Supplementary information

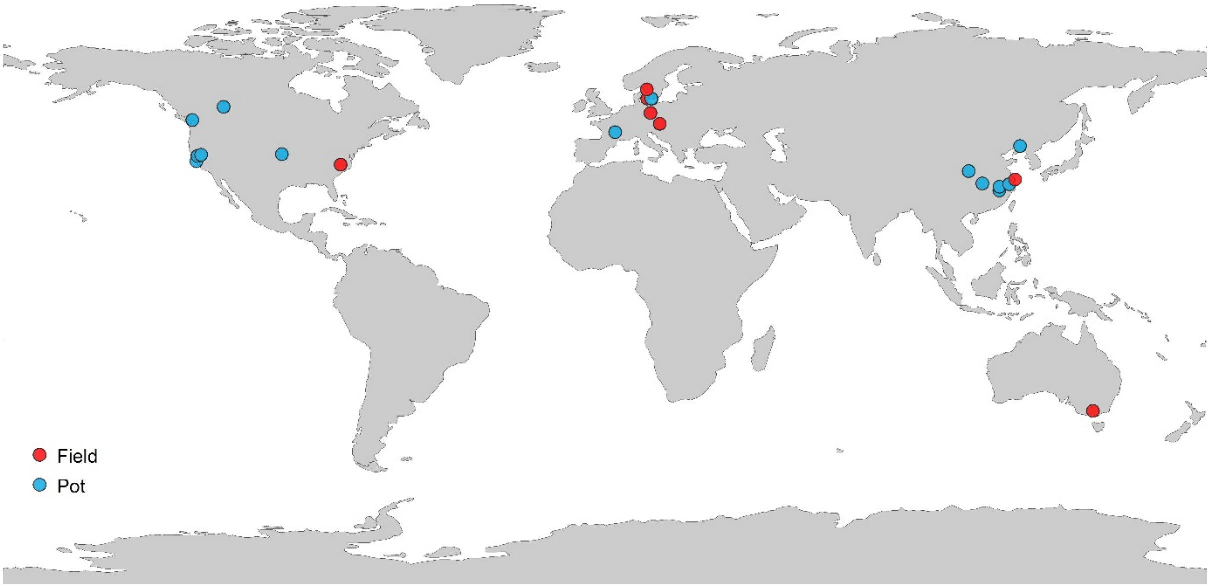

Fig. S1 Global distribution of the 23 study sites used in this meta-analysis. Red circle represents field study and blue circle represents pot study.

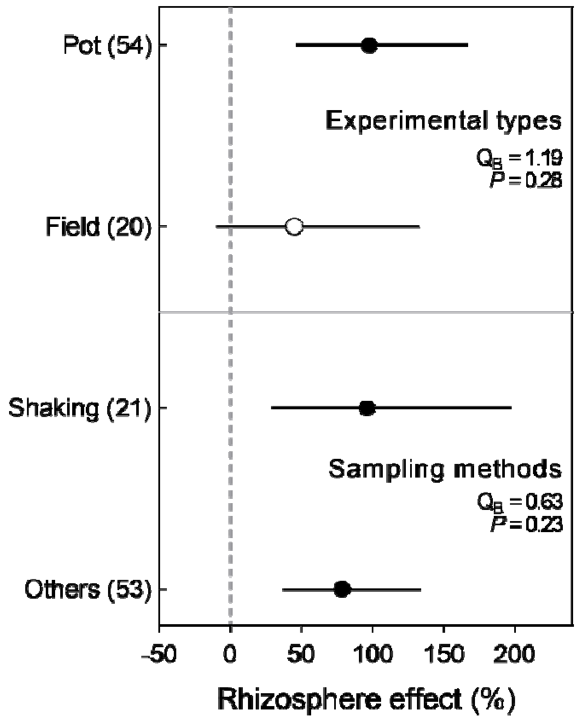

Fig. S2 Rhizosphere effects (%) on gross nitrogen mineralization rate divided by experimental types (pot and field) and sampling methods (shaking and others). The sample size for each group is in parentheses. Error bars represent 95% confidence intervals (CIs) of weighted response ratio. If 95% CIs do not overlap with zero, the rhizosphere effect is considered significant ($P < 0.05$, denoted by solid points), otherwise it is considered non-significant ($P > 0.05$, denoted by open points). Q_B represents the heterogeneity in rhizosphere effect among groups divided above, and the significant value of Q_B indicates significant differences among groups ($P < 0.05$).

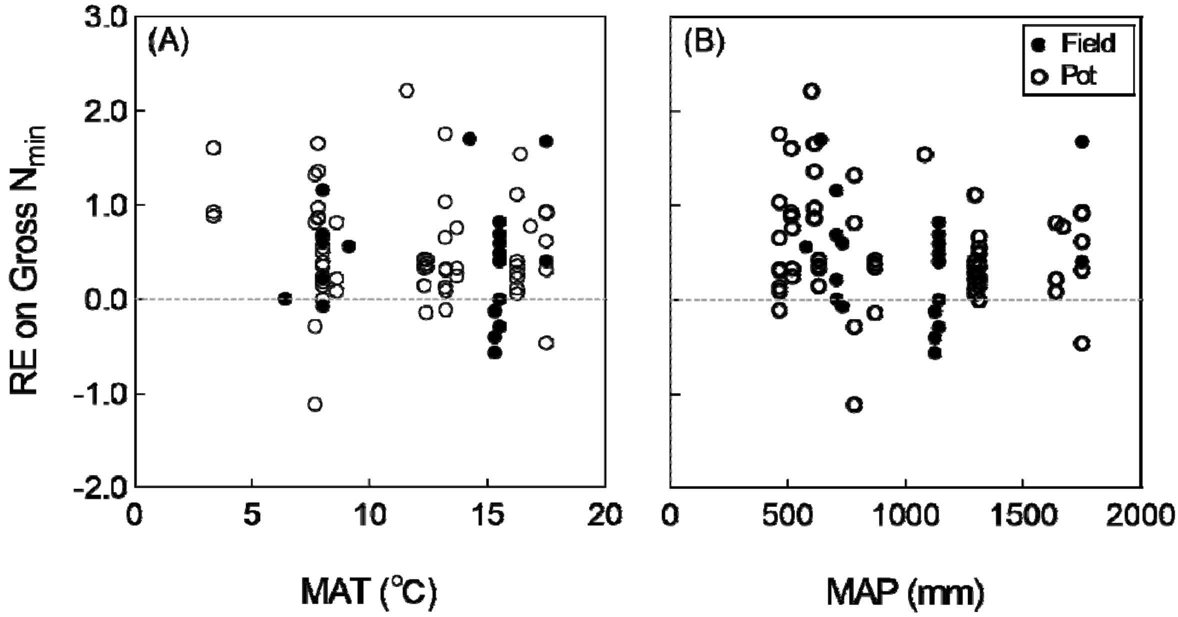

Fig. S3 Relationships of the rhizosphere effect (RE) on nitrogen mineralization rate (Gross N_{min}) with the climatic factors, including mean annual temperature (MAT) and mean annual precipitation (MAP). The RE is calculated as the natural log-transformed response ratio of rhizosphere to bulk soil. Grey area represents 95% confidence intervals and only significant relations ($P < 0.05$) are drawn with regression lines.

Table S1 Basic summary of 24 source studies used in this analysis. MAT: mean annual temperature (℃), MAP: mean annual precipitation (mm).

Study reference	Site	Location (Field site/Soil origin)		Climate (Field site/Soil origin)		Treatment	Experiment type	Sampling method (Rhizosphere / Bulk Separation Method)
		Longitude (°)	Latitude (°)	MAT (℃)	MAP (mm)			
Bengtson et al., 2012	1	123.25 W	49.26 N	8.6	1639	-	Pot	-
Dijkstra et al., 2007; 2009	2	122.05 W	36.98 N	13.2	464	-	Pot	-
Dijkstra et al., 2007; 2009	3	120.65 W	38.91 N	13.7	518	-	Pot	-
Dijkstra et al., 2016	4	145.10 E	37.42 S	14.3	640	-	Field	-
Hamer and Makeschin, 2009	5	13.26 E	51.38 N	9.1	575	-	Field	-
He et al., 2019	6	117.22 E	28.23 N	17.5	1750	air-dried/cold storage/room temperature storage	Pot	-
He et al., 2021	6	117.22 E	28.23 N	17.5	1750	-	Pot	-
Henneron et al., 2020a; 2020b	7	2.73 E	45.63 N	8.0	1313	-	Pot	shaking
Herman et al., 2006	8	121.75 W	38.54 N	11.6	600	-	Pot	measured (2mm)
Holz et al., 2016	9	12.15 E	58.38 N	6.4	709	-	Field	-
Jiang et al., 2021	10	117.25 E	29.37 N	16.8	1668	low-Fe/high-N	Pot	-
Jiang et al., 2021	11	120.16 E	30.13 N	16.3	1293	low-Fe/low-N	Pot	-
Jiang et al., 2021	12	112.18 E	30.35 N	16.4	1081	high-Fe/low-N	Pot	-
Koranda et al., 2011	13	16.05 E	48.12 N	8.0	730	girdling	Field	shaking
Li et al., 2020	14	13.58 E	55.62 N	7.7	782	low light/high light	Pot	-
Li et al., 2020	15	13.50 E	55.68 N	7.7	782	low light/high light	Pot	-
Meier et al., 2015	16	79.08 W	35.97 N	15.5	1140	ambient/elevated + N addition	Field	root box
Mo et al., 2021	17	120.14 E	30.13 N	16.3	1293	-	Pot	-
Mo et al., 2021	18	108.07 E	34.03 N	12.3	631	-	Pot	-
Nielsen et al., 1998	19	12.30 E	55.67 N	8.0	705	-	Field	shaking

Norton and Firestone 1991; 1996	20	120.65 W	38.91 N	13.7	518	N addition	Pot	-
Phillips et al., 2011	16	79.08 W	35.97 N	15.5	1140	ambient/elevated + N addition	Field	shaking
Pokharel et al., 2021	21	113.99 W	53.19 N	3.4	515	manure pellet/biochar addition	Pot	rhizobox
Yin et al., 2018	22	123.40 E	41.52 N	7.8	613	single-seedling/double-seedling	Pot	-
Zhang et al., 2019	23	121.92 E	31.53 N	15.3	1124	marsh-left/removed	Field	-
Zhu et al., 2014	2	122.05 W	36.98 N	13.2	464	-	Pot	-

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Table S2 List of the plant growth form and mycorrhizal association included in our dataset. AM: arbuscular mycorrhiza, ECM: ectomycorrhiza, AM+ECM: species which form both AM and ECM, Unknown: the mycorrhizal type could not be identified. When mycorrhizal status is not available at species level, the species is categorized according to the mycorrhizal status of other species in the same genus (Keller and Phillips, 2019; Soudzilovskaia et al., 2020).

Species	Familiy	Genus	Plant growth form	Mycorrhizal association	Mycorrhizal Reference
Anthoxanthum odoratum	Poaceae	*Anthoxanthum*	non-woody	AM	Soudzilovskaia et al., 2020
Avena barbata	Poaceae	*Avena*	non-woody	AM	Wang and Qiu, 2006
Camellia sinensis	Theaceae	*Camellia*	woody	AM	Soudzilovskaia et al., 2020
Chamerion angustifolium	Onagraceae	*Chamerion*	non-woody	AM	Keller and Phillips, 2019
Cunninghamia lanceolata	Taxodiaceae	*Cunninghamia*	woody	AM	Keller and Phillips, 2019
Eucalyptus regnans	Myrtaceae	*Eucalyptus*	woody	AM+ECM	Keller and Phillips, 2019
Fagus sylvatica	Fagaceae	*Fagus*	woody	ECM	Keller and Phillips, 2019
Festuca rubra	Poaceae	*Festuca*	non-woody	AM	Guo et al., 2008
Fraxinus mandshurica	Oleaceae	*Fraxinus*	woody	AM	Guo et al., 2008
Glycine max	Fabaceae	*Glycine*	non-woody	AM	Wang and Qiu, 2006
Helianthus annuus	Asteraceae	*Helianthus*	non-woody	AM	Wang and Qiu, 2006
Hordeum vulgare	Poaceae	*Hordeum*	non-woody	AM	Soudzilovskaia et al., 2020
Larix kaempferi	Pinaceae	*Larix*	woody	ECM	Wang and Qiu, 2006
Lespedeza bicolor	Fabaceae	*Lespedeza*	woody	AM	Soudzilovskaia et al., 2020
Lotus corniculatus	Fabaceae	*Lotus*	non-woody	AM	Wang and Qiu, 2006
Melilotus albus	Fabaceae	*Melilotus*	non-woody	AM	Wang and Qiu, 2006
Nardus stricta	Poaceae	*Nardus*	non-woody	AM	Wang and Qiu, 2006
Phragmites australis	Poaceae	*Phragmites*	non-woody	AM	Wang and Qiu, 2006
Picea abies	Pinaceae	*Picea*	woody	ECM	Wang and Qiu, 2006
Picea sitchensis	Pinaceae	*Picea*	woody	ECM	Terrer et al., 2016
Pinus ponderosa	Pinaceae	*Pinus*	woody	ECM	Terrer et al., 2016

Pinus sylvestris	Pinaceae	*Pinus*	woody	ECM	Wang and Qiu, 2006
Pinus taeda	Pinaceae	*Pinus*	woody	ECM	Wang and Qiu, 2006
Plantago lanceolata	Plantaginaceae	*Plantago*	non-woody	AM	Keller and Phillips, 2019
Poa trivialis	Poaceae	*Poa*	non-woody	AM	Keller and Phillips, 2019
Populus fremontii	Salicaceae	*Populus*	woody	AM+ECM	Keller and Phillips, 2019
Rumex acetosa	Polygonaceae	*Rumex*	non-woody	Unknown	Wang and Qiu, 2006
Saccharum officinarum	Poaceae	*Saccharum*	non-woody	AM	Wang and Qiu, 2006
Secale cereale	Poaceae	*Secale*	non-woody	AM	Wang and Qiu, 2006
Sorghum bicolor	Poaceae	*Sorghum*	non-woody	AM	Wang and Qiu, 2006
Spartina alterniflora	Poaceae	*Spartina*	non-woody	Unknown	Wang and Qiu, 2006
Taraxacum officinale	Asteraceae	*Taraxacum*	non-woody	AM	Keller and Phillips, 2019
Trifolium repens	Fabaceae	*Trifolium*	non-woody	AM	Wang and Qiu, 2006
Triticum aestivum	Poaceae	*Triticum*	non-woody	AM	Wang and Qiu, 2006
Tsuga heterophylla	Pinaceae	*Tsuga*	woody	AM+ECM	Wang and Qiu, 2006
Vicia cracca	Fabaceae	*Vicia*	non-woody	AM	Soudzilovskaia et al., 2020
Zea mays	Poaceae	*Zea*	non-woody	AM	Wang and Qiu, 2006

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Table S3 Results for publication bias. Sample size is the number of studies for a variable. Bold types indicate significance at $P < 0.05$. A significant correlation by the rank correlation test indicates possible publication bias. Rosenthal's fail-safe number gives the studies needed to shift the overall effect from statistically significant to non-significant.

Variables of rhizosphere effects	Sample size	Kendall's tau rank *P* value	Spearman's rank *P* value
Soil organic C	20	0.543	0.641
Dissolved organic C	18	0.402	0.438
Total N	8	0.355	0.470
Inorganic N	22	0.317	0.310
NH_4^+-N	22	0.261	0.153
NO_3^--N	22	0.083	0.162
Microbial biomass C	39	0.252	0.317
Microbial biomass N	27	0.483	0.559
Microbial C:N ratio	17	0.904	0.879
β-1,4-glucosidase	17	0.841	0.944
β-1,4-N-acetylglucosaminidase	25	0.111	0.211
Phenol oxidase	16	0.203	0.266
Peroxidase	16	0.289	0.321
C mineralization	46	0.170	0.269
Gross N mineralization	74	0.088	0.134

Table S4 Relationships of the rhizosphere effect (calculated as the natural log-transformed response ratio of rhizosphere to bulk soil) on gross nitrogen mineralization rate with the rhizosphere effect on other soil variables. C: carbon, N: nitrogen. N is the sample size of correlation. "–" indicates negative correlation and asterisks indicate significant relationships (*, $P < 0.05$; **, $P < 0.01$).

Variables of rhizosphere effects	The rhizosphere effect on soil gross N mineralization	
	Correlation coefficient	N
Soil organic C	− 0.140	20
Dissolved organic C	0.330	26
Total N	− 0.179	8
Inorganic N	− 0.170	30
NH_4^+-N	− 0.130	30
NO_3^--N	− 0.125	30
Microbial biomass C	− 0.075	47
Microbial biomass N	0.353*	35
Microbial C:N ratio	− 0.040	25
β-1,4-glucosidase	− 0.055	25
β-1,4-N-acetyl-glucosaminidase	− 0.201	33
Phenol oxidase	0.502*	16
Peroxidase	0.085	16
C mineralization rate	0.361**	58

Table S5 Relationships of the rhizosphere effect (calculated as the natural log-transformed response ratio of rhizosphere to bulk soil) on gross nitrogen mineralization rate with variables of bulk soil. C: carbon, N: nitrogen. N is the sample size of correlation. "–" indicates negative correlation and asterisks indicate significant relationships (*, $P < 0.05$; **, $P < 0.01$).

Variables of bulk soil properties	The rhizosphere effect on soil gross N mineralization	
	Correlation coefficient	N
Soil organic C	− 0.353	20
Dissolved organic C	− 0.468*	26
Total N	− 0.258	8
Inorganic N	0.018	30
NH_4^+-N	0.108	30
NO_3^--N	− 0.008	30