Crop response to nitrogen-phosphorus colimitation: theory, experimental evidences, mechanisms, and models. A review

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Tables for : **Crop response to nitrogen-phosphorus colimitation: theory, experimental evidences, mechanisms, and models. A review**

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Crop	Scientific name	Botanical Family	N response	P response	NxP effect	Growth response Pattern	Type of colimitation	Reference
Tomato	*Lycopersicum esculentum* L.	Solanaceae	Yes	Yes	No	MLH		Abu-Alrub et al., 2019
Barley	*Hordeum vulgare* L.	Poaceae	Yes	Yes	No	MLH		Al-Ajlouni et al. 2010
Kale (Site 2)	*Brassica oleracea* var. acephala	Brassicaceae	Yes	Yes	No	MLH		Chakwizira et al. 2009
Swede (Site 2)	*Brassica napus* subsp. *napobrassica*	Brassicaceae	Yes	Yes	No	MLH		Chakwizira et al. 2011
Common bean	*Phaseolus vulgaris* L.	Fabaceae	Yes	Yes	No	MLH		Chekanai et al. 2018
Wheat	*Triticum aestivum* L.	Poaceae	Yes	Yes	No	MLH	Independent Additive	Girma et al. 2007
Rice	*Oryza sativa* L.	Poaceae	Yes	Yes	No	MLH		Serme et al. 2018
Potato	*Solanum tuberosum* L.	Solanaceae	Yes	Yes	No	MLH		Setu et Mitiku 2019
Groundnut	*Arachis hypogaea* L.	Fabaceae	Yes	Yes	No	MLH		Tekulu et al. 2020
Sorghum	*Sorghum bicolo*r L. Moench	Poaceae	Yes	Yes	No	MLH		Wang et al. 2017
Potato	*Solanum tuberosum* L.	Solanaceae	Yes	Yes	No	MLH		Zewide et al. 2012
Canola	*Brassica napu*s L.	Brassicaceae	Yes	Yes	No	MLH		Nuttall et al. 1992
Canola	*Brassica napus* L.	Brassicacea e	Yes	Yes	Yes	MLH		Brennan and Bolland 2009
Wheat	*Triticum aestivum* L.	Poaceae	Yes	Yes	Yes	MLH	Independent Super-additive	Brennan and Bolland 2009
Kale (Site 1)	*Brassica oleracea* var. acephala	Brassicaceae	Yes	Yes	Yes	MLH		Chakwizira et al. 2009
Alfalfa	*Medicago sativa* L.	Fabaceae	Yes	Yes	Yes	MLH		Fan et al. 2016

Maize	*Zea mays* L.	Poaceae	Yes	Yes	Yes	MLH		Getnet et Dugassa 2018
Safflower	*Carthamus tinctorius* L.	Asteraceae	Yes	Yes	Yes	MLH		Golzarfar et al. 2012
Buckwheat	*Fagopyrum* esculentum Moench	Polygonaceae	Yes	Yes	Yes	MLH		Ullah et al. 2012
Maize	*Zea mays* L.	Poaceae	Yes	Yes	Yes	MLH		Kamanga et al. 2014
Potato	*Solamum tuberosum* L.	Solanaceae	Yes	Yes	Yes	MLH		Nekinike and Dechassa 2018
Egusi Melon	*Citrullus lanatus* (thunb.) Mansf	Cucurbitacea e	Yes	Yes	Yes	MLH		Olaniyi et al. 2008
Maize	*Zea mays* L.	Poaceae	Yes	Yes	Yes	MLH		Schlegel and Havlin 2017
Sorghum	*Sorghum bicolor* (L.) Moench	Poaceae	Yes	Yes	Yes	MLH		Schlegel and Havlin 2020
Mung Bean	Vigna radiata L.	Fabaceae	Yes	Yes	Yes	MLH		Yin et al. 2018
Tef	*Eragrostis* tef (Zuccagni) Trotter	Poaceae	Yes	Yes	Yes	MLH	Independent Super-additive (Low Input) / Independent Sub-Additive (High Input)	Dereje et al. 2018
Faba bean	*Vicia faba* L.	Fabaceae	Yes	Yes	Yes	MLH		Adak and Kibritici 2016
Kale (Site 3)	*Brassica oleracea* var. acephala	Brassicacea e	Yes	No	Yes	LM		Chakwizira et al. 2009
Swede (Site 1)	*Brassica napus* subsp. napobrassica	Brassicaceae	Yes	No	Yes	LM		Chakwizira et al. 2011
Sesame	*Sesamum indicum* L.	Pedaliaceae	Yes	No	Yes	LM	Serial N	El Mahdi et al. 2008
Globe Artichoke	*Cynara cardunculus* L. var. scolymus (L.) Fiori	Asteraceae	Yes	No	Yes	LM		Ierna et al. 2006
Wheat	*Triticum aestivum* L.	Poaceae	No	Yes	Yes	LM	Serial P	Takahashi and Anwar 2005

Table 2.

Crop Model	APSIM	DSSAT	EPIC	QUEFTS	PARNJIB
Model category	Semimechanistic	Semimechanistic	Semimechanistic	Hybrid	Empirical
Spatial Scale	Field	Field	Field	Field	Field
General Handling of N:P nutrient statues					
Stoichiometric Factors N/P	No	Limit P uptake	NR	NR	NR
N-P colimitation management	Law of the minimum	Law of the minimum	Law of the minimum	Mean of the potential yields	Reduction factor accounting all stresses
Soil and root representation					
Soil representation	1D profile	1D profile	1D profile	No spatialization	No spatialization
Root representation	Root depth, density and Biomass per layer	Root depth, density per layer, Root radius	Rooting depth and weight per layer	NR	NR
Root response to N deficiency	NR	Reduce shoot:root	NR	NR	NR
Root response to P deficiency	NR	Partitioning Coef	NR	NR	NR
pH simulation	Computed/Proton Balance	Input	Computed	Input	Input
Rhizospheric Processes					
Symbiotic N2 fixation	R	R	R	NR	NR
Nodules representation	Implicit	R	NR	NR	NR
N effect on N2 fixation	Triggered by N deficiency/No direct effect on the rate	Triggered by N deficiency/No direct effect on the rate	Inhibition	NR	NR
P effect on N2 fixation	NR	NR	NR	NR	NR
N effect on APase Secretion	NR	NR	NR	NR	NR
P effect on APase Secretion	NR	NR	NR	NR	NR
Organic acid secretion	Citrate only	NR	NR	NR	NR
Mycorrhizae	NR	NR	NR	NR	NR
References	Delve et al. 2009 ; Keating et al. 2003 ; Robertson et al. 2002	Dzotsi et al. 2010 ; Jones et al. 2003 ; Boote et al. 2008	Sharpley and Williams 1990 Jones et al. 1984	Sattari et al. 2014	Reid et al. 2002