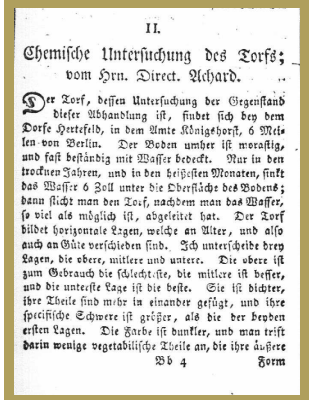
Humic acids as a plant growth promoter

L.P. Canellas

nudiba
Núcleo de Desenvolvimento
de Insumos Biológicos para a Agricultura
UENF Universidade Estadual do Norte Fluminense Darcy Ribeiro

Special thanks

Prof. Riccardo Spaccini		Prof. Alessandro Piccolo

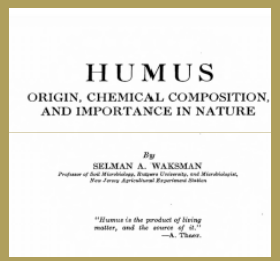


II.

Chemische Untersuchung des Torfs; vom Hrn. Direct. Achard.

Der Torf, dessen Untersuchung der Gegenstand dieser Abhandlung ist, findet sich bey dem Dorfe Hertefeld, in dem Amte Königshorst, 6 Meilen von Berlin. Der Boden umher ist morastig, und fast beständig mit Wasser bedeckt. Nur in den trocknen Jahren, und in den heißesten Monaten, sinkt das Wasser 6 Zoll unter die Oberfläche des Bodens; dann sticht man den Torf, nachdem man das Wasser, so viel als möglich ist, abgeleitet hat. Der Torf bildet horizontale Lagen, welche an Alter, und also auch an Güte verschieden sind. Ich unterscheide drey Lagen, die obere, mittlere und untere. Die obere ist zum Gebrauch die schlechteste, die mittlere ist besser, und die unterste Lage ist die beste. Sie ist dichter, ihre Theile sind mehr in einander gefügt, und ihre specifische Schwere ist größer, als die der beyden ersten Lagen. Die Farbe ist dunkler, und man trifft darin wenige vegetabilische Theile an, die ihre äußere

Bb 4 Form



HUMUS

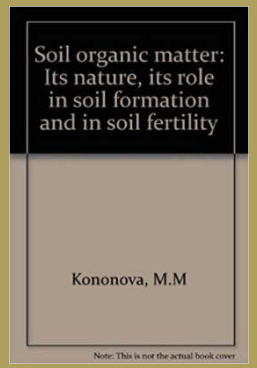
ORIGIN, CHEMICAL COMPOSITION, AND IMPORTANCE IN NATURE

By

SELMAN A. WAKSMAN

Professor of Soil Microbiology, Rutgers University, and Microbiologist, New Jersey Agricultural Experiment Station

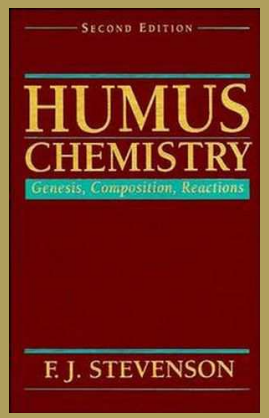
"Humus is the product of living matter, and the source of it."
—A. Thaer.



Soil organic matter: Its nature, its role in soil formation and in soil fertility

Kononova, M.M

Note: This is not the actual book cover

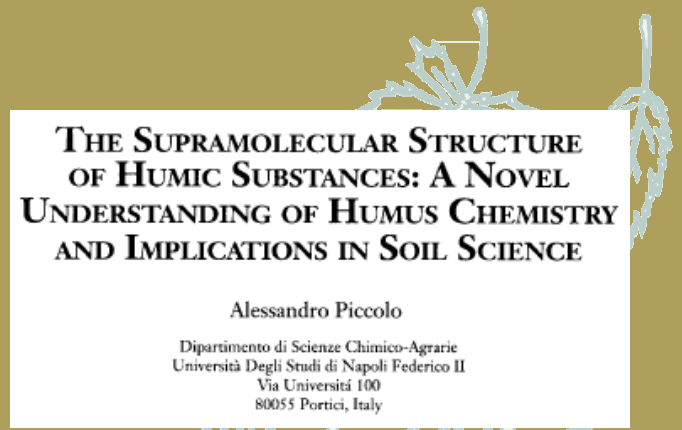


SECOND EDITION

HUMUS CHEMISTRY

Genesis, Composition, Reactions

F. J. STEVENSON



THE SUPRAMOLECULAR STRUCTURE OF HUMIC SUBSTANCES: A NOVEL UNDERSTANDING OF HUMUS CHEMISTRY AND IMPLICATIONS IN SOIL SCIENCE

Alessandro Piccolo

Dipartimento di Scienze Chimico-Agrarie
Università Degli Studi di Napoli Federico II
Via Universitá 100
80055 Portici, Italy

Fig. 2. Evolution of the soil organic matter concepts in relation with scientific recommendations for sustainable farming and management practices across the past 300 years.

Humeomics

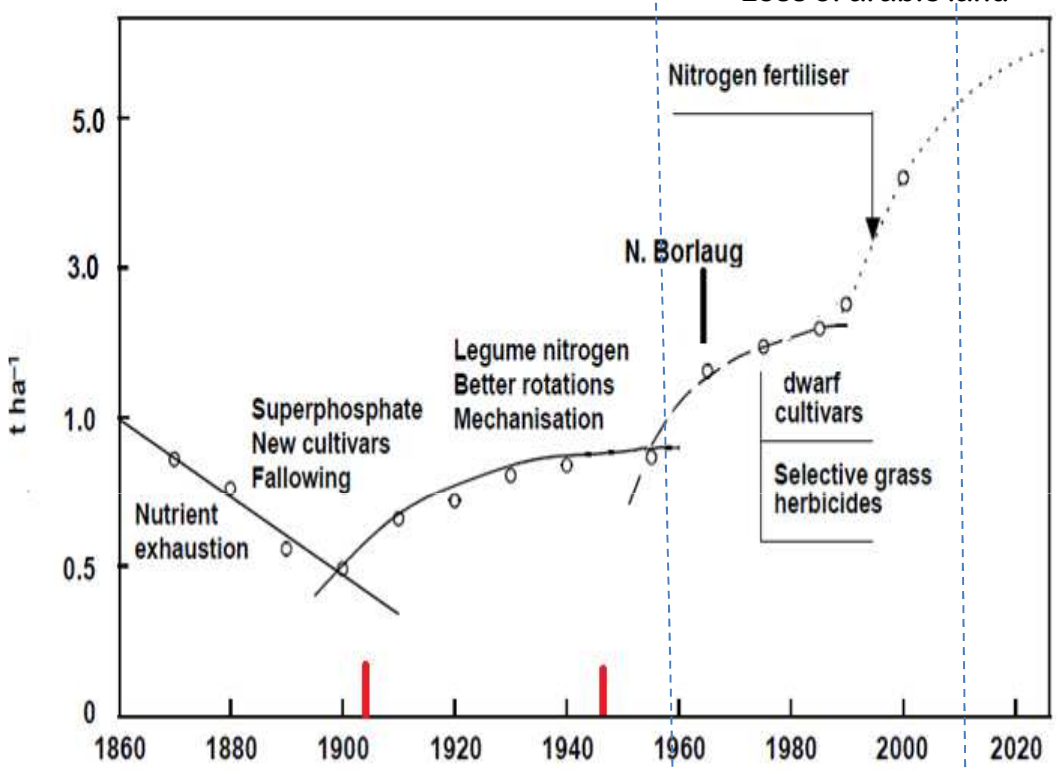
issue

1500 million ha

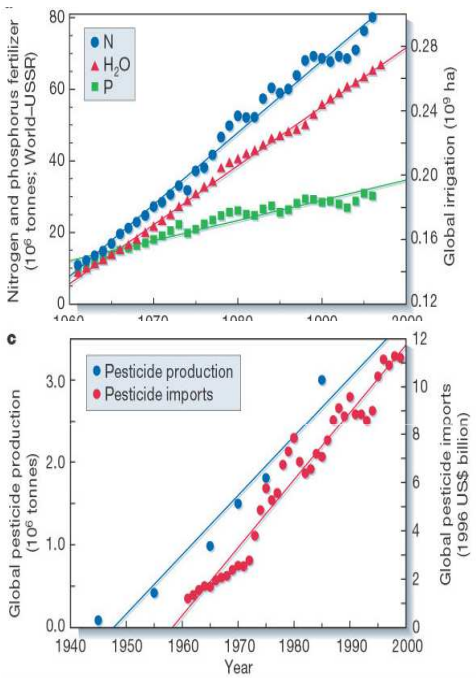
10 million ha

Loss of arable land

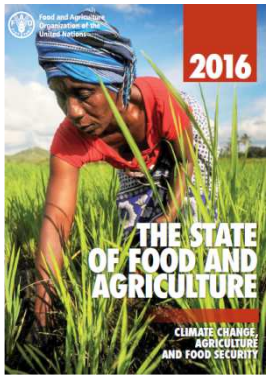
Traditional tech



Nature **418**, 671



Maize production time-line



poverty

80 millions (1970)

800 millions (2015)

Brazil: 25 millions in absolute poverty (70% in rural zone)

The use of humic products *per si* does not produce any change in the technological matrix

*in*Directs

HS

- *Pool of nutrients*
- *Component of the organo-clay complex*
  - *Chemical status*
  - *Water status*
  - *Physical status*
  - *Biological status*
- *Pool of C*
- *Pool of energy*

Directs

HS

- *Nutrient uptake* ✓
- *Water uptake* ✓
- *hormonal effects* ✓
- *Primary-secondary met* ✓
- *Morphological changes* ✓
- *Resistance against biotic and abiotic stress* ✓

BIOLOGICAL ACTIVITIES OF HUMIC SUBSTANCES

S. Nardi, P. Carletti, and D. Pizzeghello
Dipartimento di Biotecnologie Agrarie, University of Padova, Legnaro, Padova, Italy
A. Muscolo
Dipartimento Gestione dei Sistemi Agrari e Forestali, University of Reggio Calabria, Reggio Calabria, Italy

“HS enhance nutrient use efficiency, aiding assimilation of both macro and microelements and promoting plant growth by the induction of carbon, nitrogen, and secondary metabolism”.

J. Plant Nutr. Soil Sci. 2017, *180*, 5–13 **DOI:** 10.1002/jpln.201600348

Review Article

Soil–root cross-talking: The role of humic substances

Serenella Nardi[1]*, **Andrea Ertani**[1], and **Ornella Francioso**[2]

chemical and biological technologies adapted for peasants in the 3th world

Use of HS and beneficial microorganisms to plant stimulation

GRAAAT! GRAAT!
SONO SEMPLICI GHIANDE CHE IO HO TRATTATO CON UNA DELLE MIE SOLITE BEVANDE.
COSI'?
AVRESTI POTUTO FARLO IN UN MODO PIU' SOLENNE, MA NON IMPORTA.
FEEIOUP!
PRODIGIOSO!
PERCHE'? E' UNA QUERCIA COME LE ALTRE.
MA HAI VISTO CON CHE VELOCITA' E' CRESCIUTA?
MBE', E' LA PRIMA VOLTA CHE VEDO CRESCERE UNA QUERCIA. PER CUI NON SO CON QUALE VELOCITA' CRESCE DI SOLITO.

A Meta-Analysis and Review of Plant-Growth Response to Humic Substances: Practical Implications for Agriculture

Michael T. Rose[*,†], Antonio F. Patti[*], Karen R. Little[*,†,‡], Alicia L. Brown[†], W. Roy Jackson[*], Timothy R. Cavagnaro[†,§]

and regression tree techniques. Overall, random-effects meta-analysis estimated shoot dry weight increases of 22 ± 4% and root dry weight increases of 21 ± 6% in response to HS application. Nevertheless, actual responses varied considerably and were mainly

HortScience 45(6):906–910. 2010.

Humic Substances Generally Ineffective in Improving Vegetable Crop Nutrient Uptake or Productivity

Timothy K. Hartz[1] and Thomas G. Bottoms
Department of Plant Sciences, University of California, 1 Shields Avenue, Davis, CA 95616

Inequality, our local particularity? 75% of the rural population in North of Rio de Janeiro State earn less than $ 1 a day

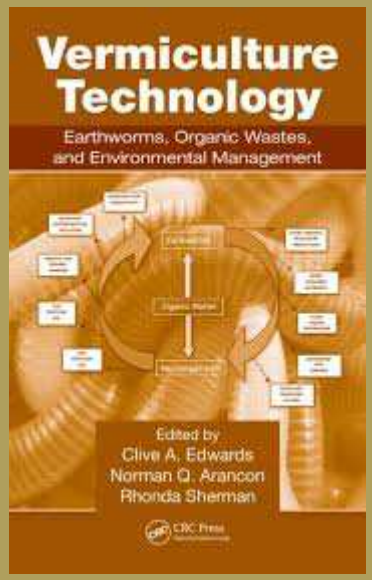
Goal

Humic acids as plant growth promoter

Basic principles

- Work together with peasants
- field responses
- Mix with PGPB
- Understand the mechanism to amplify the use

Use of renewed source of organic matter to extraction of like-humic products



Use of beneficial microorganisms together with HA

help peasants organization

Field responses

Field responses

Review

Humic and fulvic acids as biostimulants in horticulture

Luciano P. Canellas[a,b,*], Fábio L. Olivares[a], Natália O. Aguiar[a], Davey L. Jones[b], Antonio Nebbioso[c], Pierluigi Mazzei[c], Alessandro Piccolo[c]

Table 1
Effect of humic substances (HS) on vegetables, fruit crops, and ornamental plants.

Crop	Simplified assay description	Effects	References
Apricot	Soil and foliar spray of commercial humic acids at different doses	Increased of yield which ranged from 16 to 33%	Fathy et al. (2010)
Brazilian red-cloak and sanchezia	HA from vermicompost; different doses; pot experiment in greenhouse	Increased by 140% of adventitious rooting	Baldotto and Baldotto (2014)
Broad bean	Humic acid were applied to the seeds	Increased seed germination, yield, nutrient uptake, root weight and length	Akinci et al. (2009)
Broccoli	Commercial liquid HS combined with NPK fertilizers; fertigation; field experiment	Increased 15% of marketable yield and nutrient use efficiency	Selim and Mosa, (2012)
Calathea insignis Hort.	HA combined with biochar; different doses; substrate application; greenhouse experiment	Increased shoot fresh weight, crown breadth and number of leaves by 57%, 45% and 89%, respectively	Zhang et al. (2014)
Chicory	Potassium humate from compost; different doses in soil; greenhouse experiment	Bell shaped dose response curve for shoot fresh and dry weight. Shoot fresh weight increased from 9 to 69%	Valdrighi et al. (1996)
Chrysanthemum	HA from peat combined or not with NPK fertilizers; foliar spray, greenhouse experiment	Dose–effect response curve for shoot and root fresh and dry weight; increased flower diameter by 33%	Fan et al. (2014)
Common beans	HA and FA isolated from charcoal mine used in different concentration with nutrient solution; hydroponic culture; greenhouse experiment	Influenced the kinetic parameters of K uptake. Increased nutrient uptake by 41% on root dry weight	Rosa et al. (2009)
Common beans	Potassium-humate combined with micronutrients and chitosan; foliar spray; field experiment	Increased yield by 25–35%	Ibrahim and Ramadan (2015)
Cucumber	FA from 20 to 2000 ppm added to Hoagland solution	Increased growth and development, nutrient uptake and flowering	Rauthan and Schnitzer (1981)
Croton and hibiscus	HA from vermicompost at different doses; stakes production; greenhouse experiment	Speeded up the rooting of cuttings	Baldotto et al. (2012)
Cymbidium sp	HA from manures at different doses; immersion of cuttings; greenhouse experiment	Decreased the time required for acclimatization; increase in commercial product price due to better standard	Baldotto et al. (2014)
Eggplant	Foliar spray of commercial HA and different N doses; field experiment	Enhanced fruit yield from 23 to 63% and N use efficiency	Azarpour et al. (2012)

Table 1 (*Continued*)

Crop	Simplified assay description	Effects	References
Pepper	Soluble humate, pot experiment in greenhouse	Increased N use efficiency and yield by 13%	Varga and Ducsay (2003)
Pineapple	HA from vermicompost combined with beneficial microorganisms; pot filled with soil; greenhouse experiment	Improved growth and adaptation of pineapple plantlets to the ex vitro environment	Baldotto et al. (2010)
Potato	Commercial HA and FA applied to the soil or as foliar spray; field experiment	Enhanced nutrient use efficiency, and tuber weight (by 13%) and decreased incidence of hollow heart	Suh et al. (2014)
Potato	Commercial HA applied to soil at different doses; field experiment	Increased yield from 11% to 22%.	Seyedbagheri (2010)
Strawberry	Vermicompost leachates; foliar spray; field experiment	Increased fruit yield (10–14%) and decreased incidence of grey mould	Singh et al. (2010)
Strawberry	HA commercial soluble product; foliar spray at different doses; hydroponic culture under greenhouse	Enhanced yield (33%), fruit firmness and total soluble solid percent	Farahi et al. (2013)
Strawberry	HS combined with N fertilizers; foliar spray	Enhanced fruit quality reducing the number of misshapen and rotten fruits, and increased the sugar content	Neri et al. (2002)
Strawberry	HA at different doses; foliar spray and fertigation; field experiment	Increased nutrient use efficiency	Ameri and Tehranifar (2012)
Tomato	HA and FA from compost at different doses; hydroponic culture; growth chamber	Doses–response curve for shoot and root growth of tomato seedlings; HA were more bioactive than FA	Lulakis and Petsas (1995)
Tomato and cucumber	HA from vermicompost applied to substrate; different doses; pot greenhouse experiment	Increased tomato and cucumber growth	Atiyeh et al. (2002)
Tomato	HA from vermicompost combined with beneficial microorganisms; substrate application and foliar spray; field experiment	Increased fruit yield by 44–80%; decreased incidence of *Phytophora infestans*	Olivares et al. (2015)
Tomato	Different HA from forest soil mixed with nutrient solution; hydroponic culture	Enhanced net photosynthesis by 68–436% during the vegetative stages and increased fruit sugar content	Haghighi and Teixeira da Silva (2013)
Yellow passion fruit	HA at different doses and times of application as foliar spray	Increased root dry weight by 124% in seedlings	Cavalcante et al. (2013)

Faba bean	Commercial HA plus amino acids were used as foliar treatments in a field experiment	Increased growth and mineral content, 100-seed weight (by 26%) and decreased the damage by chocolate spot and rust diseases	El-Ghamry et al. (2009)
Garlic	HA from peat; different doses; foliar spray; field experiment	Enhanced efficiency of mineral nutrition, and increased from 1.96 to 2.28 fold the pyruvic acid concentration as an indicator of pungency	Denre et al. (2014)
Garlic	Biofertilizer (mix of *Azobacter*, *Azospirillum* and *Klebsiella*) and 3 sprays with humic acid (rate 2 g/L); field experiment	Increased bulb yield (from 2 to 6%) and quality as well as bulbs storage properties	Abdel-Razzak and El-Sharkawy (2013)
Gladiolus	HA from composts at different doses; corms soaked for 24 h in treatment solutions; greenhouse experiment	Increased growth and promoted early flowering	Baldotto and Baldotto (2013)
Grape	Foliar spray of HA at different plant stages	Increased berry size (width and weight) and improved fruit quality (titratable acidity and soluble solids/titratable acidity)	Ferrara and Brunetti (2010)
Lettuce	HA from vermicompost; foliar spray; field experiment in urban agriculture	Shortened cropping cycle	Hernandez et al. (2015)
Muskmelon	Microbial-enriched compost tea	Enhanced fruit yield (18% of fruit fresh weight), fruit soluble solids, firmness and linear increment in the fruit diameter, decreased powdery mildew incidence and increased nutrient use efficiency	Naidu et al. (2013)
Onion	Solution of commercial HS from leonardite was applied to substrate; greenhouse experiment	Increased root fresh weight by 42–102%	Bettonia et al. (2014)
Onion	Commercial humic acids in solution combined with micronutrients or hormone; field experiment	Increased marketable of bulbs by 26%	Boyhan et al. (2001)
Onion	Field experiment with foliar spray of HA and amino acids at different N doses	Increased total yield by 5–6%	Kandil et al. (2013)
Okra	Compost extracts combined with *Trichoderma*; foliar spray; field experiment	The shoot and tap root length, number of leaves per plant, leaf area were significantly increased; reduced Choanephora wet rot incidence by 76%	Siddiqui et al. (2008)
Peach	Soil and foliar spray of commercial humic acids	Increased fruit yield by 80%	Mansour et al. (2013)

Field responses

nudiba

Núcleo de Desenvolvimento
de Insumos Biológicos para a Agricultura

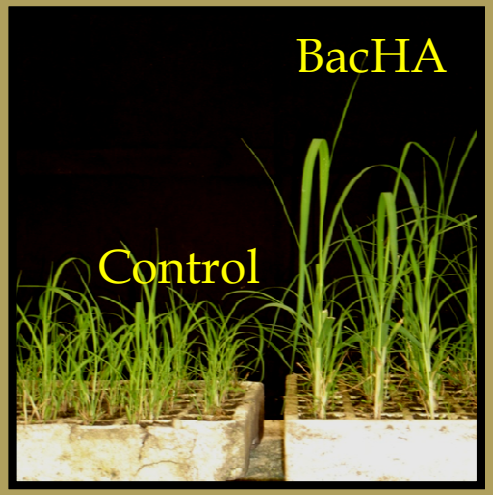
UENF Universidade Estadual do Norte Fluminense Darcy Ribeiro

Sugarcane

Maize

Other crops

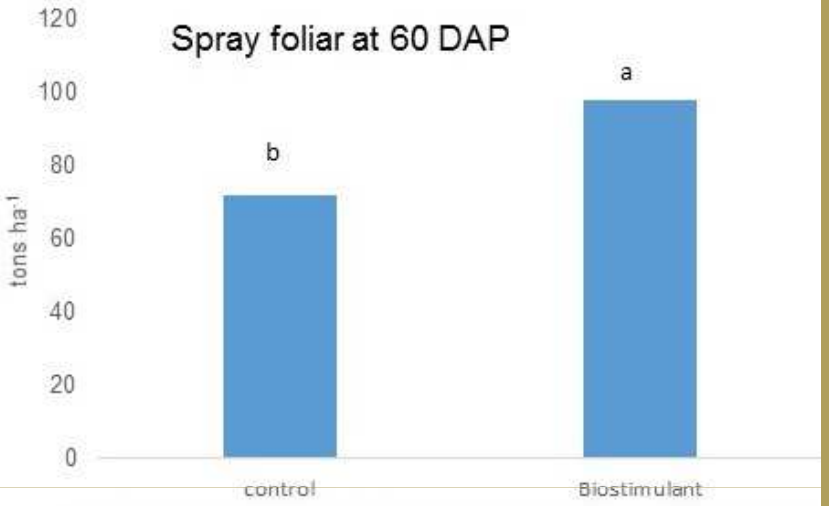
Sugarcane field experiments – HA and PGPB



Biostimulant manufactured with plant growth promoting bacteria and humic acids

furrow

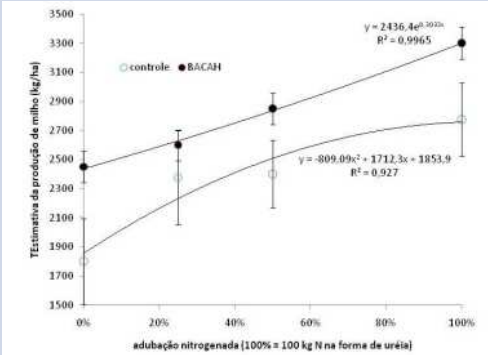
Foliar spray

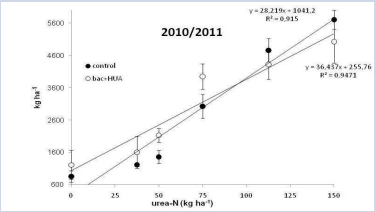
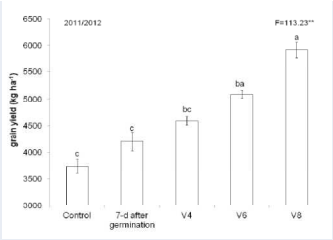
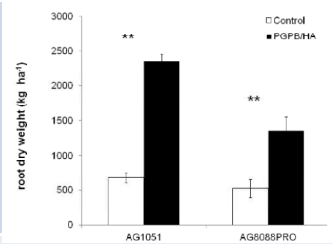
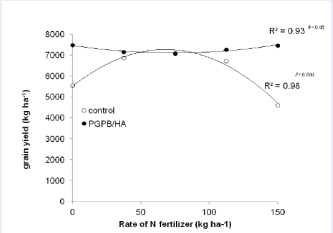


Trials	Treatments	Some details	results
Sugarcane var. NA5679	Mixed inoculant (five diazotrophic bacteria) + HA (20 mg C L^{-1})	Micropropagated plants; in vitro inoculation. 3 years	Increase of **32%** in crop yield; Increase of 10% in crop yield 1st ratoon No effect in crop yield 2nd ratoon
Sugarcane var. RB867515	H. seropedicae HRC54 + HA (20 mg C L^{-1})	foliar spray at 60 day after germination.	Increase of **24%** in crop yield;
Sugarcane RB 96 7515	Mixed inoculant (five diazotrophic bacteria) + HA (20 mg C L^{-1})	Furrow x foliar spray; Foliar spray at 30, 60 and 90-d; 3 yrs	Increase of **37 %** in crop yield (first harvesting) **No effect** 1st ratoon (5%) Increase of **24%** in crop yield 2nd ratoon;
Sugarcane RB 96 7515	Mixed inoculant (five diazotrophic bacteria) + HA (20 mg C L^{-1})	Strip trial – commercial plantation	Increase of crop yield during 3 consecutive yrs (**24%, 19% and 18%,** respectively)

A

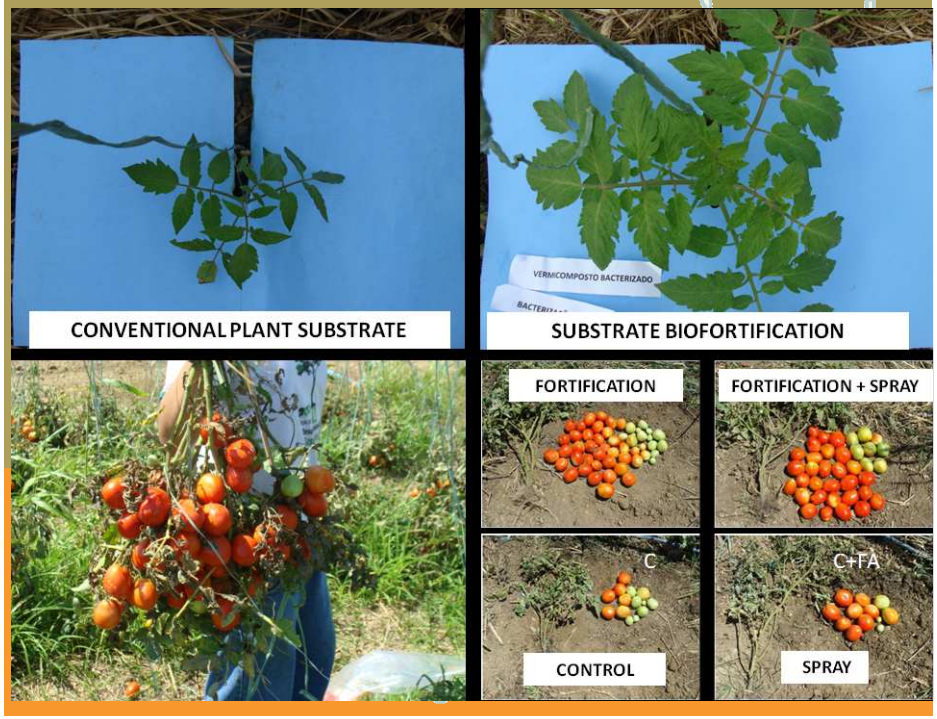
B

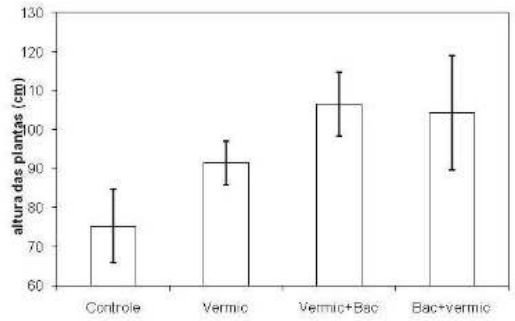
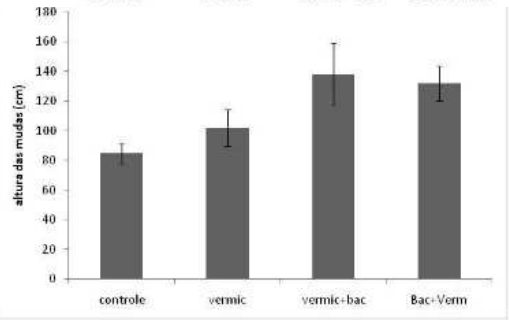
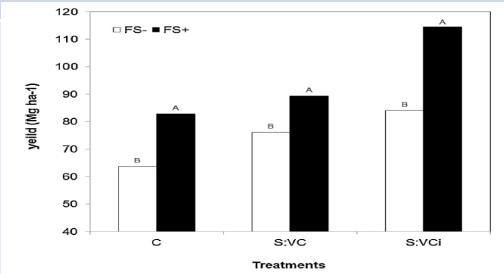
Trials	Treatments	Some details	results
Maize cv. DKB 789	*H. seropedicae* HIII206b + HA (20 mg C L^{-1})	Foliar spray at V8.N (0 e 50 Kg/ha)	+ 21 and 29% in crop yield (respectively).
Creoule/native maize	*H. seropedicae* HIII206b + HA (20 mg C L^{-1})	Applied two times at V3 and V6. (no fertilization)	+ 29% in crop yield
Maize hyb AG 1051	*H. seropedicae* HIII206b + HA (20 mg C L^{-1})	Foliar spray at **V6**. 200 Kg/ha (4-20-20) and 80 Kg N/ha (cover)	+ 65% in crop yield
Maize hyb Pionner	*H.seropedicae* Z67 + HA (20 mg C L^{-1})	Foliar spray at **V6**. No fertilization	+39% in crop yield
Maize hyb Agroceres	*Burkholderia sp.* 103, B. *silvatlantica* 101 and *H. seropedicae* HRC54 + HA (20 mg C L^{-1})	Foliar spray at V6.0, 25, 50 and 100 kg ha^{-1} urea; severe drought during growing season	

Trials	Treatments	Some details	results
Maize hyb Agroceres	Burkholderia sp. 103, B. silvatlantica 101 and H. seropedicae HRC54 + HA (20 mg C L^{-1})	Foliar spray at V6. 0, 10.4, 30, 60, 62.5 and 120 kg ha^{-1} urea; normal rain	
Maize hyb Agroceres	Burkholderia sp. 103, B. silvatlantica 101 and H. seropedicae HRC54 + HA (20 mg C L^{-1})	Different times of spray application (0, 7-d; V4, V6 and V8)	
maize AG1051 (A) and AG8088PRO (B)	*H. seropedicae* and humic acids (2 x 10^8 cells mL and 50 mg L^{-1}	450 L ha-1 at the V6 stage	
Maize hyb Agroceres	*H. seropedicae* and humic acids (2 x 10^8 cells mL and 50 mg L^{-1}	High fertilization (600 kg ha^{-1} of 4:14:8 and different N-urea 0, 37.5, 75, 112.5 and 150 kg ha)	

HidroFarm
FALKER

A
B
C
D


CONVENTIONAL PLANT SUBSTRATE
SUBSTRATE BIOFORTIFICATION
VERMICOMPOSTO BACTERIZADO
FORTIFICATION
FORTIFICATION + SPRAY
C
CONTROL
C+FA
SPRAY

Trial	treatmemts	Some details	results
Orange (Bahia)	Biological fortification of vermicompost and foliar application of diazotrophic bacteria (*H. seropedicae* strain 101, 103 and HRC54) + HA (20 mg C L^{-1})	T1: control; T2: VC (3L/pit); T2: VC + bac (3 L/pit + 150 mL bac); T3: bac+VC (foliar spray + VC in pit)	
Orange (seleta)	Biological fortification of vermicompost and foliar application of diazotrophic bacteria (*H. seropedicae* strain 101, 103 and HRC54) + HA (20 mg C L^{-1})	T1: control; T2: VC (3L/pit); T2: VC + bac (3 L/pit + 150 mL bac); T3: bac+VC (foliar spray + VC in pit)	
Lettuce	K^{+}-humates	Foliar spray: 1,6, 1,3 e 1,2 mmol C 15 d.a.t.	Reduction of 21 days in the production cycle; + 21% in the number of leaves per plant
Tomato	Biological fortification of vermicompost and foliar application of diazotrophic bacteria (*H. seropedicae* strain HRC54) + HA (20 mg C L^{-1})	Backpack sprayer with a rate equivalent to 350 L ha−1.	

The main results were obtained when some abiotic stress occurred during growth period

Basic physiological mechanism

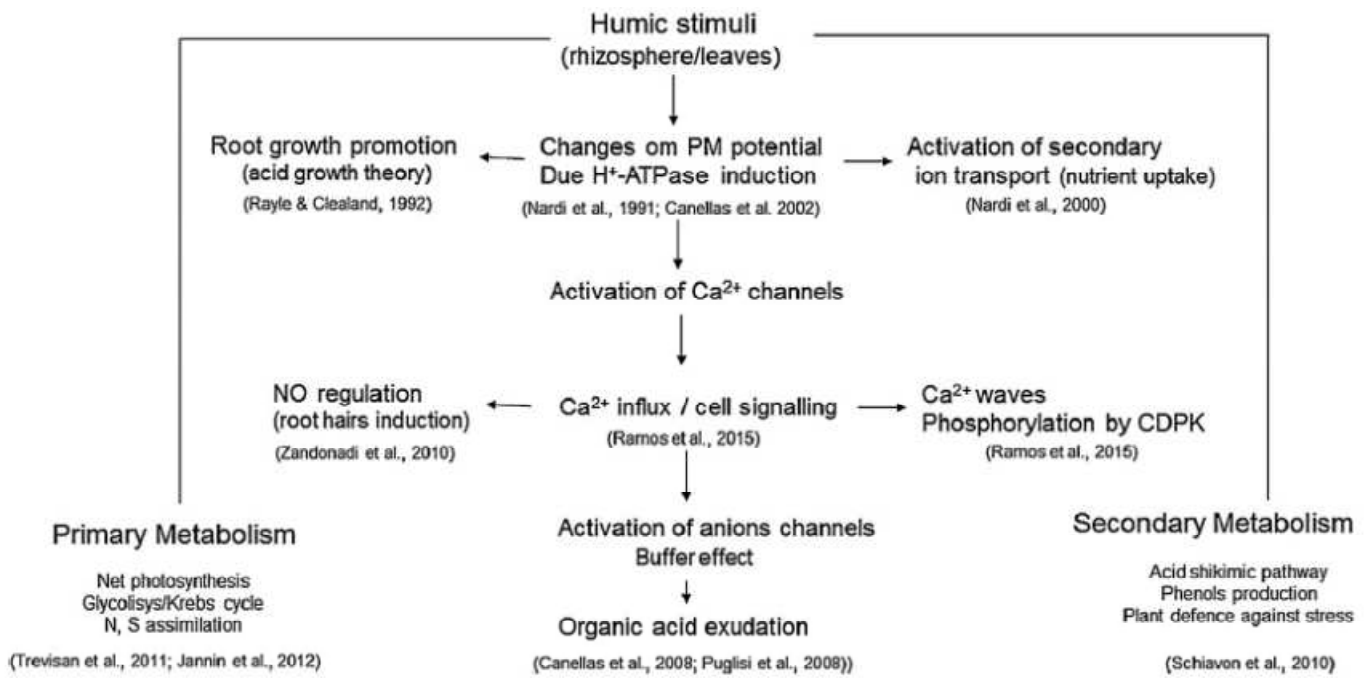


Fig. 2. General picture showing the modes of action of humic substances, in line with the acid growth theory, as elicitor of cell signalling by induction of plasma membrane (PM) H^+-ATPase. NO = nitric oxide; CDPK = calcium-dependent protein kinase.

Humic and fulvic acids as biostimulants in horticulture

Luciano P. Canellas[a,b,*], Fábio L. Olivares[a], Natália O. Aguiar[a], Davey L. Jones[b], Antonio Nebbioso[c], Pierluigi Mazzei[c], Alessandro Piccolo[c]

Scientia Horticulturae 196 (2015) 15–27

Integrative approach

Humic substances affect *Arabidopsis* physiology by altering the expression of genes involved in primary metabolism, growth and development

Sara Trevisan[a], Alessandro Botton[b], Silvia Vaccaro[a], Alice Vezzaro[a], Silvia Quaggiotti[a,*], Serenella Nardi[a]

Environmental and Experimental Botany 74 (2011) 45–55

Table 3
List of *Arabidopsis* up-regulated transcripts isolated by cDNA-AFLP along with Blast results. Results obtained by BlastN and tBlastX* algorithms.

TDF	Length (bp)	AGI no.	Putative gene function	*E* value	Primers combination	Expression patterns
40	253	ATCG00150	ATPase complex CF0 subunit (ATPI)	0.021	G03	+
54	276	AT2G21870	Putative ATP synthase. Unknown protein	0.096	G08	+
142	119	AT4G19210	Member of RLI subfamily. ABC transporter (ATRLI2)	0.001	I09	+
46	356	AT1G08930	EARLY RESPONSE TO DEHYDRATION 6 (ERD6)	2E−11	J02	+
81	60	AT3G23660	Transport protein, putative (GAD2)	1E−21	A09	+
61	314	ATCG00730	Cytochrome b6/f complex subunit IV (PETD)	0.87	B05	+
119	75	AT5G23190	Cytochrome P450, family 86, subfamily B, polypeptide 1 (CYP86B1)	1E−13	I02	+
11	68	ATCG00680	Photosystem II 47 kDa protein (PSBB)	2E−08	D02	+
42	209	AT1G79040	Photosystem II subunit R (PSBR)	8E−17	G03	+
110	147	ATCG00020	Chlorophyll binding protein D1 (PSBA)	4E−27	I02	+
112	140	AT5G54270	LIGHT-HARVESTING CHLOROPHYLL BINDING PROTEIN 3 (LHCB3)	1E−14	I02	+
60	143	AT1G67090	RuBisCO small subunit 1 (RBCS-1A)	2E−07	B05	+
66	140	AT5G45680	FKBP-type peptidyl-prolyl cis-trans isomerase3 (AtFKBP13)	1E−26	A16	+
139	239	AT1G09130	ClpP protease complex subunit (ClpR3)	4E−11	I09	+
4	206	AT4G24190	SHEPHERD (SHD)	2E−05	D02	+
9	131	AT3G46000	ACTIN DEPOLYMERIZING FACTOR 2 (ADF2)	1E−14	D02	+
137	268	AT3G17850	IRE homolog; protein kinase-like protein	2E−04	I09	+
111	147	AT1G50030	TARGET OF RAPAMYCIN (TOR)	3E−15	I02	+
113	135	AT3G57390	AGAMOUS-LIKE 18(AGL18)	1E−23	I02	+
114	167	AT5G23720	PROPYZAMIDE-HYPERSENSITIVE 1 (PHS1)	2E−57	I02	+
128	71	AT1G12360	KEULE	2E−04	I08	+
93	154	AT1G53380	Unknown protein (Similar to UNE1 (unfertilized embryo sac 1 At1g29300))	2E−05	C04	+
29	304	AT2G40940	ETHYLENE RESPONSE SENSOR 1 (ERS1)	1E−04	H03	+
10	84	AT3G16460	Jacalin lectin family protein	4E−08	D02	+
31	236	AT3G60370	Immunophilin/FKBP-type peptidyl-prolyl cis-trans isomerase family protein	1E−04	H03	+

TOR kinase

Sensor of nutrients and other environmental cues

Nutrient and energy sensing and signalling mechanisms constitute the most ancient and fundamental regulatory networks to control growth and development of all life form. The target of rapamycin (TOR) protein kinase is modulated by diverse **nutrient, energy, hormone and stress inputs** and **plays a central role in regulation of cell proliferation, growth, metabolism and stress responses form yeasts to plants and animals.**

ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Current Opinion in Plant Biology

Novel links in the plant TOR kinase signaling network

Yan Xiong[1] and Jen Sheen[2,3]

CrossMark

A recent report nicely demonstrates that the vacuolar H^+-ATPase activates the TORC1 complex in the presence of amino acids. This In plants the v-ATPase has also important roles in nutrient storage and possibly signalling. Interestingly it has been recently shown that growth-promoting humic substances can stimulate the expression of the *Arabidopsis* TOR gene (*Trevisan et al., 2011)*

ELSEVIER

Available online at www.sciencedirect.com

SciVerse ScienceDirect

Current Opinion in Plant Biology

Sensing nutrient and energy status by SnRK1 and TOR kinases

Christophe Robaglia[1], Martine Thomas[2] and Christian Meyer[3]

HS changes the plant nutrient sensing

Phosphorus speciation and high-affinity transporters are influenced by humic substances

Keiji Jindo[1,2], Tatiane Sanches Soares[1], Lázaro Eustáquio Pereira Peres[3], Inga Golçalvez Azevedo[1], Natália Oliveira Aguiar[1], Pierluigi Mazzei[4], Riccardo Spaccini[4], Alessandro Piccolo[4], Fábio Lopes Olivares[1], and Luciano Pasqualoto Canellas[1*]

10.1002/jpln.201500228 *J. Plant Nutr. Soil Sci.* 2016, *179*, 206–214

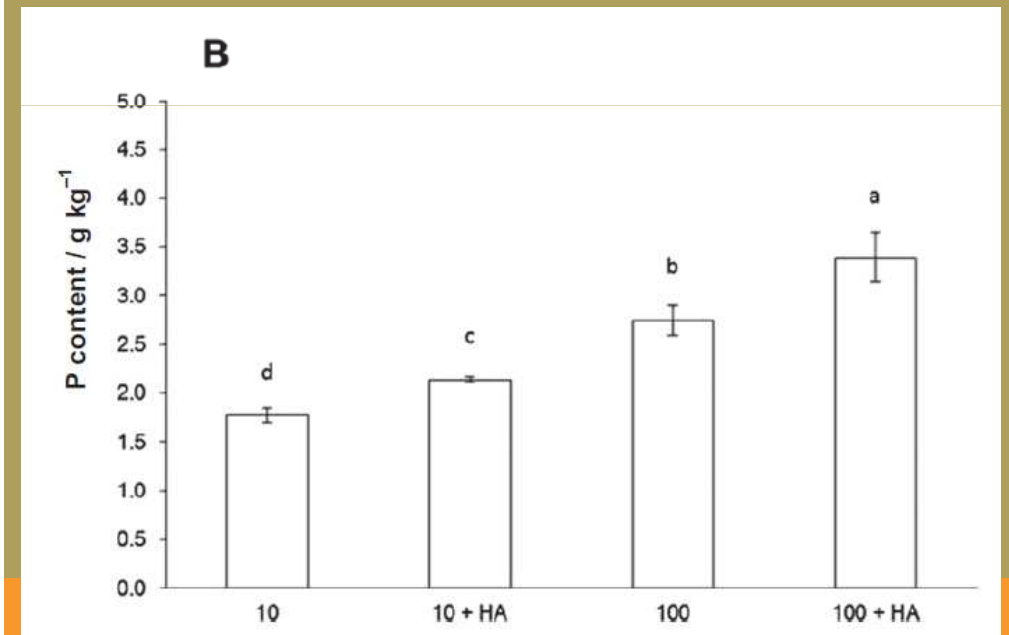
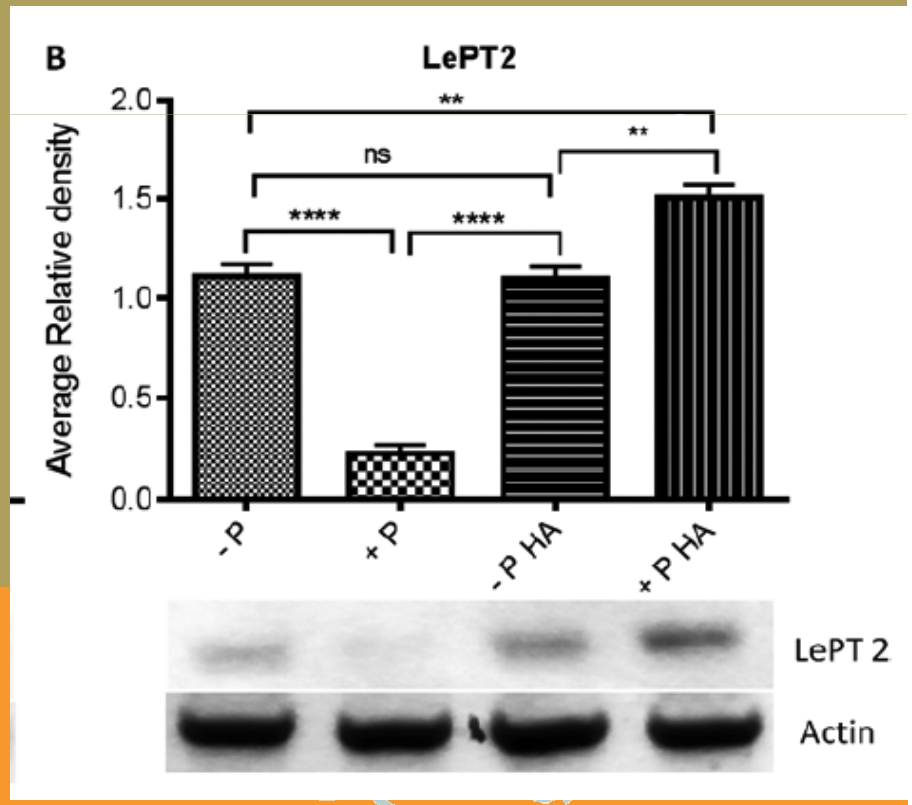
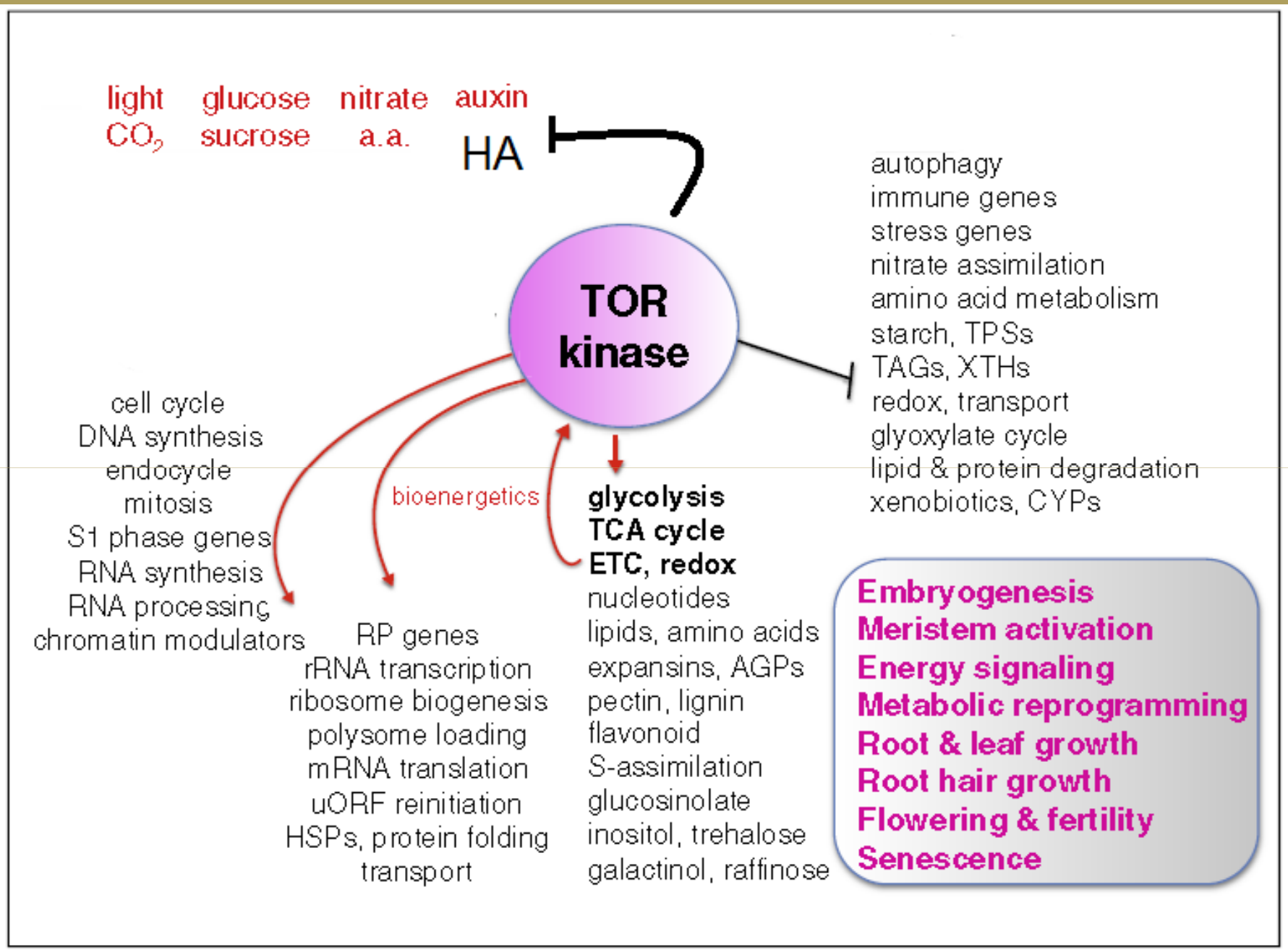
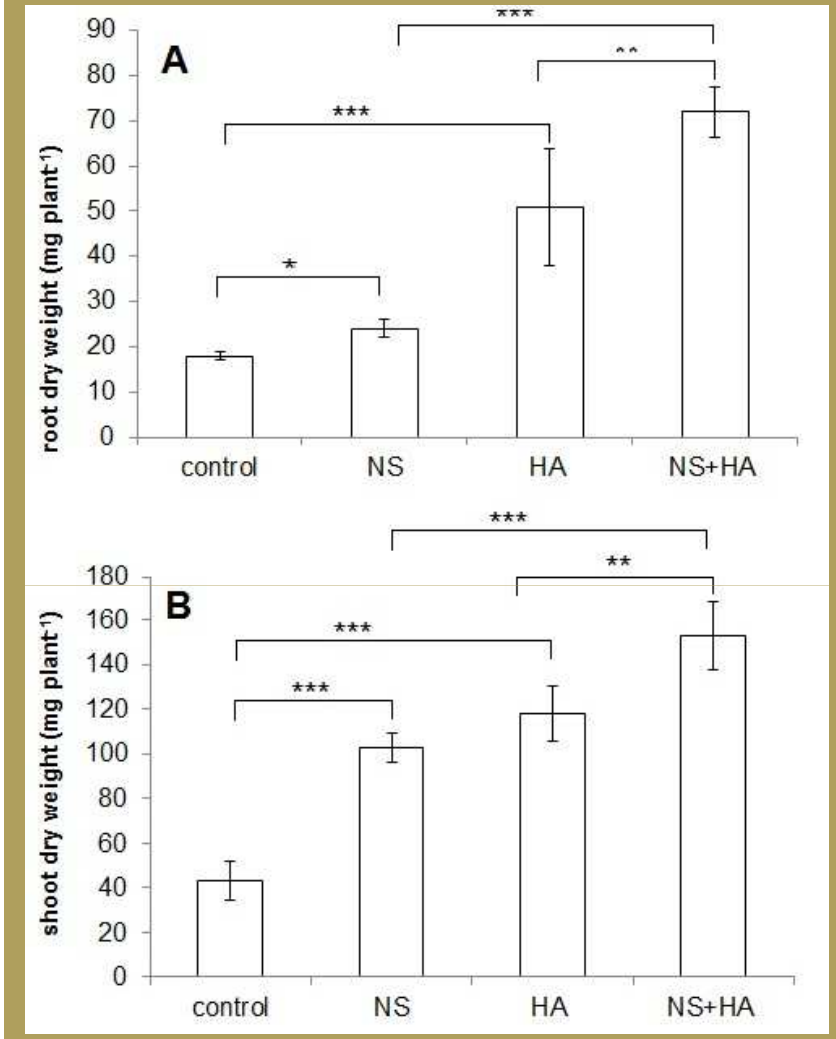


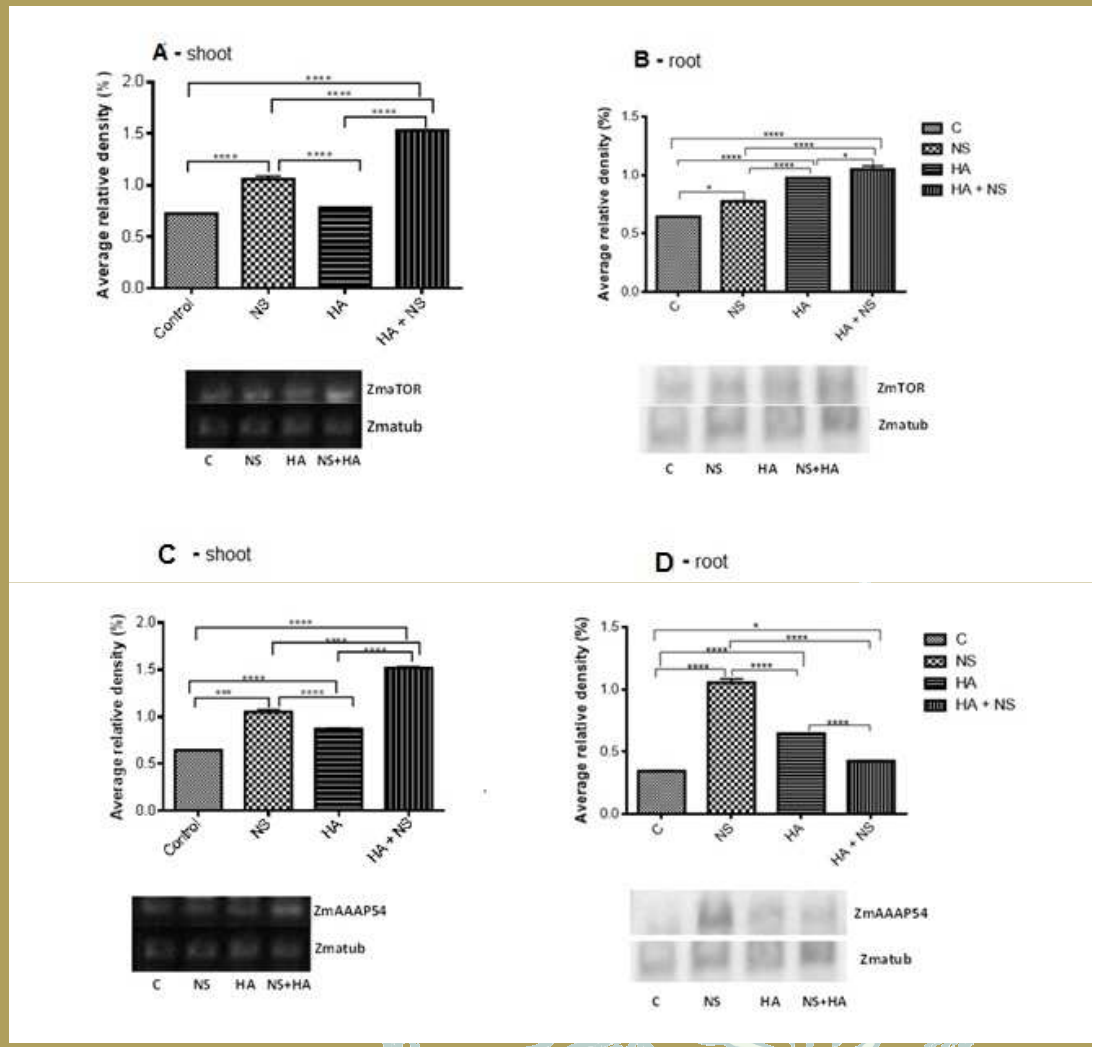
Figure 3: Phosphorus concentrations of the leaves (A), and roots (B) of tomato seedlings treated with two different P concentrations (10 and 100 mg kg^{-1} KH_2PO_4) with or without humic acids. The bars represent the ± standard deviations of the means (n = 6). The Tukey's test (P < 5%) for comparison of the means are reported as minor letters above each bar.



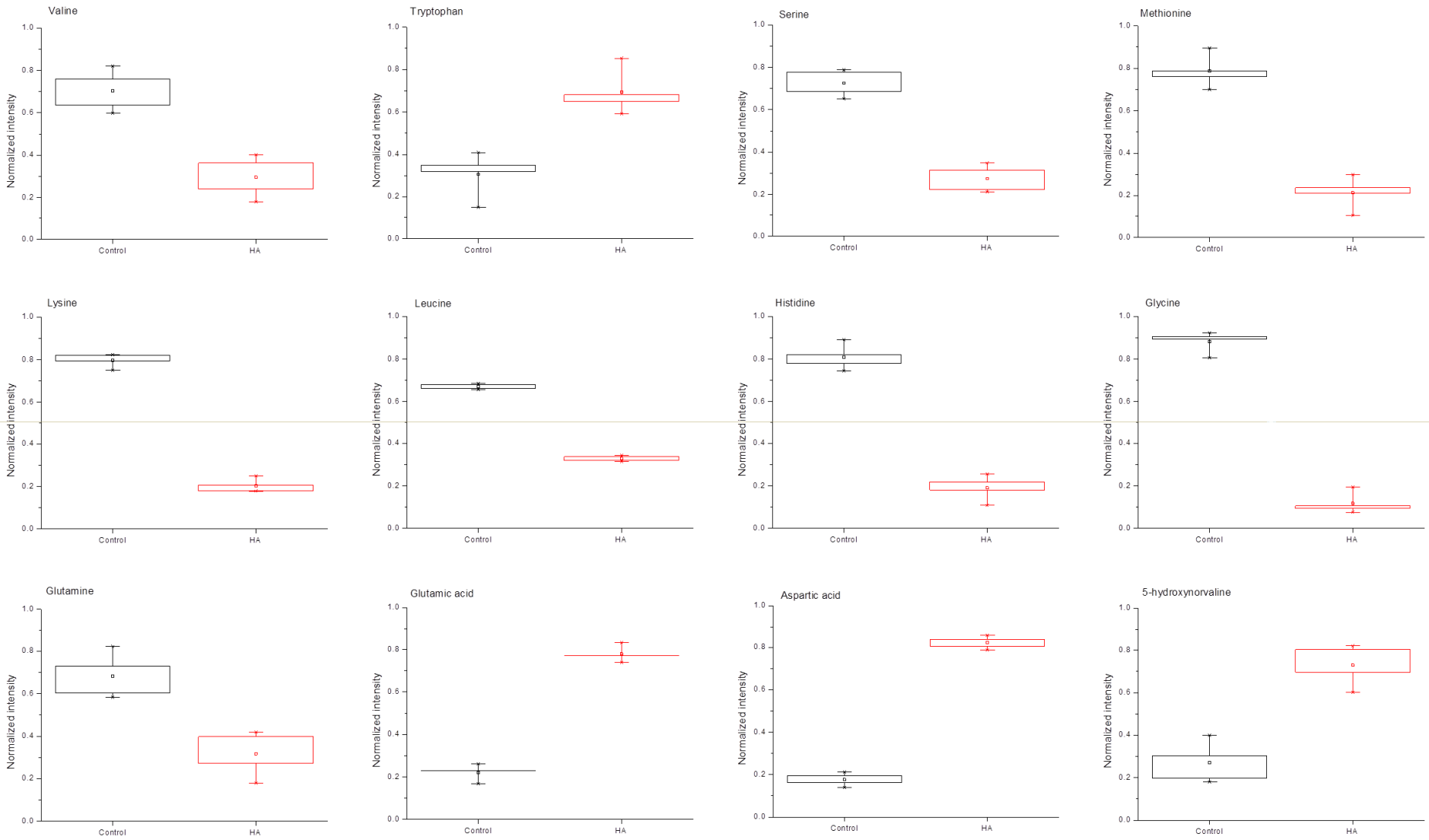

light
CO_2
glucose
sucrose
nitrate
a.a.
auxin
HA
TOR kinase
autophagy
immune genes
stress genes
nitrate assimilation
amino acid metabolism
starch, TPSs
TAGs, XTHs
redox, transport
glyoxylate cycle
lipid & protein degradation
xenobiotics, CYPs
cell cycle
DNA synthesis
endocycle
mitosis
S1 phase genes
RNA synthesis
RNA processing
chromatin modulators
bioenergetics
RP genes
rRNA transcription
ribosome biogenesis
polysome loading
mRNA translation
uORF reinitiation
HSPs, protein folding
transport
glycolysis
TCA cycle
ETC, redox
nucleotides
lipids, amino acids
expansins, AGPs
pectin, lignin
flavonoid
S-assimilation
glucosinolate
inositol, trehalose
galactinol, raffinose
Embryogenesis
Meristem activation
Energy signaling
Metabolic reprogramming
Root & leaf growth
Root hair growth
Flowering & fertility
Senescence

Changes in nutrient sensing



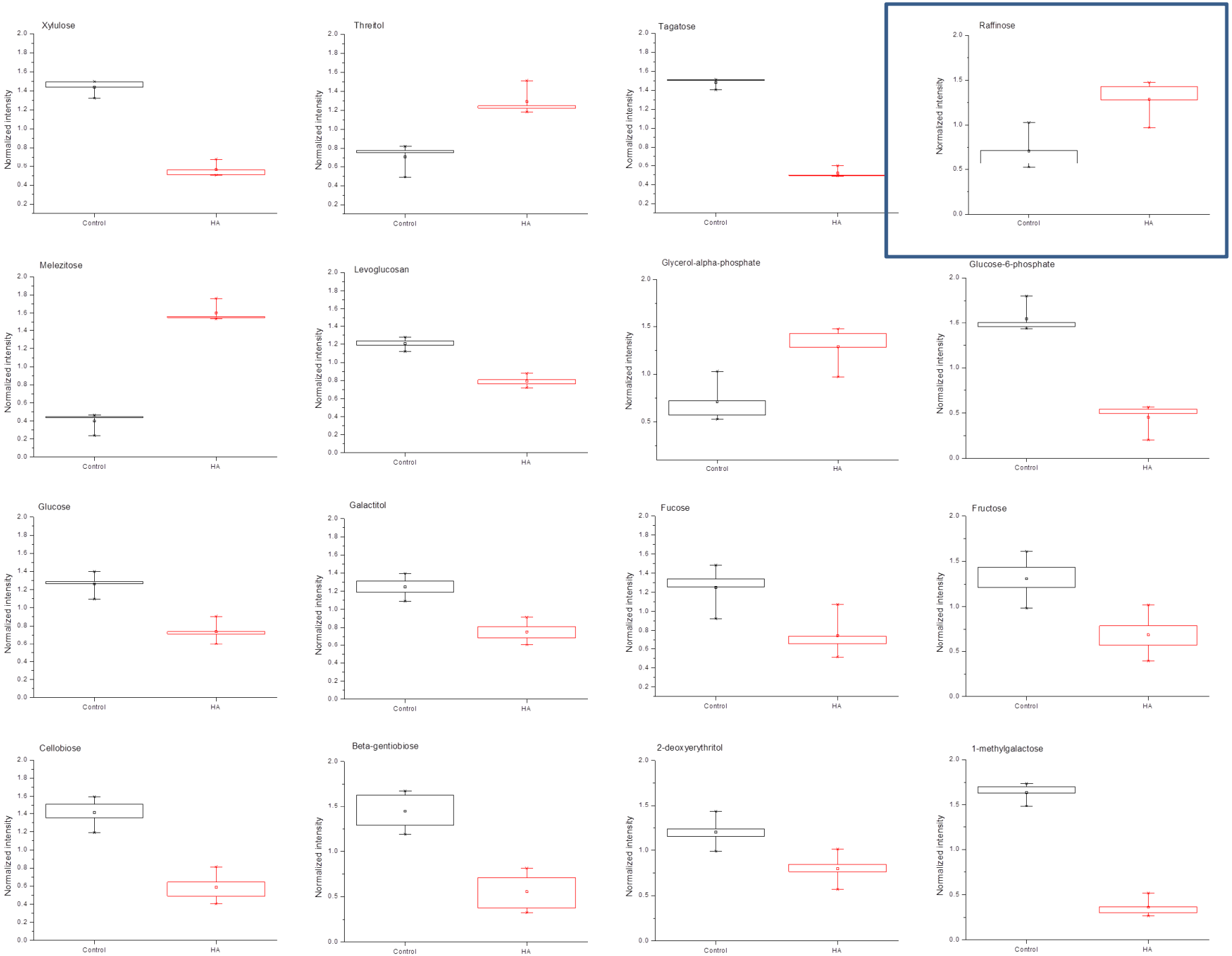


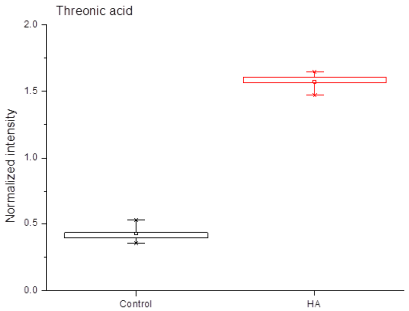
Amino acids – Leaves extract

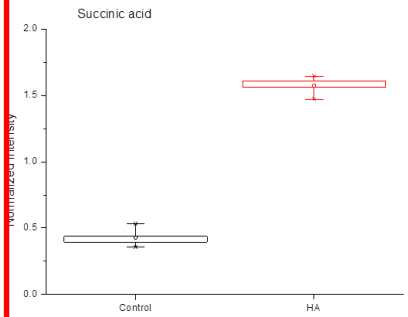


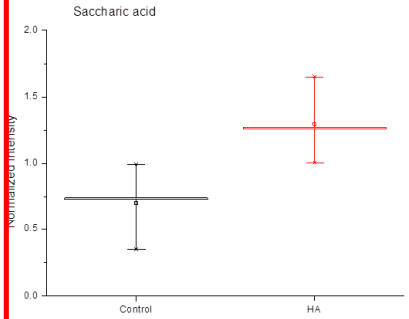
CONTROL

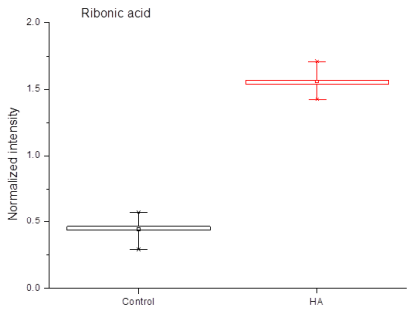
HA

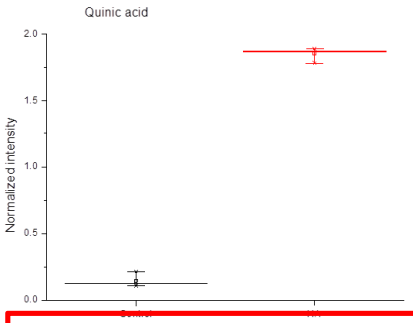

Xylulose
Threitol
Tagatose
Raffinose
Melezitose
Levoglucosan
Glycerol-alpha-phosphate
Glucose-6-phosphate
Glucose
Galactitol
Fucose
Fructose
Cellobiose
Beta-gentiobiose
2-deoxyerythritol
1-methylgalactose
Normalized intensity
Control
HA

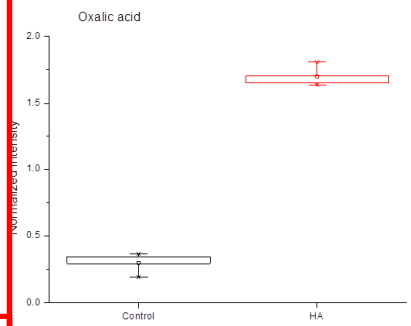

Threonic acid
Normalized intensity
2.0
1.5
1.0
0.5
0.0
Control
HA

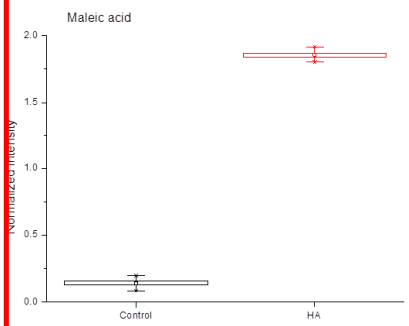

Succinic acid
2.0
1.5
1.0
0.5
0.0
Control
HA

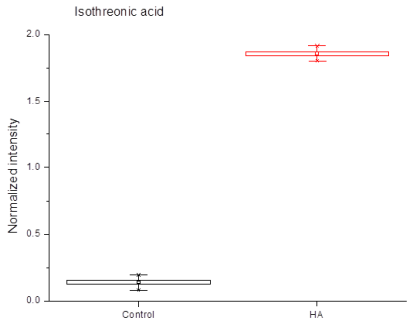

Saccharic acid
2.0
1.5
1.0
0.5
0.0
Control
HA

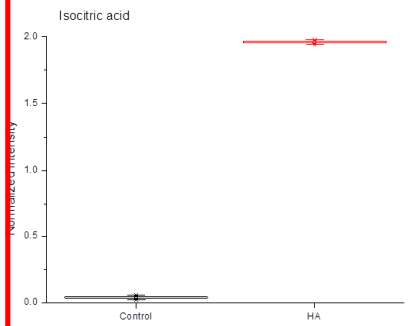

Ribonic acid
Normalized intensity
2.0
1.5
1.0
0.5
0.0
Control
HA

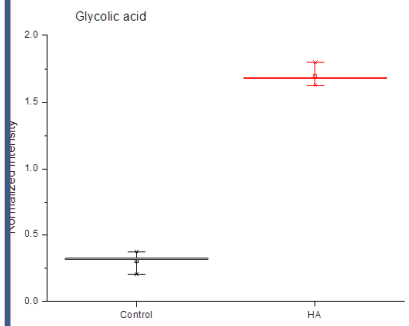

Quinic acid
Normalized intensity
2.0
1.5
1.0
0.5
0.0

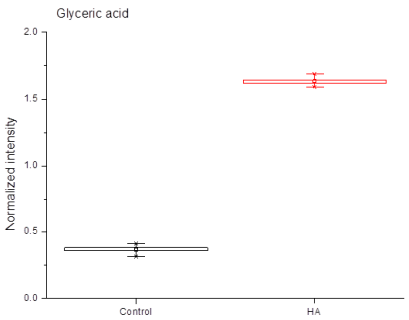

Oxalic acid
2.0
1.5
1.0
0.5
0.0
Control
HA

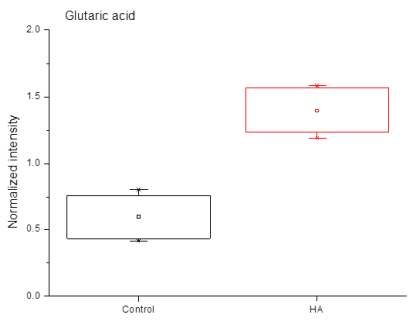

Maleic acid
2.0
1.5
1.0
0.5
0.0
Control
HA

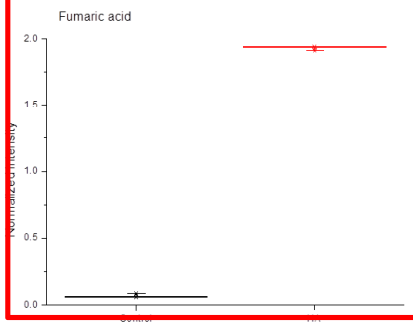

Isothreonic acid
Normalized intensity
2.0
1.5
1.0
0.5
0.0
Control
HA

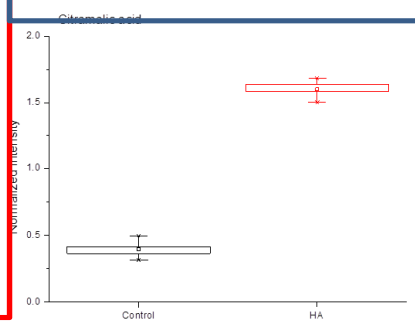

Isocitric acid
2.0
1.5
1.0
0.5
0.0
Control
HA

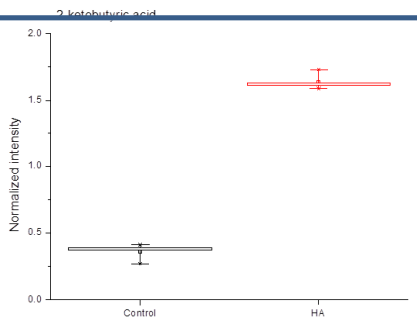

Glycolic acid
2.0
1.5
1.0
0.5
0.0
Control
HA

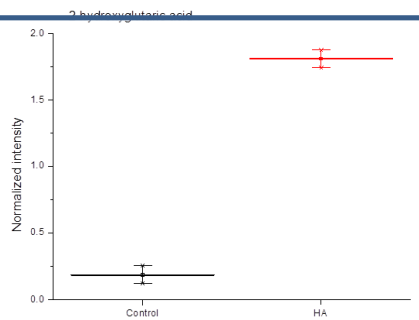

Glyceric acid
Normalized intensity
2.0
1.5
1.0
0.5
0.0
Control
HA


Glutaric acid
Normalized intensity
2.0
1.5
1.0
0.5
0.0
Control
HA

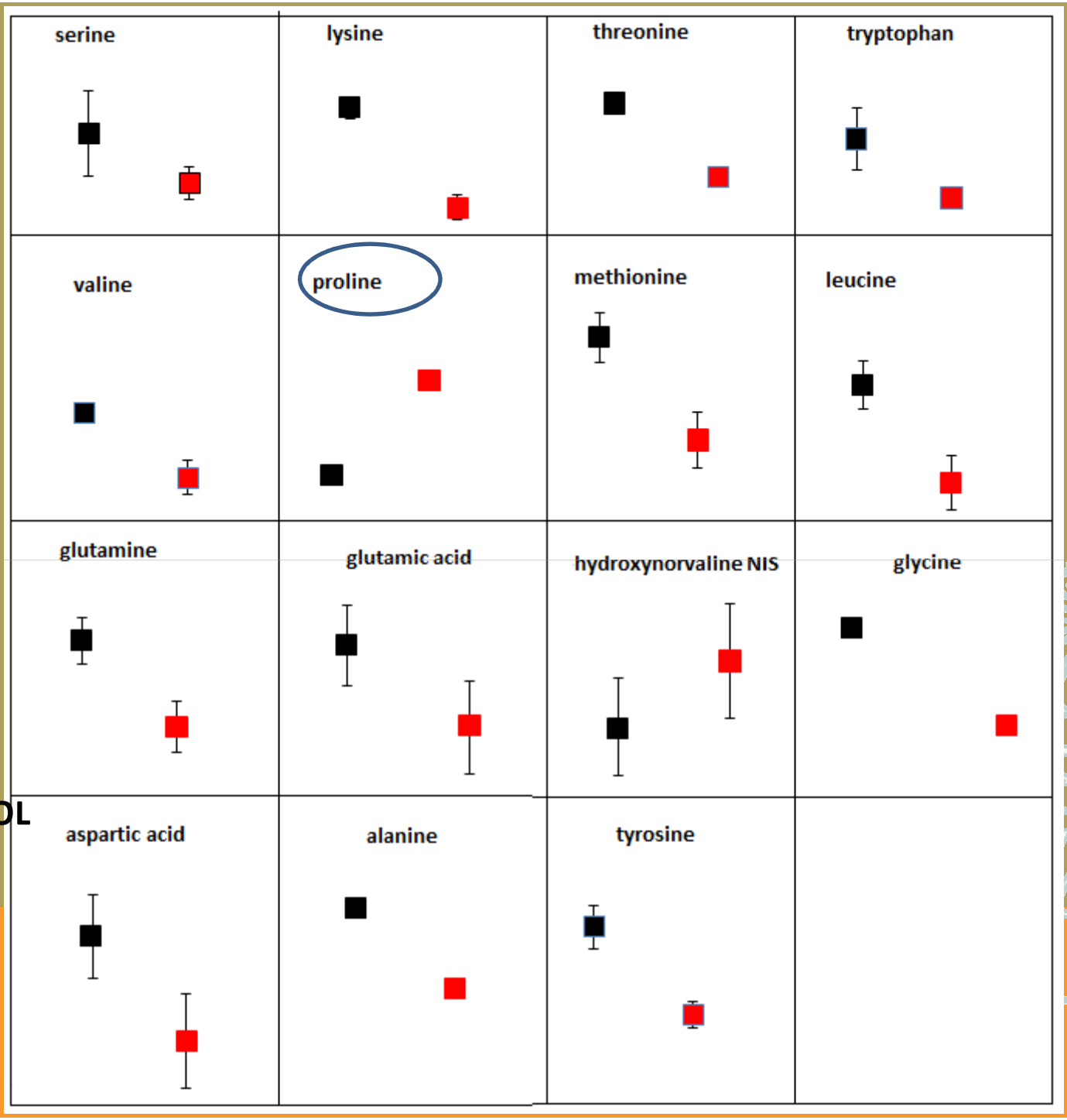

Fumaric acid
2.0
1.5
1.0
0.5
0.0


2.0
1.5
1.0
0.5
0.0
Control
HA


Normalized intensity
2.0
1.5
1.0
0.5
0.0
Control
HA

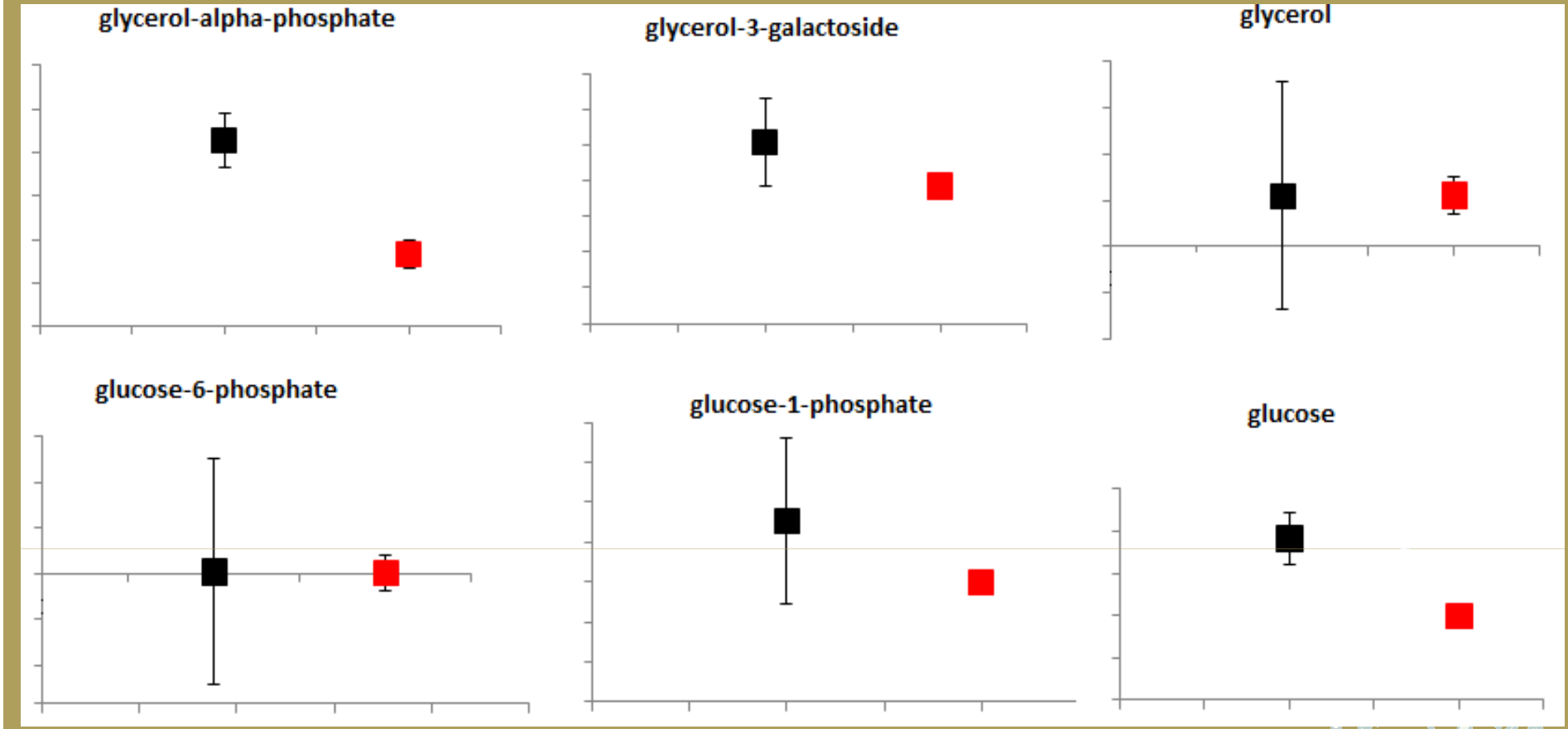

Normalized intensity
2.0
1.5
1.0
0.5
0.0
Control
HA

Amino acids - Root extracts



CONTROL

HA

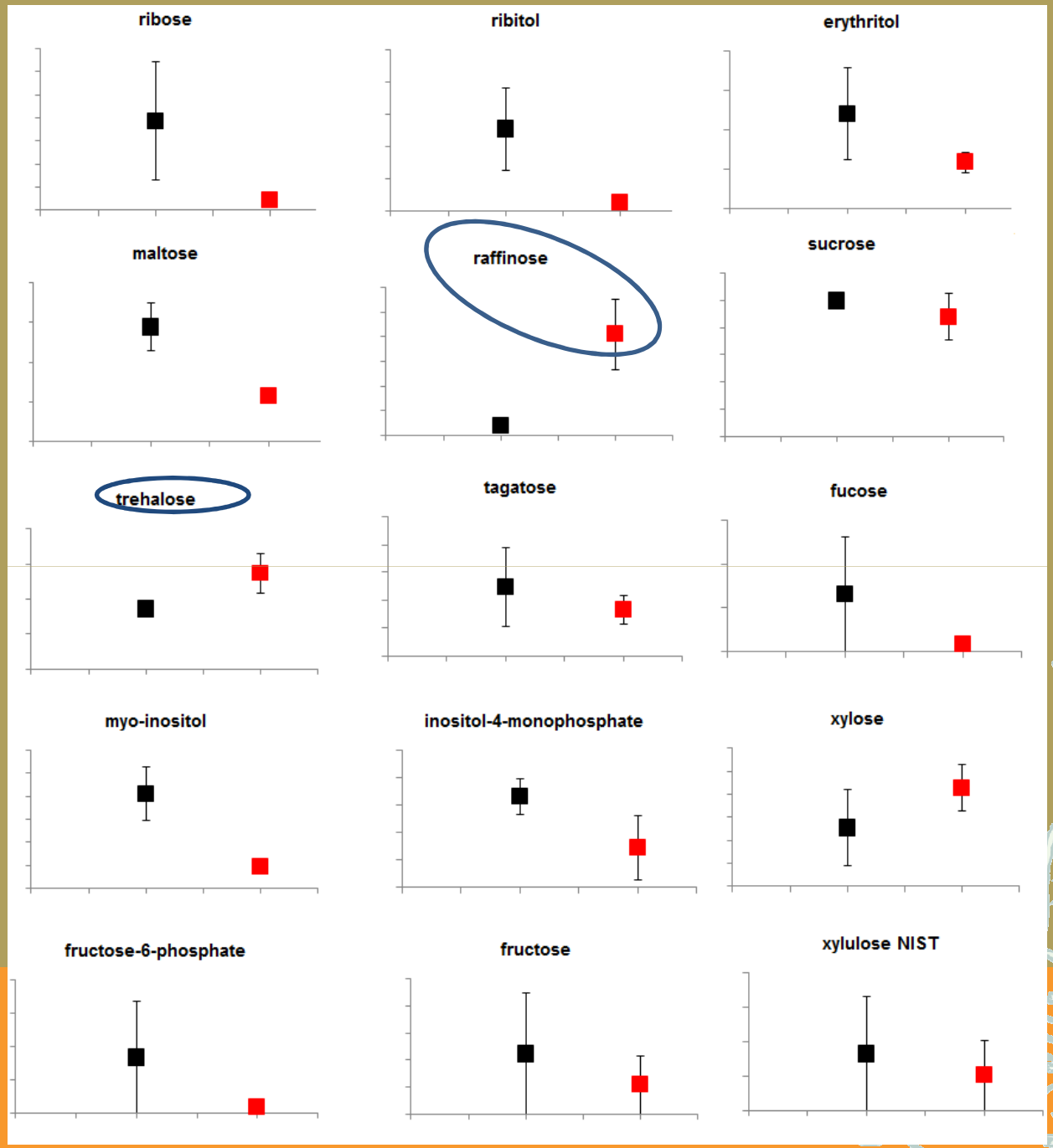


Sugars- ROOT EXTRACTS

CONTROL

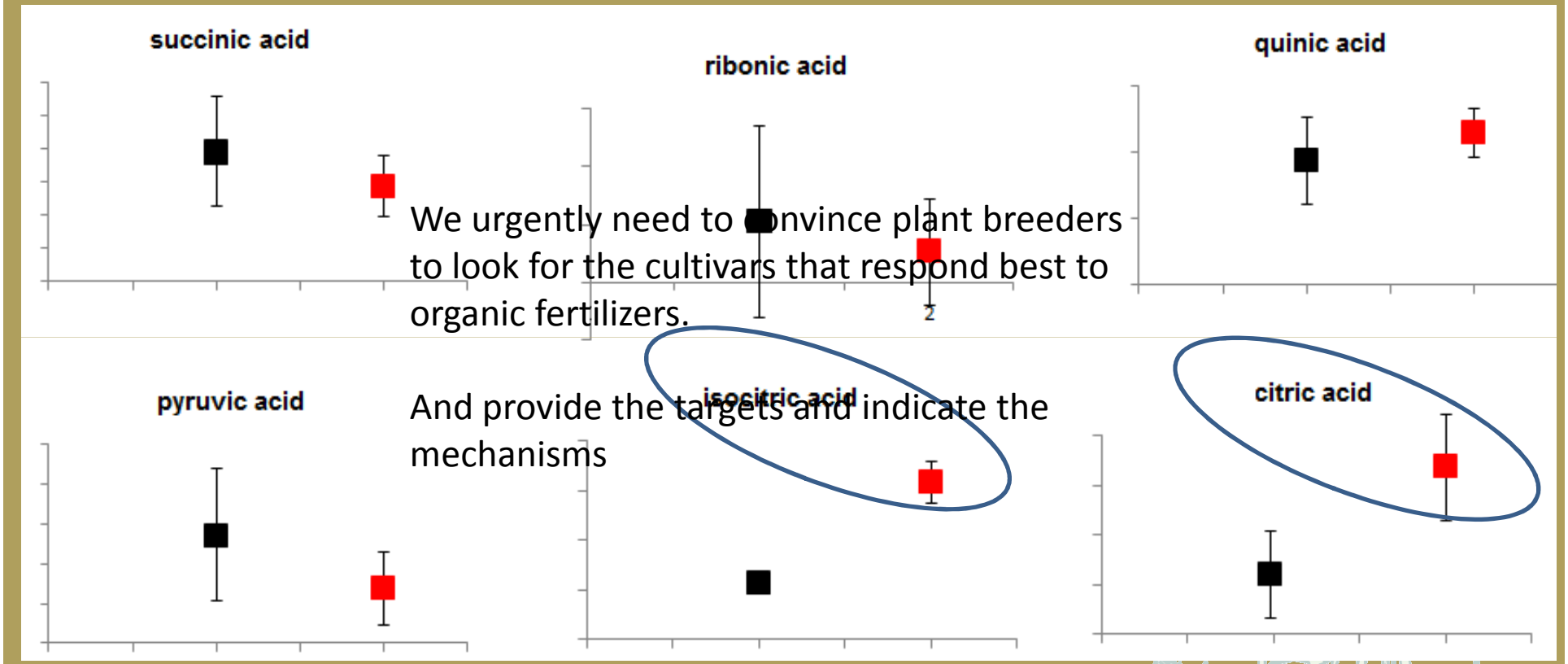
HA

Sugars- ROOT EXTRACTS



CONTROL

HA



We urgently need to convince plant breeders to look for the cultivars that respond best to organic fertilizers.

And provide the targets and indicate the mechanisms

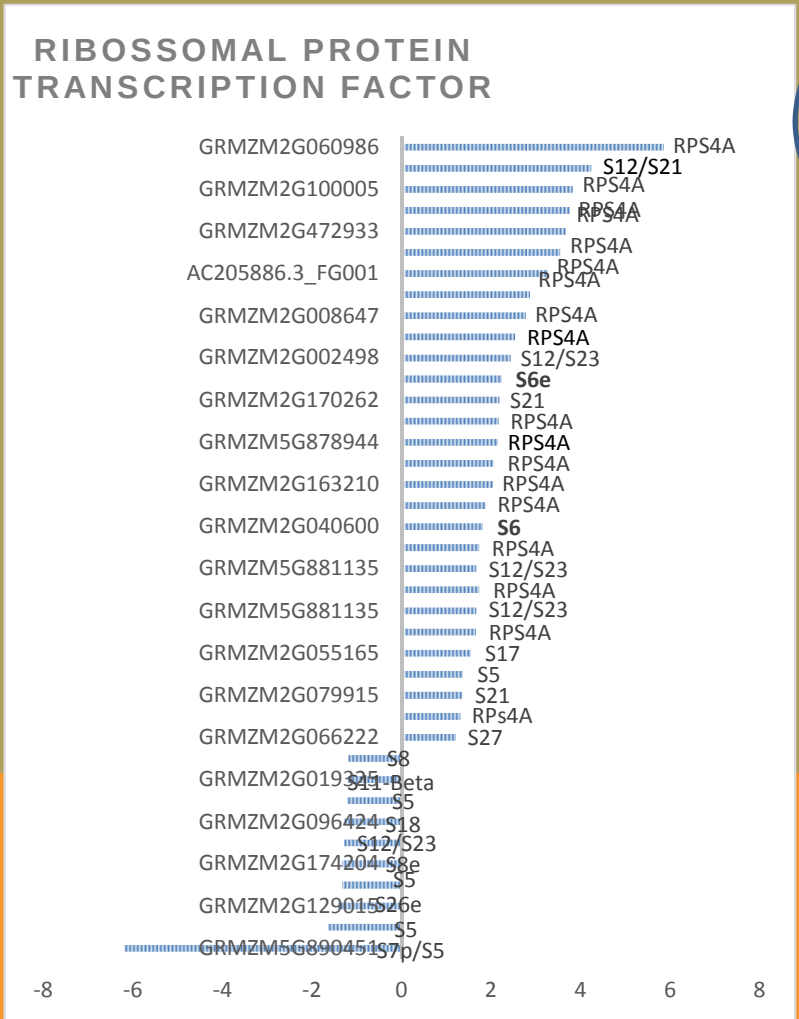
ORGANIC ACIDS- ROOT EXTRACTS

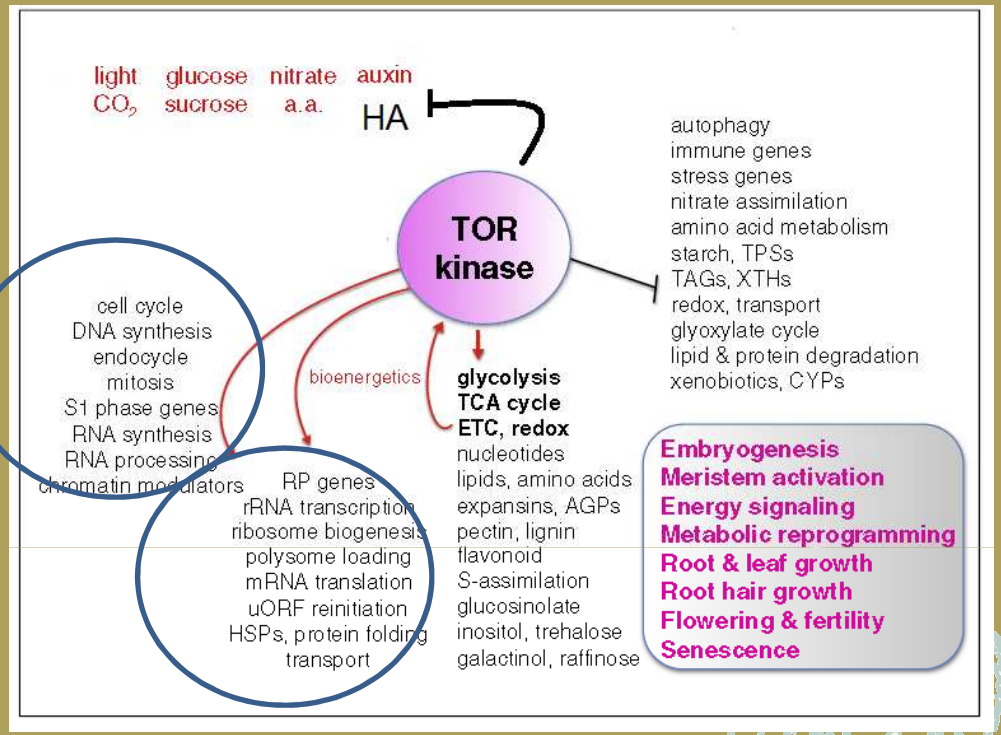
CONTROL

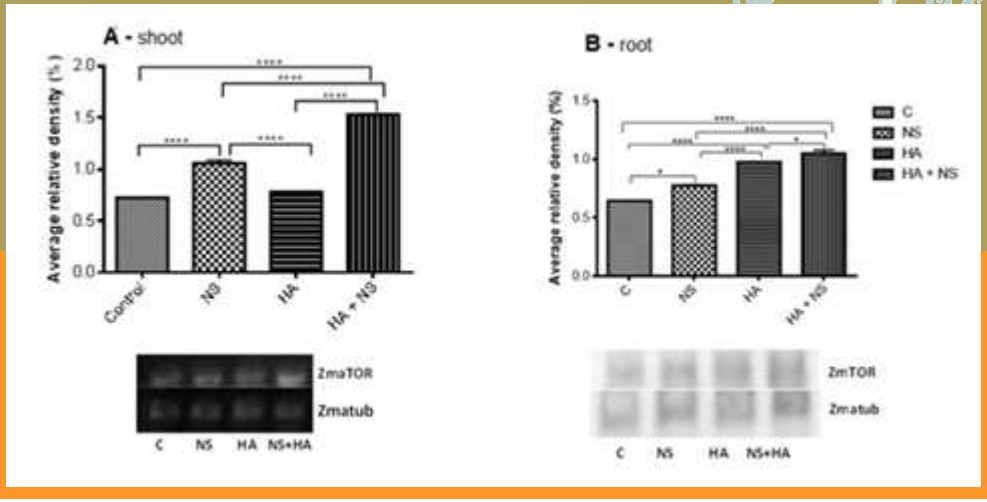
HA

In conclusion:

Humic acids modify the nutrient plant sensing changing the expression of TOR kinase ; this effect can be useful as molecular target to screening cultivars in breeding programs concerning HS







In conclusion II

We urgently need to convince plant breeders to look for the cultivars that respond to organic fertilizers.

and provide the targets and indicate the mechanisms for this search

Thanks for the attention