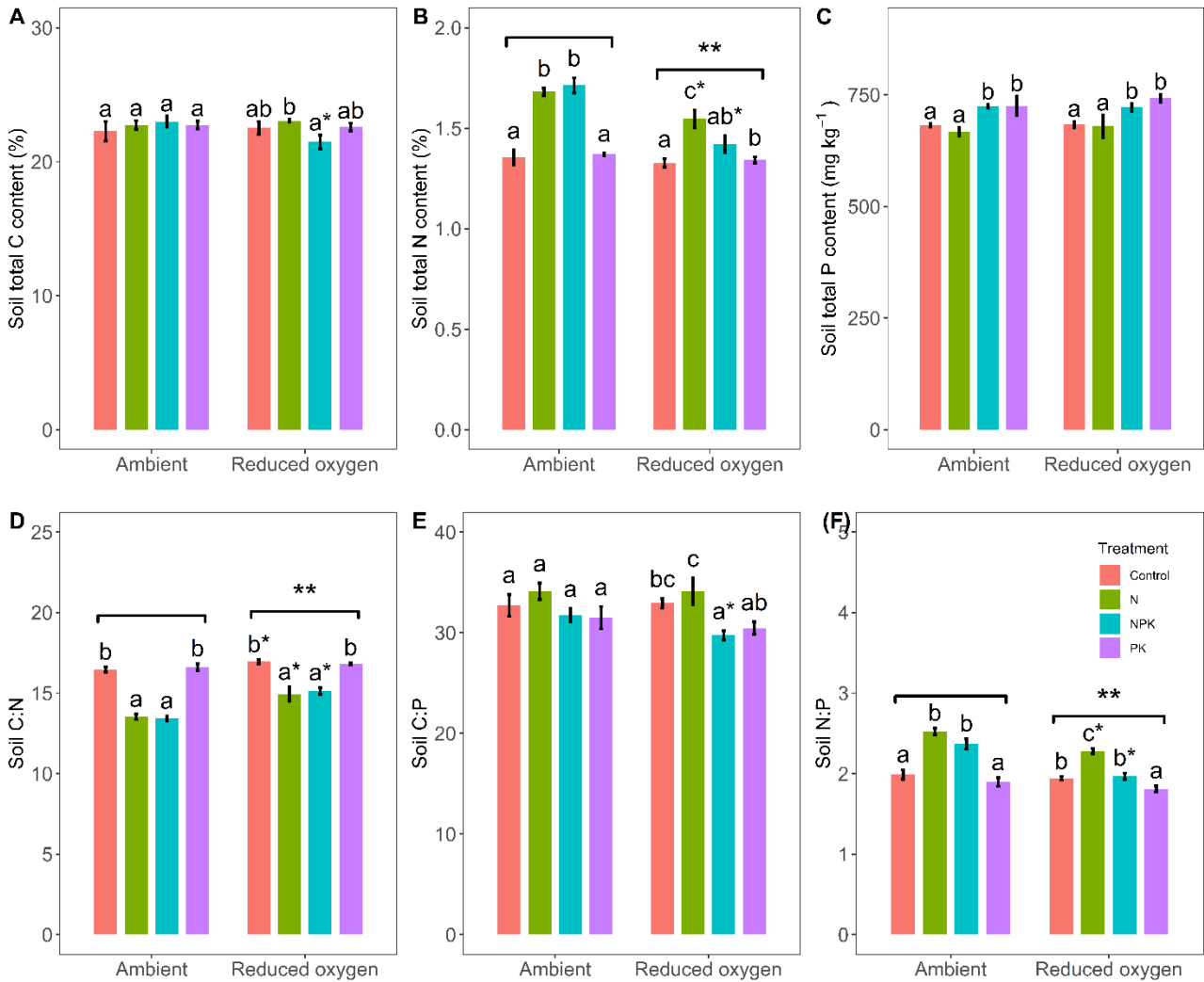


Figure S1. Effects of nutrient and oxygen treatments on (A) soil total C content, (B) soil total N content, (C) soil total P content, (D) soil C:N, (E) soil C:P, and (F) soil N:P. Double asterisks above the braces indicate significant differences ( $\alpha = 0.05$ ) between ambient and reduced oxygen treatments when different nutrient levels are considered as random factors. Single asterisks above the error bars show the significant differences between ambient and reduced oxygen treatments for each nutrient level. Different lower-case letters describe the differences between various nutrient levels for either ambient or reduced oxygen treatments. Values are mean  $\pm$  standard error for five replicates.

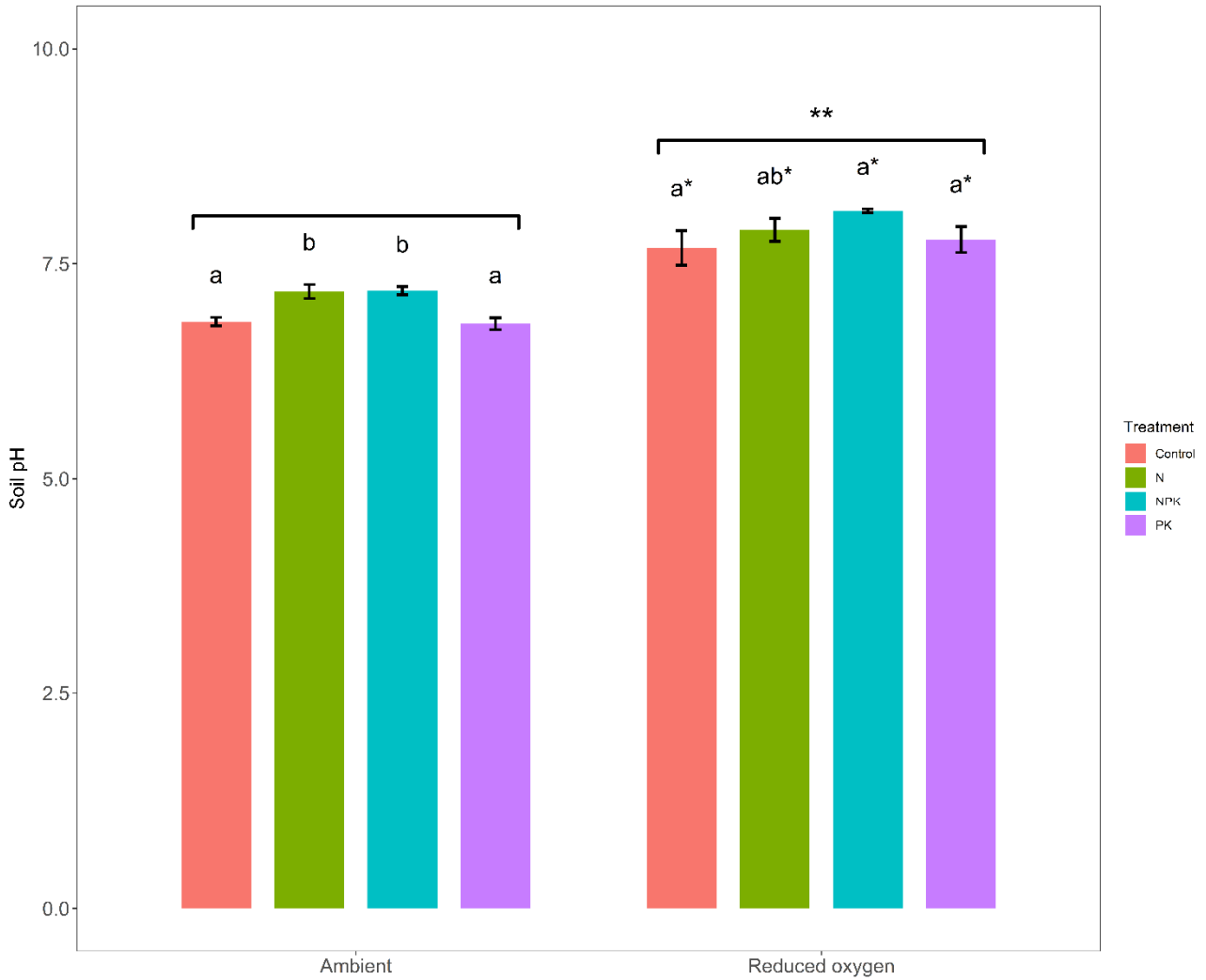


Figure S2. Effects of nutrient and oxygen treatments on soil pH. Double asterisks above the braces indicate significant differences ( $\alpha = 0.05$ ) between ambient and reduced oxygen treatments when different nutrient levels are considered as random factors. Single asterisks above the error bars show the significant differences between ambient and reduced oxygen treatments for each nutrient level. Different lower-case letters describe the differences between various nutrient levels for either ambient or reduced oxygen treatments. Values are mean  $\pm$  standard error for five replicates.

Table S1 A description of the enzymes measured in this study.

Enzyme	EC number	Abbreviation	Function	Substrate	Slurry concentration	Incubation time
Phenol oxidase	1.10.3.2	POX	C-N-targeting oxidation	L-3,4-dihydroxyphenylalanine (20 mM)	0.5 g soil + 25 mL buffer	20
Lignin peroxidase	1.11.1.7	PER	C-N-targeting oxidation	L-3,4-dihydroxyphenylalanine and H <sub>2</sub> O <sub>2</sub> (20 mM)	0.5 g soil + 25 mL buffer	1.5
$\beta$ -glucosidase	3.2.1.2.1	BG	C-targeting hydrolysis	pNP- $\beta$ -D-glucopyranoside (30 mM)	3.75 g + 5 mL buffer	2.5
$\beta$ -xylosidase	3.2.1.3.7	BX	C-targeting hydrolysis	pNP- $\beta$ -D-xylopyranoside (25 mM)	3.75 g + 5 mL buffer	7
Cellobiohydrolase	3.2.1.9.1	CBH	C-targeting hydrolysis	pNP- $\beta$ -D-cellobioside (4 mM)	3.75 g + 5 mL buffer	8
N-acetyl- $\beta$ -glucosaminidase	3.1.6.1	NAG	C-N-targeting hydrolysis	pNP- N-acetyl- $\beta$ -D-glucosaminide (5 mM)	3.75 g + 5 mL buffer	6
Acid phosphatase	3.1.3.2	AP	P-targeting hydrolysis	pNP-phosphatedisodium salt hexahydrate (30 mM)	3.75 g + 5 mL buffer	0.5

EC: Enzyme commission number. pNP, p-nitrophenyl.

Table S2 Linear mixed-effects models of reduced oxygen on soil total C, total N, total P, soil C:N, soil C:P, soil N:P, and soil pH under different oxygen and nutrient treatments.

Variable	Nutrient	Oxygen	numDF	denDF	F-value	p-value	
Soil total C	All	Intercept	1	31	20748.563	<.0001	
		Oxygen	1	31	1.050	0.313	
		Treatment	3	31	0.765	0.522	
		Oxygen:Treatment	3	31	1.840	0.160	
	Control	Intercept	1	8	2643.363	<.0001	
		Oxygen	1	8	0.064	0.807	
	+N	Intercept	1	7	14517.830	<.0001	
		Oxygen	1	7	0.679	0.437	
	+NPK	Intercept	1	8	4616.386	<.0001	
		Oxygen	1	8	5.378	0.049	
	+PK	Intercept	1	8	11526.110	<.0001	
		Oxygen	1	8	0.151	0.708	
	Soil total N	All	Intercept	1	31	19321.704	<.0001
			Oxygen	1	31	36.341	<.0001
Treatment			3	31	44.607	<.0001	
Oxygen:Treatment			3	31	9.018	<.0001	
Control		Intercept	1	8	3909.307	<.0001	
		Oxygen	1	8	0.367	0.561	
+N		Intercept	1	7	5571.874	<.0001	
		Oxygen	1	7	9.457	0.018	
+NPK		Intercept	1	8	3152.082	<.0001	
		Oxygen	1	8	27.328	0.001	
+PK		Intercept	1	8	25016.816	<.0001	
		Oxygen	1	8	2.667	0.141	
Soil total P		All	Intercept	1	31	25090.010	<.0001
			Oxygen	1	31	0.925	0.344
	Treatment		3	31	11.094	<.0001	
	Oxygen:Treatment		3	31	0.253	0.858	
	Control	Intercept	1	8	30656.880	<.0001	
		Oxygen	1	8	0.064	0.806	
	+N	Intercept	1	7	3013.926	<.0001	
		Oxygen	1	7	0.233	0.644	
	+NPK	Intercept	1	8	22663.090	<.0001	
		Oxygen	1	8	0.063	0.808	
	+PK	Intercept	1	8	3794.689	<.0001	
		Oxygen	1	8	0.506	0.497	
	Soil C:N	All	Intercept	1	31	49332.650	<.0001
			Oxygen	1	31	52.270	<.0001
Treatment			3	31	104.520	<.0001	
Oxygen:Treatment			3	31	6.520	0.002	
Control		Intercept	1	8	29362.592	<.0001	
		Oxygen	1	8	6.291	0.036	
+N		Intercept	1	7	4465.347	<.0001	
		Oxygen	1	7	11.001	0.013	
+NPK	Intercept	1	8	12269.046	<.0001		

		Oxygen	1	8	43.250	<.0001	
	+PK	Intercept	1	8	23037.629	<.0001	
		Oxygen	1	8	1.032	0.340	
Soil C:P	All	Intercept	1	31	11523.123	<.0001	
		Oxygen	1	31	1.964	0.171	
		Treatment	3	31	6.744	0.001	
		Oxygen:Treatment	3	31	0.733	0.540	
	Control	Intercept	1	8	3036.224	<.0001	
		Oxygen	1	8	0.031	0.865	
	+N	Intercept	1	7	2111.944	<.0001	
		Oxygen	1	7	0.000	0.985	
	+NPK	Intercept	1	8	5802.188	<.0001	
		Oxygen	1	8	6.241	0.037	
	+PK	Intercept	1	8	2392.480	<.0001	
		Oxygen	1	8	0.671	0.436	
	Soil N:P	All	Intercept	1	31	16463.351	<.0001
			Oxygen	1	31	40.476	<.0001
Treatment			3	31	53.578	<.0001	
Oxygen:Treatment			3	31	6.280	0.002	
Control		Intercept	1	8	3814.438	<.0001	
		Oxygen	1	8	0.491	0.503	
+N		Intercept	1	7	8073.928	<.0001	
		Oxygen	1	7	19.930	0.003	
+NPK		Intercept	1	8	3494.985	<.0001	
		Oxygen	1	8	29.633	0.001	
+PK		Intercept	1	8	3144.104	<.0001	
		Oxygen	1	8	1.685	0.230	
Soil pH		All	Intercept	1	31	37385.330	<.0001
			Oxygen	1	31	127.930	<.0001
	Treatment		3	31	6.340	0.002	
	Oxygen:Treatment		3	31	0.520	0.670	
	Control	Intercept	1	8	4989.214	<.0001	
		Oxygen	1	8	17.397	0.003	
	+N	Intercept	1	7	10275.988	<.0001	
		Oxygen	1	7	23.200	0.002	
	+NPK	Intercept	1	8	90179.551	<.0001	
		Oxygen	1	8	331.671	<.0001	
	+PK	Intercept	1	8	7868.025	<.0001	
		Oxygen	1	8	35.373	<.0001	

numDF, numerator degree of freedom. denDF, denominator degree of freedom. Linear mixed-effects models were conducted when all soil samples are pooled together or separately for each nutrient treatment. For all soil samples, reduced oxygen was considered a fixed factor, while various nutrient treatments and jar number were considered random factors. For observations under each nutrient treatment, reduced oxygen was considered a fixed factor, while jar number was considered a random factor.

Table S3 Linear mixed-effects models of reduced oxygen on microbial metabolic quotient and specific extracellular enzyme activities for C-, N- and P-acquisition.

Variable	Nutrient	Oxygen	numDF	denDF	F-value	p-value	
qCO <sub>2</sub>	All	Intercept	1	31	98.526	<.0001	
		Oxygen	1	31	25.484	<.0001	
		Treatment	3	31	6.974	0.001	
		Oxygen:Treatment	3	31	7.931	0.001	
	Control	Intercept	1	8	310.890	<.0001	
		Oxygen	1	8	0.421	0.535	
	+N	Intercept	1	7	9.869	0.016	
		Oxygen	1	7	3.809	0.092	
	+NPK	Intercept	1	8	57.210	<.0001	
		Oxygen	1	8	30.194	0.001	
	+PK	Intercept	1	8	95.723	<.0001	
		Oxygen	1	8	3.700	0.091	
	Specific hydrolytic C-acquiring EEA	All	Intercept	1	31	154.024	<.0001
			Oxygen	1	31	21.534	<.0001
Treatment			3	31	4.064	0.015	
Oxygen:Treatment			3	31	3.984	0.016	
Control		Intercept	1	8	220.338	<.0001	
		Oxygen	1	8	1.880	0.208	
+N		Intercept	1	7	12.359	0.010	
		Oxygen	1	7	3.586	0.100	
+NPK		Intercept	1	8	276.330	<.0001	
		Oxygen	1	8	70.504	<.0001	
+PK		Intercept	1	8	553.555	<.0001	
		Oxygen	1	8	22.950	0.001	
Specific oxidative C-acquiring EEA		All	Intercept	1	31	110.495	<.0001
			Oxygen	1	31	12.429	0.001
	Treatment		3	31	3.278	0.034	
	Oxygen:Treatment		3	31	3.307	0.033	
	Control	Intercept	1	8	91.084	<.0001	
		Oxygen	1	8	0.876	0.377	
	+N	Intercept	1	7	13.999	0.007	
		Oxygen	1	7	2.912	0.132	
	+NPK	Intercept	1	8	26.612	0.001	
		Oxygen	1	8	7.448	0.026	
	+PK	Intercept	1	8	146.784	<.0001	
		Oxygen	1	8	1.129	0.319	
	Specific N-acquiring EEA	All	Intercept	1	31	188.822	<.0001
			Oxygen	1	31	23.221	<.0001
Treatment			3	31	6.145	0.002	

		Oxygen:Treatment	3	31	7.034	0.001
Control		Intercept	1	8	213.337	<.0001
		Oxygen	1	8	0.233	0.642
+N		Intercept	1	7	15.423	0.006
		Oxygen	1	7	3.808	0.092
+NPK		Intercept	1	8	149.402	<.0001
		Oxygen	1	8	45.640	<.0001
+PK		Intercept	1	8	387.652	<.0001
		Oxygen	1	8	2.339	0.165
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All		Intercept	1	31	386.741	<.0001
		Oxygen	1	31	18.341	<.0001
		Treatment	3	31	2.292	0.098
Specific P-acquiring EEA		Oxygen:Treatment	3	31	4.446	0.010
	Control	Intercept	1	8	342.216	<.0001
		Oxygen	1	8	0.709	0.424
	+N	Intercept	1	7	28.804	0.001
		Oxygen	1	7	3.376	0.109
	+NPK	Intercept	1	8	217.691	<.0001
		Oxygen	1	8	31.112	0.001
	+PK	Intercept	1	8	595.921	<.0001
		Oxygen	1	8	1.374	0.275

numDF, numerator degree of freedom. denDF, denominator degree of freedom. Linear mixed-effects models were conducted when all soil samples are pooled together or separately for each nutrient treatment. For all soil samples, reduced oxygen was considered a fixed factor, while various nutrient treatments and jar number were considered random factors. For observations under each nutrient treatment, reduced oxygen was considered a fixed factor, while jar number was considered a random factor.  $qCO_2$ , microbial metabolic quotient. EEA, extracellular enzyme activity.

Table S4 Linear mixed-effects models of reduced oxygen on enzyme vector length and vector angle.

Variable	Nutrient	Oxygen	numDF	denDF	F-value	p-value	
enzymevectorlength	All	Intercept	1	31	73980.320	<.0001	
		Oxygen	1	31	7.490	0.010	
		Treatment	3	31	0.850	0.477	
		Oxygen:Treatment	3	31	6.220	0.002	
	Control	Intercept	1	8	9673.682	<.0001	
		Oxygen	1	8	3.884	0.084	
	+N	Intercept	1	7	19907.990	<.0001	
		Oxygen	1	7	0.790	0.404	
	+NPK	Intercept	1	8	32073.193	<.0001	
		Oxygen	1	8	5.835	0.042	
	+PK	Intercept	1	8	32994.343	<.0001	
		Oxygen	1	8	26.002	0.001	
	enzymevector angle	All	Intercept	1	31	248506.300	<.0001
			Oxygen	1	31	34.030	<.0001
			Treatment	3	31	12.030	<.0001
			Oxygen:Treatment	3	31	1.850	0.158
Control		Intercept	1	8	140819.500	<.0001	
		Oxygen	1	8	3.085	0.117	
+N		Intercept	1	7	30886.950	<.0001	
		Oxygen	1	7	7.302	0.031	
+NPK		Intercept	1	8	118802.405	<.0001	
		Oxygen	1	8	34.949	<.0001	
+PK		Intercept	1	8	50291.454	<.0001	
		Oxygen	1	8	6.154	0.038	

numDF, numerator degree of freedom. denDF, denominator degree of freedom. Linear mixed-effects models were conducted when all soil samples are pooled together or separately for each nutrient treatment. For all soil samples, reduced oxygen was considered a fixed factor, while various nutrient treatments and jar number were considered random factors. For observations under each nutrient treatment, reduced oxygen was considered a fixed factor, while jar number was considered a random factor.