



The physiology of symbiotic plant nutrition

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Biofertilizers, biostimulants and mineral nutrition

Why do we need **biofertilizers**? response of spinach to soil inoculant

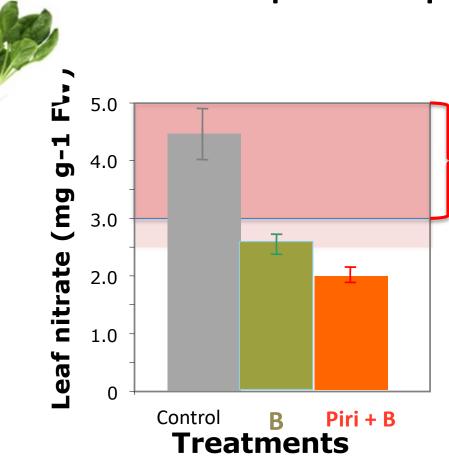
Ammonium nutrition | Cristina Cruz

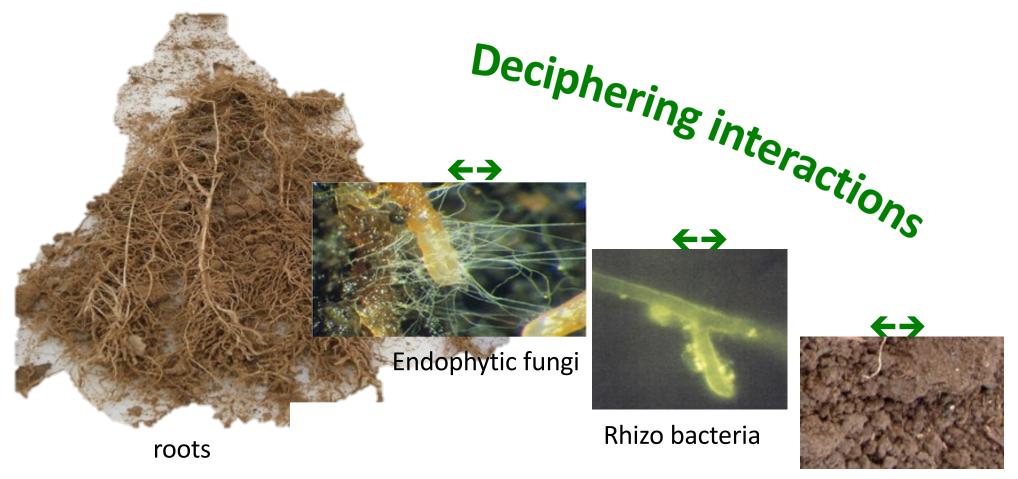
Leaf nitrate

Not for sale = money lost

Regulation CE nº1881/2006

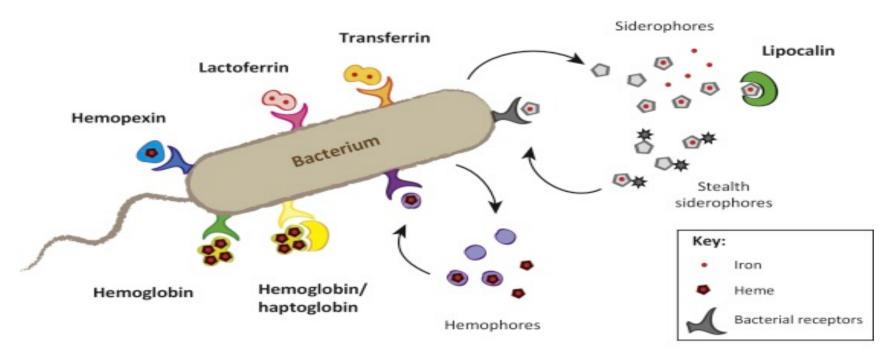
Nitrate is a normal component of the human diet (average daily intake 75 mg. Upon ingestion, ±5% of the nitrate is reduced to nitrite by bacteria When the pH of the gastric fluid is high (>5) nitratereducing bacteria increase and more N-nitroso compounds can be formed.





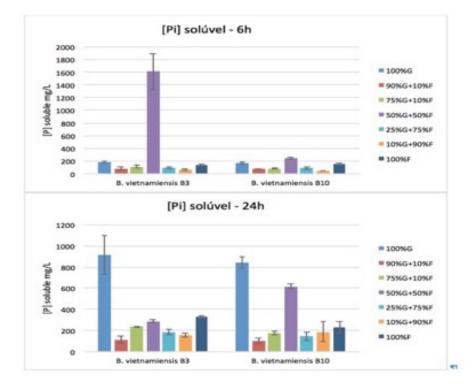
Soil

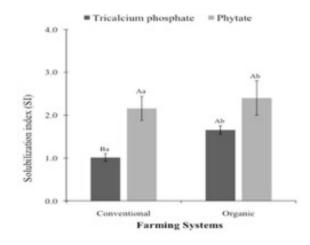
Iron dynamics in soils



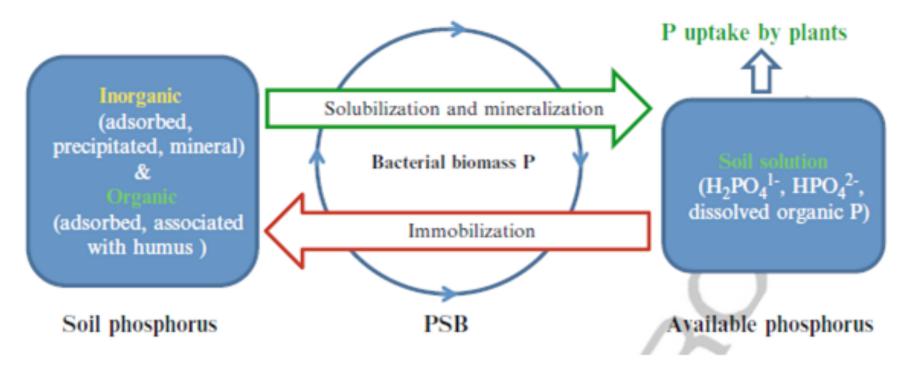
Trends in Genetics

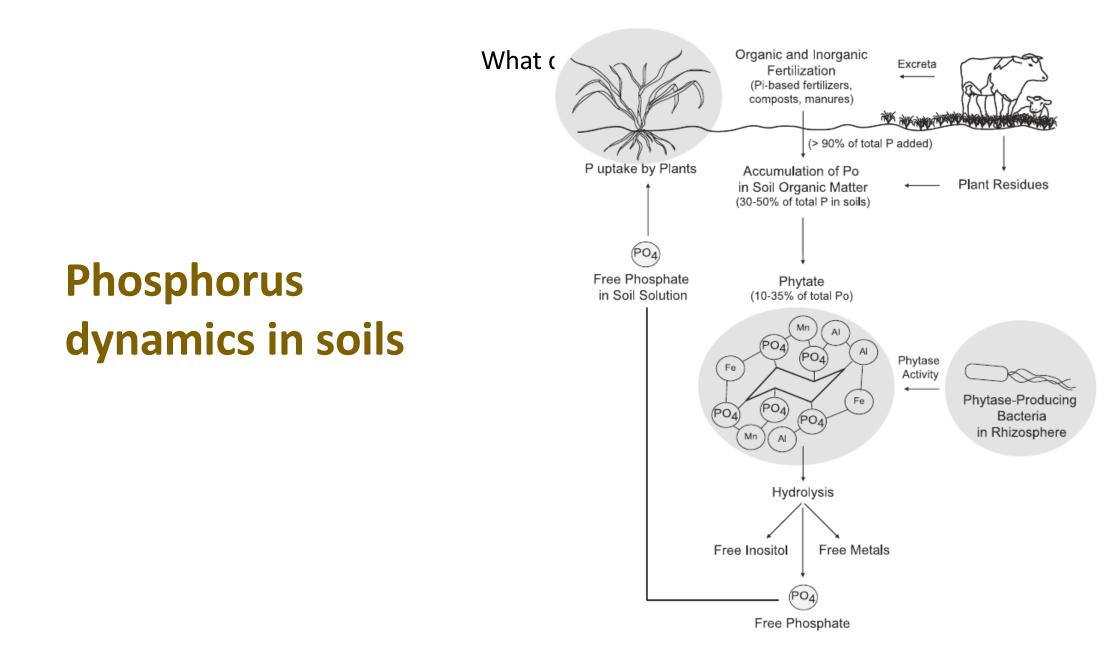
Why do we need **biofertilizers**? Phosphorus dynamics in soils





Phosphorus dynamics in soils





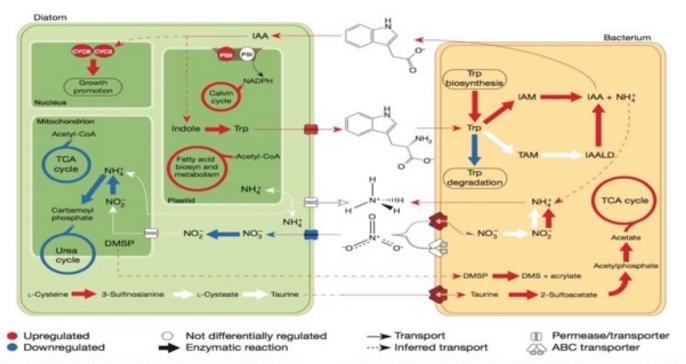
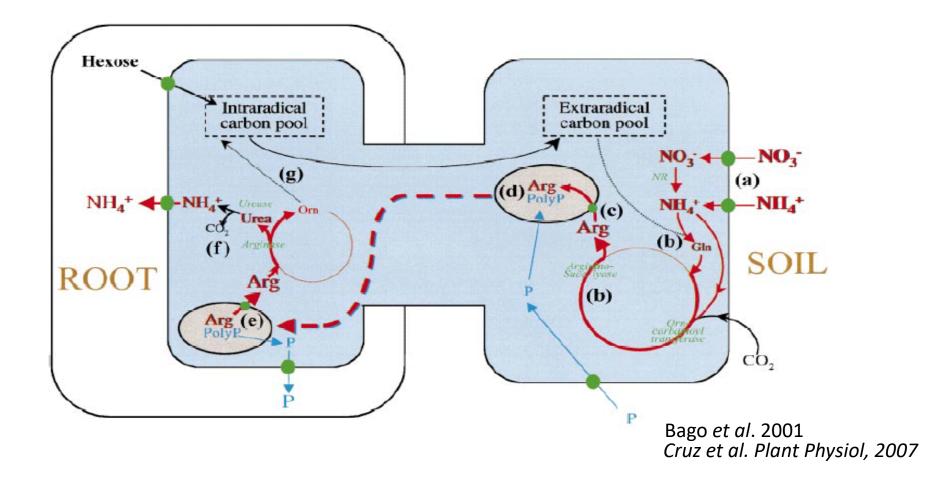
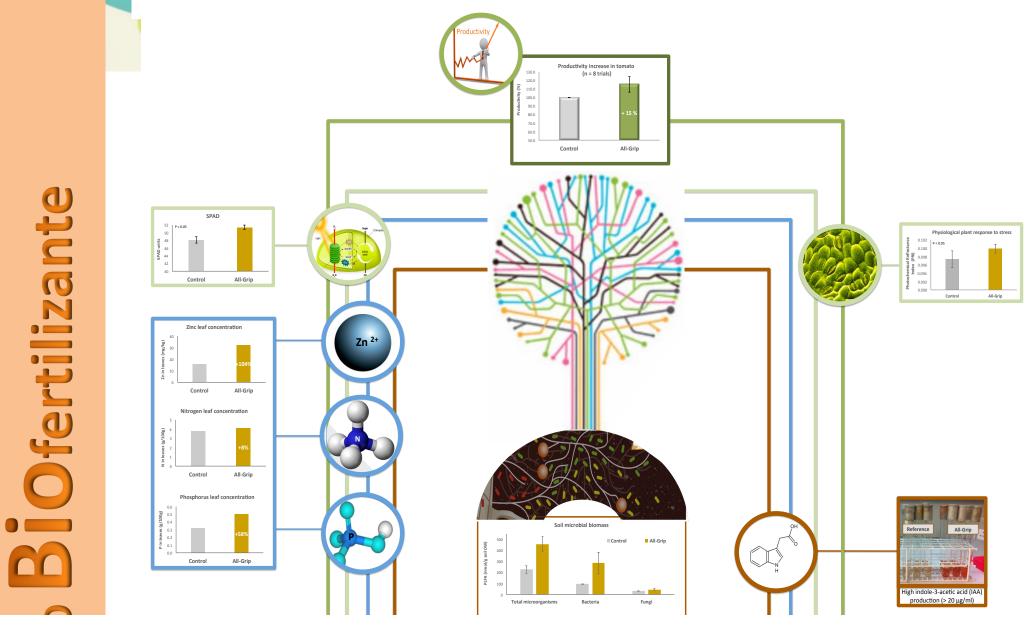


Figure 2 | Model of *P. multiseries–Sulfitobacter* interactions based on transcriptomic and targeted metabolite analyses. Molecules with a structure indicate detection in the co-culture supernatant. Genes/transporters/metabolic cycles are shown as upregulated (red), downregulated (blue), or not differentially regulated (white) in co-culture relative to monocultures. Metabolic cycles were assigned an expression pattern if at least one gene specific for the

cycle was differentially expressed and no others were regulated in the opposite direction. Supplementary Information Tables 1 and 2 list fold-expression and statistical significance based on triplicate biological experiments. IAA potentially regulates expression of two cyclins that typically regulate the cell cycle³⁰. Trp, tryptophan; DMS, dimethyl sulfide; PSI, PSII, photosystem I, II; CYC2, CYC8, cyclins 2 and 8; IAALD, indole-3-acetaldehyde.







Metabolomic analysis

Legende compositos a vente - ácidos orgânicos Composito nare			Executation Trigger aC1 - trigg mole aC2 - trigg durs aC3 - trigg forragern aC4 - trigg forragern				Executation Bactivitian Azospinillum brazilarina Ac245 Azospinillum brazilarina Arg2 Harbospinillum saropedicae RAM Harbospinillum saropedicae RAM					Executairos interagries trigos/bachárias										
	Formula																	-				
				-					1			AD				vg2			PLAME			NGG
		AEIOG mese	#[1	408	403	404	A(245	Ag2	R/NM	100	401	468	#03 j #	64 #	1. 408	408	+04	a[1] a	68.1.40	3 . #04	#01 #	02 #03 #
1,2,4,5 Tatramethylkeruane.Durane (M+H(=)		136,1168269									1			-				_				
(3-5-seo 1.3-campholide (see KEGG C02952); (VRUN)-1.8.8-binethyl-2-coabicyclo(3.2.1)schere 3.8-dore	e C10+1403	180,1016708																				
Edmohenium (M+Na(+)	C10H18NO	180,1124098																				
(+) Camphor (see KECG C00408) (C10 soprenoids (monoterpenes) (PR0102) (N+H)+)	C10H180	163,1273916						1000														
(*) Ardeolar (M*+0*)	C10+1802	186,1223062						_									_					
(3P) 3 hopropertyl & control acute (3P) 3 teopropertyl & control acut (M=r(+)	CHOHMOD	188,1172258																				
toosterylyUanic acid. (20) 2 (3-methyloutanoylamins(pertendition acid (safscepto acid) (M-M(+)	CRIDH17NOS	202, 1179481																				
(*) Neonatatation (M+H)*	C10H1802	171,1379563					1.															
Dettyl adpate/Diettyl hexanadicals (M+H)+)	C10+1804	203,1277868																				
13.8-Nachihaleneritol 13.8-Tritydroxynaphihalene (MHID-)	C104803	177.0546206																				
3-Methyl 1-(2,4,8-Inhydrosuphenylibuten 1-one (MrVIDr)	011111404	211.0064854						_														
Educarper (M+H+)	C19+18	148,132477						1.00							_							
3 kert Butyl 5-methyloaechol (Mr-Hr-)	C1941802	181,1223062																				
Thisperital (M+H)+	CVINIANCICUS	243,1161753																				
Candione, Annonum, (p-hydrosphenethy((trimethyl- (Nr-Na)+)	C1/IH18NO	203, 1280689									1000	1. The					-			_		
2.5-undecedenal (Fally aldehydes (FAOE) (N+H)+)	CHIMINO .	167, 1430417																				
10-undergrosic and 5-Insaturated faily acids (FAC100) (54+10+)	CTRASBOD .	183,1379563															_	_				
10-hendecencic acid, 10-undecencic acid [Lineaturated fetty acids (FAD100)] (MH04)	C1940000	185.1536363									1000						_					
2-hydroxy-10-undecence and 3hydroxy felly acids (FA01085 (M+http)	C119-60003	201,148521																				
Undecember and Undecember and Disaboryls and (#A/117) (M-H)	C1/1H200H	217,1434386																				
Caproylcholme (salor) (M=K38)+)	CTHORNCO	241(1430634															-					
os 1.2 Ditylroxy 1.2 ditylroditerzotkiptere (MrH)+)	C10H10085	218.047437		_					1								_	_	_			
3-Burgholene 7-hydroxyphtheside (M+H)+)	C12H12OB	208.089620F				_																
25 AC MI, 10E-Dookcaletramatics; and Diractoryle axis (FA3117) (Molds)	CIGHIADA	321.006A864																				

FTICR-MS – Fourier Transform Ion Cyclotron Resonance Mass Spectrometry

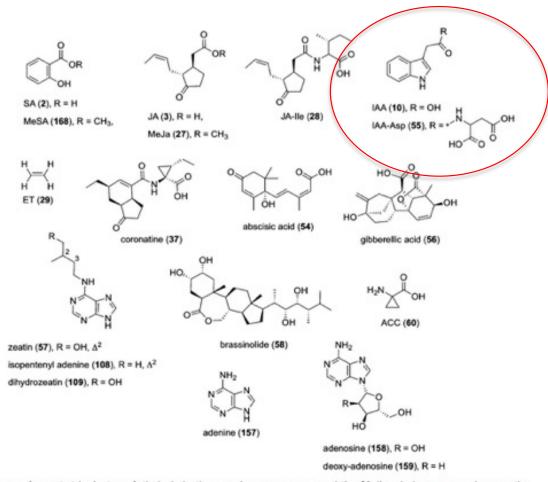
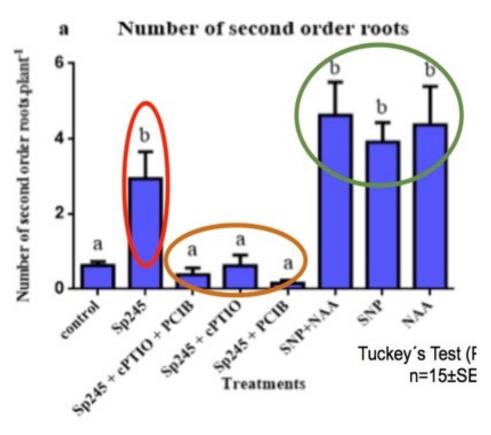


Chart 4 Plant hormones (except strigolactones), their derivatives, analogs, precursors and the JA-Ile mimic compound coronatine



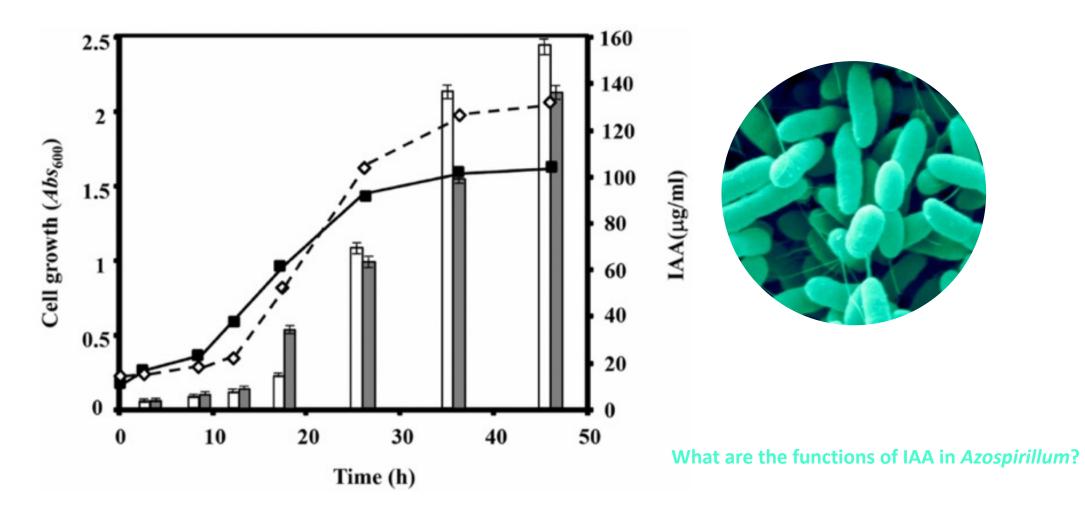


Inoculation with A. brasilense Sp245 or ARG2, increased the number of second order roots.

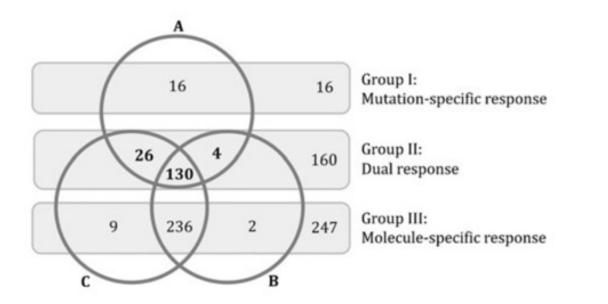
Application of a NO scavenger (cPTIO) and an auxin scavenger (PCIB), either together or apart, block the effects of inoculation

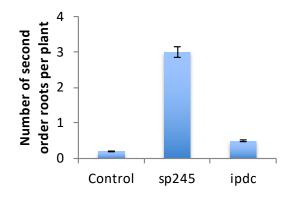
Application of a NO donor (SNP) and a synthetic auxin (NAA), either together or apart, mimic the effects of inoculation.

NO and auxins mediate the A. brasilense-induced increase in the number of second order roots in wheat



Transcriptome Analysis of the Rhizosphere Bacterium Azospirillum brasilense Reveals an Extensive Auxin Response





Venn diagram showing the distribution of genes with significant differences in absolute fold Change. A significantly expressed genes, comparing wild type with ipdC mutante gene profile without the addition of IAA. B and C genes with a significant altered expression by addition of IAA to the wild type and ipdC mutant strain, respectively

Ferreira et al 2019, Frontiers in Microbiology

How do **biofertilizers work**?

But the question is how does the biofertilizer promote Plant growth?

Increased nutrient availability does not imply improved growth

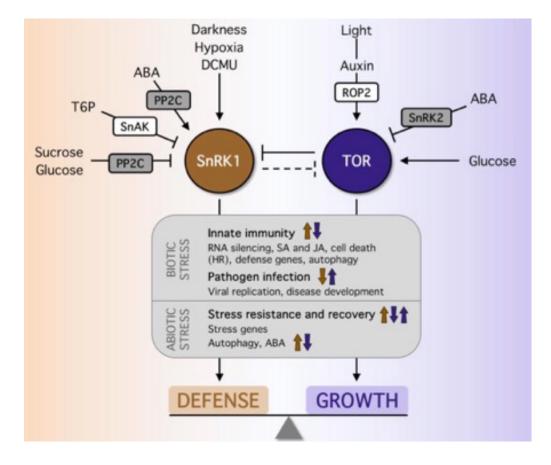
Auxin is essential in mediating the Azospirillum PGPR effect

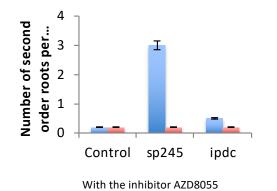
(For other organisms it may be sugars, or other compounds)

So what is the mechanism that triggers the effect?

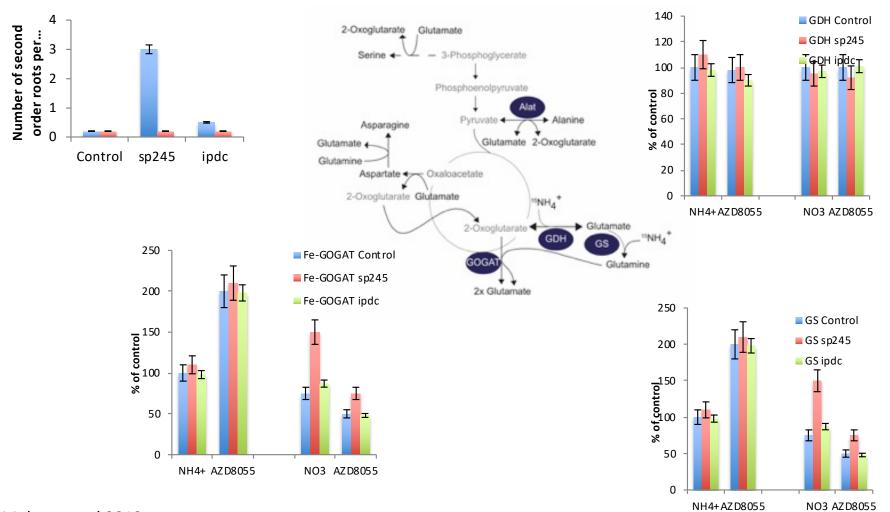


An evolutionary model of the eukaryotic TOR signaling pathway, showing the possible loss or acquisition of TOR signaling modules from the putative common eukaryote ancestor. The gray box lists the possible primitive eukaryotic core signaling components, with colors indicating different regulatory modules.





Gin, Leu aKG Glucose T6P 0 Vps34 LST8 Snf1 P13K AMPK SnRK1 TOR SnRK1 RAPTOR 0 8 2 bZIPs RagA/B_GTR1-GTP RagC/D_GTR2-GDP 2 Atg13 Atg1 Autophagy Ragulator ULK1 Ego complex Vacuole E2F Cell division Lysosome Tap42 N assimilation Tap46 a4 V-ATPase S6K Sch9 Translation Amino acids, sugars



Mubeen et al 2019

