Supporting Information

Article title: **The role of nutrients in plant and herbivore interactions**

The following supporting information is available for this article:

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Table S1 The effect of nutrients on plant-herbivore interactions

Element//n-utrients	Plant	Herbivore interacting with plants	Effect	References
N, S	Tomato (Santa Clara)	*Tuta absoluta*	Dose-dependent, susceptibility	(Queiroz et al., 2022)
P	*Arabidopsis thaliana* *Solanum lycopersicum* *Nicotiana benthamiana*	*Spodoptera littoralis*	Dose-dependent, resistance	(Khan et al., 2016)
K	*Oryza sativa* (Shua-92)	*Scirpophaga incertulas*	Resistance	(Sarwar, 2012)
Ca	*Triticum aestivum L.*	*Schizaphis graminum Rondani*	Resistance	(Wang et al., 2021)
Mg, Ca	*Vicia fabae* L., ssp. maior	*Aphis fabae* Scop.	Resistance	(Jaworska and Gospodarek, 2003)
Zn	*Thlaspi caerulescens* J. & C. Presl	*Schistocerca gregaria*	Resistance	(Behmer et al., 2005)
Na	*grasses, forbs and litter*	Native herbivores	Susceptibility	(Welti and Kaspari, 2021)
Al, Cu, Fe, Mn, Zn	*Eremanthus erythropappus* (Asteraceae)	Native herbivores	Compensatory/tolerance	(Dueli et al., 2021)
Ce	*Solanum lycopersicum*	*Helicoverpa armigera*	Resistance	(Xiao et al., 2021)
Se	*Pisum sativum*	*Acyrthosiphon pisum*	Resistance	(Łukaszewicz et al., 2021)
	Tetranychus cinnabarinus; Tetranychus urticae; Tetranychus truncatus	*Vigna sinensis* *Solanum melongena*	Resistance	(Xu et al., 2021)
Cd	*Populus yunnanensis*	*Botyodes diniasalis* *Spodoptera exigua*	Resistance	(Lin et al., 2020)
	Thlaspi caerulescens	*Frankliniella occidentalis*	Resistance	(Jiang et al., 2005)
B	*Lycopersicon esculentum*	*Meloidogyne incognita*	Resistance	(El-Batal et al., 2019)
Ni	*Streptanthus polygaloides*	*Spodoptera exigua*	Resistance	(Boyd and Moar, 1999)
Pb	*Brassica oleracea L., var. acephala*	*Chewing, sucking, parasites*	Resistance	(Morales-Silva et al., 2022)

Co, Cu, Ni, Zn	Not stated	*Spodoptera exigua*	Resistance	(Cheruiyot et al., 2013)
S	*Brassica oleracea* var. *capitata*	*Plutella xylostella*	Susceptibility	(Santos et al., 2018)
Si	*Glycine max cv FS HiSOY® HS33A14-98SB132B* *Zea mays*	*Spodoptera frugiperda*	Resistance	(Acevedo et al., 2021)
Mn, Fe	*Eremanthus erythropappus; Eremanthus incanus*			
Al	*Lychnophora ericoides*	Native herbivores	Resistance	(Ribeiro et al., 2017)
Mn	*Byrsonima variabilis*			
N, P, K (Fertilizer: Plantex)	*Citrus aurantium* L.	*Diaprepes abbreviatus* L.	No effect or susceptibility	(Borowicz et al., 2003)
N	*Festuca ovina*	*Reindeer*	Tolerance	(Barthelemy et al., 2019)
C	*Zea mays*	*Romalea guttata*	Increased C fluxes	(Holland et al., 1996)
N, P, K, micronutrient mix; C flux	C3 grasses, C4 grasses, legumes and forbs	*Arthropod herbivores*	Susceptibility	(Zaret et al., 2023)

Table S2 Nutrients involved in microbe-plant-herbivore interactions

Element//nutr-ients	Microbe	Plant	Herbivore interacting with plants	Effect	References
S	*Bacillus amyloliquefaciens*	*Arabidopsis thaliana*	*Spodoptera exigua*	Resistance	(Aziz et al., 2016)
Si	*Glomus etunicatum*; *G. coronatum*; *G. intraradices*; *G. mosseae*; native AM inoculum	*Saccharum* spp. hybrid	*Dermolepida albohirtum*	Resistance	(Frew et al., 2017)
AAs	*Pepper golden mosaic virus*	*Capsicum annuum*	*Trialeurodes vaporariorum*	"Adaptive host manipulation"	(Ángeles-López et al., 2016)
AAs	Nitrogen-fixing bacteria	*Medicago sativa*	*Acyrthosiphon pisum*	Susceptibility	(Johnson et al., 2017)
N, AAs, sugars, sugar alcohol, VBs	*Melampsora larici-populina*	*Populus nigra*	*Lymantria dispar*	Susceptibility	(Eberl et al., 2020)
N	*Neotyphodium*	*Festuca arizonica* *Pinus ponderosa*	rodents and invertebrates	Context-dependency	(Faeth and Fagan, 2002)
N	Native soil microbes	*Lolium perenne*	Native nematodes	No increase of plant biomass	(Gebremikael et al., 2014)
C, N, P	Native soil microbes	*Lolium perenne*	Native nematodes	Increased nutrient uptake	(Gebremikael et al., 2016)
N	Native soil microbes	*Brassica oleracea*	*Meloidogyne incognita*	Tolerance	(Wurst et al., 2006)

C, N	Native soil microbes	*Festuca arundinacea* Schreb	*Popillia japonica* Newman; *Maladera castanea* Arrow	Increased nutrient cycling	(Gan et al., 2018)
C. N	Native soil microbes	*Trifolium repens* L.; *Lolium perenne* L.	*Heterodera trifolii* Goggart	Increased N fluxes	(Ayres et al., 2007)
C, N	Native soil mycorrhizae	Shrubs	Reindeer	Decreased nutrient partitioning	(Barthelemy et al., 2017)
C, N	Native soil microbes	*Quercus rubra*	*Orgyia leucostigma*	Shifts of C and N allocation	(Frost and Hunter, 2008)
N, sugars	Bradyrhizobium japonicum; B. elkani; Rhizobium fredii	*Glycine max* L.	*Aphis glycines* Matsumura	Decreased nutrient uptake	(Katayama et al., 2014)
N, C	Native soil microbes	*Dactylis glomerata*	*Chorthippus dorsatus*	Altered C allocation and N uptake	(Potthast et al., 2021)
N, C	Native soil microbes	Grasslands	mammalian herbivores	Increased soil C and N pools	(Sitters et al., 2020)
N (NO^{3-} and NH^{4+}), C, P, K (in soil)	Native soil microbes	Kobresia humilis; Elymus nutans; Stipa sareptana; Potentilla acaulis; Leymus secalinus	Yak; sheep	Tolerance	(Liu et al., 2023)

Table S3 Nutrients involved in AM fungi-or rhizobia-plant-herbivore interactions

Element//nutr-ients	Microbe	Plant	Herbivore interacting with plants	Effect	References
C, P	*Rhizophagus irregularis*	*Triticum aestivum* (L.)	Rhopalosiphum padi	Asymmetry in nutrient exchange	(Charters et al., 2020)
Sugar, starch, total N, protein	*Glomus etunicatum* *Glomus mosseae*	*Solanum lycopersicon*	Mechanical damage and *Manduca sexta* regurgitant/oral secretion	Shifts in C-and N-based resources	(Orians et al., 2018)
C, N, P	*Rhizophagus irregularis*	*Solanum tuberosum*	*Globodera pallida*	Shifts in nutrient exchange	(Bell et al., 2022)
C, N, P	*Rhizophagus irregularis*	*Medicago truncatula*	*Spodoptera exigua*	Tolerance	(Zeng et al., 2022)
N, P	*Funneliformis mosseae*	*Plantago lanceolata L.*	*Mamestra brassicae*	Context-dependency	(Qu et al., 2021)
N, AAs, C, protein	*Funneliformis mosseae* *Rhizophagus irregularis*	*Zea mays hybrid* DK-2061)	*Spodoptera exigua*	Resistance	(Ramírez-Serrano et al., 2022)
C, N	*Funneliformis mosseae*	*Elymus nutans* *Elymus sibiricus* Linn.	*Locusta migratoria manilensis*	Improved defense response	(Yu et al., 2022)
N, P	*Rhizophagus irregularis*; *Funneliformis mosseae*;	*Asclepias curassavica; Asclepias latifolia;*	*Danaus plexippus*; *Tetraopes* spp.; *Oncopeltus fasciatus*;	Resistance and tolerance	(Tao et al., 2016)

	Glomus aggregatum; *Claroideoglomus etunicatum*	*Asclepias syriaca; Asclepias purpurascens; Asclepias verticillate; Asclepias incarnata*	Aphids		
Cu, Ca, Mg, Na, K	*Trichoderma harzianum*	*Zea mays* L.	*Phyllophaga vetula*	Tolerance	(Contreras-Cornejo et al., 2021)
P	*Funneliformis mosseae* *Botrytis cinerea*	*Solanum lycopersicum*	*Spodoptera exigua*	Resistance depending on P availability	(Dejana et al., 2022)
N	*Frankia*	*Alnus rubra*	*Arion rufus*	Short-term susceptibility	(Ballhorn et al., 2017)
C, N	*Ensifer meliloti*	*Medicago sativa*	*Empoasca fabae*	N-dependent allocation strategy	(Thompson and Lamp, 2021)
Sugar, AA	*Rhizobium fredii*; B. japonicum; Bradyrhizobium elkani	*Glycine max*	*Aphis glycines*	Changes in nutrient cycling	(Whitaker et al., 2014)
C, N	*Bradyrhizobium japonicu;, B. elkani; Rhizobium fredii,*	*Glycine max* L.	*Tetranycus urticae*	Susceptibility	(Katayama et al., 2010)

Method S1: Literature search for Figure 3, Figure 4, Table S2 and S3

A literature search in the “Web of Science” database was performed before Oct 16 2022. Publications were identified by the terms "plant" AND "herbivo*" AND "nutri*" AND "microb*". As a result, 2292 articles were collected and their abstracts were exported to the electronic library. On Jul 31 2023, a second search was performed using the same terms from Oct 16 2022 to Jul 31 2023. There are another 45 studies. After excluding the off-topic articles by reading the abstracts, a total of 227 full articles were downloaded for further evaluation. The selected articles needed to meet these criteria: i) a clear statement of soil microbe(s), plant(s) and herbivore(s) in the bioassays, ii) the microbe(s) interacting with plant roots/leaves, iii) herbivore(s) feeding on plant tissues, iv) herbivory resulting in the shift of plant/soil nutrient content. Finally, a total of 31 articles (Table S2 and S3) met the established criteria.

Method S2: Data analysis

The selected 31 articles were further checked to determine if the data of plant nutrient content (N and C) are approachable. I also contacted an author for the contribution of published raw data. The two most common response variables, plant N and C, were used for the meta-analysis to assess the effects of herbivory on plant nutrient status. The finally selected articles are listed in Fig. 4. The data of plant total N and C content are prioritized, followed by percentage/concentration of N and C. The data collected from shoots/leaves are prioritized, followed by roots or stems. If there are several feeding time points, the data from the latest feeding time point were chosen. If there are several fertilization conditions, the one with well-fertilized conditions was chosen to avoid any intentionally imposed stress apart from herbivory. If there are several species (plants or microbes) in one article and the bioassays of each species are independent, the bioassays of each species were regarded as independent studies. Data from figures were extracted using an online tool PlotDigitizer (https://plotdigitizer.com/). Within a study, the mean, standard deviation (SD) and sample size (n) can be used to calculate the standardized mean difference (SMD), a powerful effect size when comparing continuous variable data between the experimental (with herbivory) and control (without herbivory) groups. If an article provides standard error (SE) rather than SD, the following equation was used to calculate the SD.

$$\mathrm{SD} = \mathrm{SE} * \sqrt{n}$$

To measure the effect sizes of herbivory on plant N and C content in the presence of microbes, the *metacont* function from R package **meta** (Schwarzer, 2007; Balduzzi et al., 2019) was used to calculate the SMD (method: Hedges). Hedges is a good method of calculating effect size when comparing two groups with a small sample size. The mean effect size and 95% confidence interval (CI) for each outcome associated with the herbivory effect were calculated. A positive Hedges value indicates positive effects of herbivory on their host performance in microbe-plant-herbivore interactions, while a negative value indicates the opposite. The mean effect size was considered to be significant when the CI range did not include zero (Borenstein, 2009).

The heterogeneity of effect sizes was assessed through *metacont* function which indicates the presence or absence of heterogeneity across studies (Borenstein, 2009). When there is high heterogeneity ($I^2 > 50\%$) of studies, a random effect model (Hedges and Vevea, 1996) was selected to test whether the overall effect of herbivory on plant N and C contents showed differences across studies.

Publication bias was assessed graphically with funnel plots by *funnel* function. In addition, publication bias was tested statistically using Egger's test by *metabias* function. All the analyses were conducted in an R environment (R Core Team, 2023).

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