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A plant–microbe interaction framework explaining nutrient effects on primary production

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Table S1

List of studies used in the meta-analysis. The table includes information about the ecosystem in which the particular study was conducted, measured plant characteristics, soil N to P ratio ($N:P_{SOIL}$), plant and microbial N to P critical ratio ($N:P_{CR}^{plant}$, $N:P_{CR}^{mic}$), soil C to N ratio ($C:N_{SOIL}$), microbial biomass C to N critical ratio ($C:N_{CR}$) and the dominant plant-microbial relationship. A comparison of $C:N_{SOIL}$ and $C:N_{CR}$ reflects the presence or absence of the C limitation of soil microbial community. If $C:N_{SOIL}$ is greater than $C:N_{CR}$, limitation of the soil microbial community by organic carbon is unlikely. If $C:N_{SOIL}$ and $C:N_{CR}$ could not be compared, we identified presence or absence of C-limitation based on the soil classification or experimental treatment. If this was not possible. Microbial C-limitation was considered unknown and it is treated as being C limited in statistical analysis. C limitation is not important in cooperative plant-microbial system and therefore it is not reported in the table.

Study	*Ecosystem*	*Measured characteristic*	***$N:P_{SOIL}$***	$N:P_{CR}^{plant}$	$N:P_{CR}^{mic}$	***$C:N_{SOIL}$***	***$C:N_{CR}$***	*Plant-microbial relationship*
Wassen et al., 1998[1]	Wetland	Plant biomass	13.6	32.0	6.3*	51.1	12.0*	competitive
			13.6	29.8	6.3*	51.1	12.0*	competitive
			13.6	10.6	6.3*	51.1	12.0*	competitive
			13.6	22.6	6.3*	51.1	12.0*	competitive
Wright et al., 2011[2]	Tropical forest	Relative growth rate	19.8	36.6*	6.3*	18.2	12.0*	competitive
Campo and Vázques-Yanes, 2004[3]	Tropical forest	Diameter increment	24.4	38.1*	6.3*	20.2	12.0*	cooperative
		Basal area increment	15.7	35.0*	6.3*	20.2	12.0*	cooperative
Santiago et al., 2012[4]	Tropical forest	Specific leave area	25.7	38.5*	6.3*	18.2	12.0*	competitive
		Relative growth rate	25.7	38.5*	6.3*	18.2	12.0*	competitive
Carpetner et al., 1990[5]	Steppe	Primary production	22.0	37.4*	6.3*	20.0	12.0*	competitive
		Plant numbers	22.0	37.4*	6.3*	20.0	12.0*	competitive
Schmidt et al., 1997a[6]	Tundra	Plant nitrogen	9.1	36.1	10.6			cooperative
			11.6	32.1	13.9	Glucose addition		competitive
			7.3	27.3	15.4	Glucose addition		competitive
		Root nitrogen	9.1	36.1	10.6			cooperative
			11.6	32.1	13.9	Glucose addition		competitive
			7.3	27.3	15.4	Glucose addition		competitive
		Plant nitrogen	3.2	36.1	10.6			cooperative
			3.8	32.1	13.9	Glucose addition		competitive
			4.4	27.3	15.4	Glucose addition		competitive
		Shoot nitrogen	3.2	36.1	10.6			cooperative
			3.8	32.1	13.9	Glucose addition		competitive
			4.4	27.3	15.4	Glucose addition		competitive
		Root nitrogen	3.2	36.1	10.6			cooperative
			3.8	32.1	13.9	Glucose addition		competitive
			4.4	27.3	15.4	Glucose addition		competitive
Schmidt et al., 1997b[7]	Tundra	Plant biomass	9.5	31.9*	6.3*			cooperative
			11.4	33.0*	6.3*	Glucose addition		competitive
			6.9	25.9*	6.3*	Glucose addition		competitive
			3.2	26.5*	6.3*			cooperative
			3.7	27.5*	6.3*	Glucose addition		competitive
			4.4	27.5*	6.3*	Glucose addition		competitive
Vitousek et al., 1993[8]	Tropical forest	Diameter increment	0.9	19.3	6.3*			cooperative
		High increment	0.9	19.3	6.3*			cooperative

		Leaf production	0.9	19.3	6.3*			cooperative
		Photosynthetic rate	0.9	19.3	6.3*			cooperative
		Diameter increment	22.1	38.4	6.3*			cooperative
Battermann et al., 2013[9]	Tropical forest	Biomass growth	11.7	33.1*	6.3*			cooperative
Limpens et al., 2004[10]	Wetland	Biomass increment	19.9	36.7*	6.3*	C-limitation unlikely		competitive
			84.0	48.3*	6.3*	C-limitation unlikely		competitive
			30.9	39.9*	6.3*	C-limitation unlikely		competitive
			7.2	30.2*	6.3*	C-limitation unlikely		competitive
Zamin et al., 2014[11]	Tundra	Above-ground biomass	24.2	38.1*	6.3*			cooperative
		Apical growth	24.2	38.1*	6.3*			cooperative
Koide et al., 1988[12]	Grassland	Shoot dry weight	16.7	35.5*	6.3*			cooperative
Lammerts et al., 1999[13]	Grassland	Biomass	0.0	7.4*	6.3*			cooperative
			22.6	37.6*	6.3*	47.3	12.0*	competitive
			28.1	39.2*	6.3*			cooperative
			19.6	36.5*	6.3*			cooperative
Zhu et al., 2014[14]	Tropical forest	Maximum assimilation	8.8	31.7	6.3*			cooperative
			8.8	27.6	6.3*			cooperative
Vitousek and Farrington, 1997[15]	Tropical forest	Diameter increment	27.0	28.7	6.3*			cooperative
			10.0	28.7	6.3*			cooperative
Augustine et al., 2003[16]	Grassland	Above-ground biomass production	3.2	25.8*	6.3*			cooperative
Alvarez et al., 2013[17]	Tropical forest	Relative growth rate	20.3	36.8*	6.3*			cooperative
Chen et al., 2010[18]	Grassland	Leaf carbon concentration	14.0	9.7	6.3*	13.4	12.0*	competitive
Mayor et al., 2015[19]	Temperate forest	Leaf carbon concentration	0.7	15.5	6.3*			cooperative
Duren et al., 1997[20]	Wetland	Above-ground biomass	2.9	25.4*	6.3*	57.0	12.0*	competitive
			2.2	24.1*	6.3*	43.8	12.0*	competitive
Haag, 1973[21]	Tundra	Above-ground production	0.1	13.2*	6.3*			cooperative
			0.5	17.9*	6.3*			cooperative
Sundqvist et al., 2014[22]	Tundra	Vegetation density	0.4	17.5*	6.3*			cooperative
			0.9	20.5*	6.3*			cooperative
			7.6	30.5*	6.3*			cooperative
			5.9	29.1*	6.3*			cooperative
			14.5	34.5*	6.3*			cooperative
Hoek et al., 2004[23]	Wetland	Above-ground biomass	61.2	45.4*	6.3*			cooperative
			41.3	42.1*	6.3*			cooperative
Bowman et al., 1993[24]	Tundra	Biomass per tiller	0.3	23.9	6.3*			cooperative
			4.2	42.6	6.3*			cooperative
		Photosynthetic rate	0.3	23.9	6.3*			cooperative
			0.3	31.4	6.3*			cooperative
			4.2	51.1	6.3*			cooperative
			4.2	34.0	6.3*			cooperative
			4.2	27.2*	6.3*			cooperative
		N concentration	0.3	23.9	6.3*			cooperative

			0.3	31.4	6.3*		cooperative
			4.2	51.1	6.3*		cooperative
			4.2	34.0	6.3*		cooperative
			4.2	27.2*	6.3*		cooperative
		Dry biomass	0.3	23.9	6.3*		cooperative
			4.2	42.6	6.3*		cooperative
Davidson et al., 2004[25]	Tropical forest	Biomass change	8.3	23.2	6.3*		cooperative
Gusewell et al., 2002[26]	Wetland	Above-ground biomass	13.3	33.9*	6.3*	C-limitation unlikely	competitive
Ngai and Jefferies,2004[27]	Wetland	Above-ground biomass	30.5	39.8*	6.3*	C-limitation unlikely	competitive
Potthast et al., 2012[28]	Tropical forest	Yield	2.5	24.6*	3.9		cooperative
Johnson et al., 2015[29]	Grassland	Plant mass	3.5	32.9	6.3*		cooperative
			3.5	45.0	6.3*		cooperative
			2.8	33.8	6.3*		cooperative
			2.8	46.4	6.3*		cooperative
			2.8	29.0	6.3*		cooperative
			2.8	50.8	6.3*		cooperative
Barger et al., 2002[30]	Savana	Above-ground biomass	8.8	31.4*	6.3*		cooperative
Soudzilovskaia et al., 2005[31]	Tundra	Above-ground biomass	4.4	64.1	6.3*		cooperative
Gill et al., 2006[32]	Grassland	Above-ground biomass	20.6	36.9*	6.3*		cooperative
Craine et al., 2008[33]	Grassland	Above-ground biomass	6.0	20.3	6.3*		cooperative
			0.3	14.6	6.3*		cooperative
			0.8	7.1	6.3*		cooperative
			0.3	9.7	6.3*		cooperative
			0.8	11.3	6.3*		cooperative
Oheimb et al., 2010[34]	Wetland	Shoot length	0.6	30.9	6.3*		cooperative
Iversen et al., 2010[35]	Wetland	Biomass	1.0	20.9*	6.3*		cooperative
		N uptake	1.0	20.9*	6.3*		cooperative
		Biomass	16.3	35.3*	6.3*		cooperative
		N uptake	16.3	35.3*	6.3*		cooperative
		Biomass	17.2	35.7*	6.3*		cooperative
		N uptake	17.2	35.7*	6.3*		cooperative
Laliberte et al., 2012[36]	Desert	Plant growth	0.5	18.5*	6.3*		cooperative
			8.7	31.3*	6.3*		cooperative
			10.3	32.4*	6.3*		cooperative
			28.7	39.3*	6.3*		cooperative
			86.5	48.5*	6.3*		cooperative
Onipchenko et al., 2012[37]	Alpine tundra	Above-ground biomass	32.5	40.3*	6.3*		cooperative
			13.5	34.1*	6.3*		cooperative
			14.3	34.4*	6.3*		cooperative
			19.4	36.5*	6.3*		cooperative
Fisher et al., 2013[38]	Tropical forest	Growth rate	26.3	62.6	6.3*		cooperative
			36.3	51.5	6.3*		cooperative
			25.8	31.2	6.3*		cooperative

			37.5	27.1	6.3*			cooperative
Cusell et al., 2014[39]	Wetland	Above-ground biomass	48.7	49.1	6.3*	C-limitation unlikely		competitive
			37.4	36.1	6.3*	C-limitation unlikely		competitive
			13.7	20.7	6.3*			cooperative
Zhan et al., 2017[40]	Steppe	Above-ground biomass	10.5	42.8	9.8			cooperative
			10.5	45.5	9.8			cooperative
			10.5	38.4	9.8			cooperative
			10.5	40.2	9.8			cooperative
Tischer et al., 2015[41]	Grassland	Shoot biomass	3.4	47.1	6.9			cooperative
He and Dijskra, 2015[42]	Grassland	Plant biomass	1.4	19.4	13.0			cooperative
Keuskamp et al., 2015[43]	Mangrove forest	Tree hight	300.0	61.6*	4.0	24.0	22.2	competitive
			5.0	28.2*	4.5	23.4	30.8	competitive
Zhan et al., 2016[44]	Grassland	Height	13.7	22.0	6.3*			cooperative
		Total dry mass	13.7	22.0	6.3*			cooperative
		Specific leave area	13.7	22.0	6.3*			cooperative
Chen et al., 2015[45]	Fir plantation	Girth growth rate	9.8	56.8	6.3*			cooperative
Alvarez-Clare and Mack, 2015[46]	Tropical forest	DBH increase	9.7	21.9	6.3*			cooperative
		Relative growth rate	9.7	21.9	6.3*			cooperative
Homeier et al. 2012[47]	Tropical forest	Tree basal area increment	73.1	47.0*	6.3*			cooperative
Feller et al. 2003[48]	Mangrove forest	Shoot elongation	363.1	33.8	6.3*	uknown		competitive
			557.1	33.8	6.3*	uknown		competitive
			733.5	33.8	6.3*	uknown		competitive
			140.1	39.3	6.3*	uknown		competitive
			458.0	39.3	6.3*	uknown		competitive
			1801.2	39.3	6.3*	uknown		competitive
			410.7	53.1	6.3*	uknown		competitive
			410.5	53.1	6.3*	uknown		competitive
			1380.6	53.1	6.3*	uknown		competitive
Dai et al. 2013[49]	Crop field	Grain yield	14.1	34.3*	6.3*			cooperative
Lagrange et al. 2013[50]	Tropical forest	Total dry mass	25.3	89.8	6.3*			cooperative
Wanatabe et a. 2015[51]	Crop field	Shoot weight	5.2	51.0	6.3*			cooperative

***Estimated values, see Supporting Information, section 2.1. and 2.2.**

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