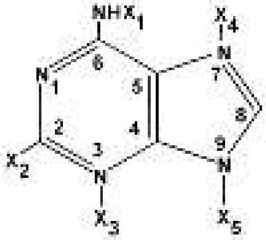
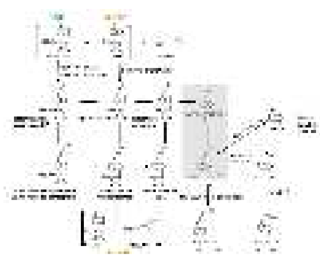
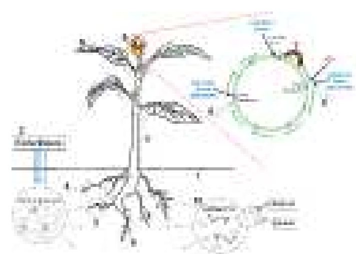


Circular systems from Water to Land: the use of Fish Manure from Aquaculture in Agriculture





Jean W. H. Yong (“John” 杨远方)

SLU

Hortikulturell produktionsfysiologi (HPF),
Institutionen för biosystem och teknologi

Curtin University

Swedish University of Agricultural Sciences

THE UNIVERSITY OF WESTERN AUSTRALIA

NANYANG TECHNOLOGICAL UNIVERSITY

“Accidental” soil scientist!

2018


Mangroves
Sustainable Growth in
SEA to FRESH-
WATER!
Eastern Thailand

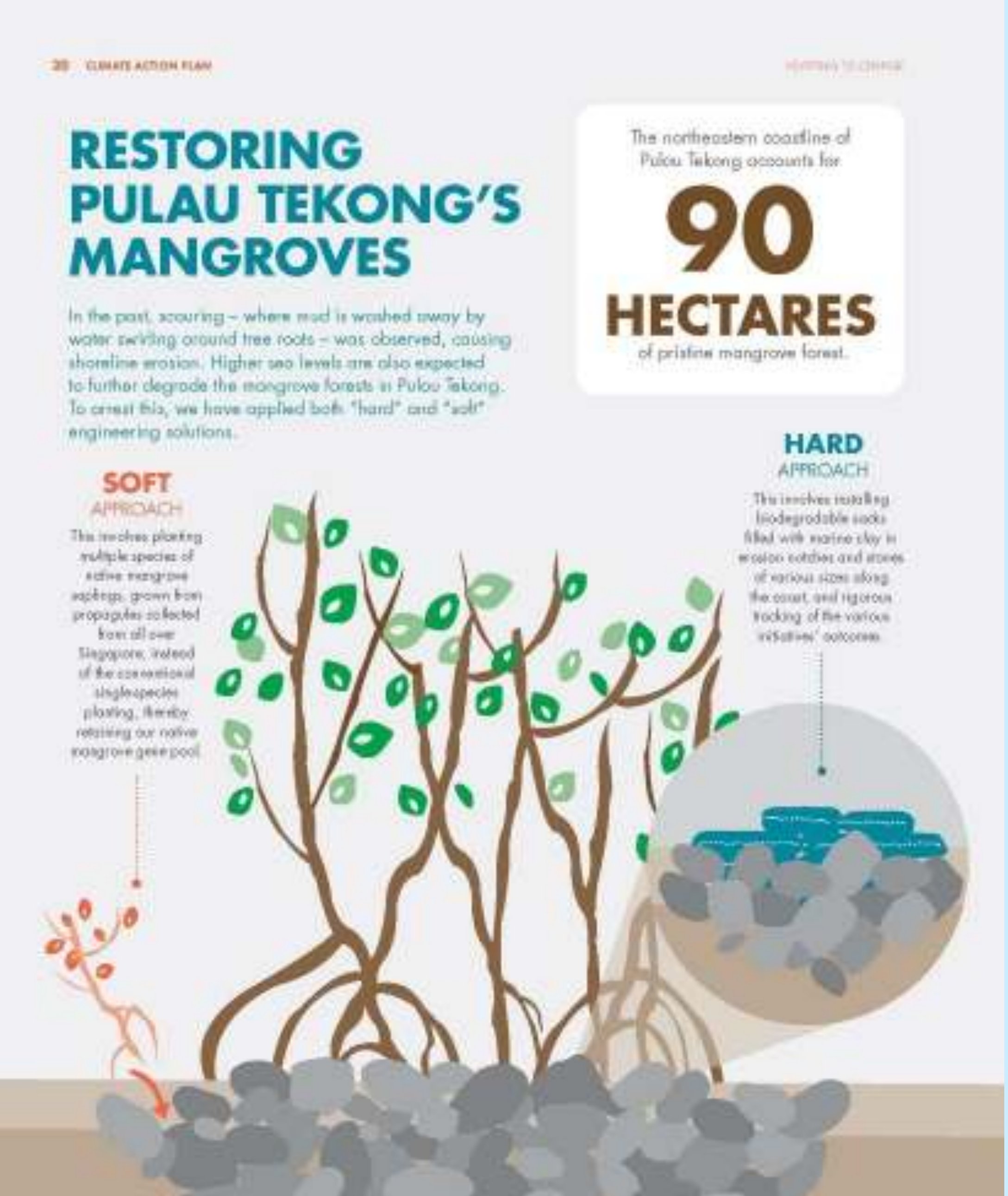

Marine Fish Habitats
NORTHERN SPECIES
Mullet
Mangrove jack
Red mangroves
Orange mangroves
Paperbarks
Tiger prawns
Connectivity (water flow) between our varied coastal habitats is vitally important. These diverse habitats support aquatic life including fish, crabs and shellfish. Many species need to move between habitats at different times of their lives to breed and complete their life cycle. It is important to protect these habitats so that fish gain access when needed. Under the Fisheries Act 1994, all marine plants are protected, including mangroves, seagrasses, algae, saltmarsh plants and adjacent plants growing in the tidal zone.
The Department of Primary Industries has responsibility under the Fisheries Act to ensure the continuation of fish habitats and fish stocks into the future.
For more information, contact:
DPI Call Centre on 13 25 23, or visit our website at www.dpi.qld.gov.au/fishweb
Remember! No habitat = No fish!
Seagrasses
Barramundi
Mud crabs
Telescope mud whelks
Sedges
Vital community assets
Managing our fish habitats
Primary Industries and Fisheries


Aquaculture and Mangroves can
Co-EXIST
Surabaya, Java, Indonesia

Mangroves growing in freshwater

Christmas island, Australia

Aquaculture and Mangroves can Co-EXIST



CLIMATE ACTION PLAN

RESTORING PULAU TEKONG'S MANGROVES

In the past, scouring – where mud is washed away by water swirling around tree roots – was observed, causing shoreline erosion. Higher sea levels are also expected to further degrade the mangrove forests in Pulau Tekong. To arrest this, we have applied both "hard" and "soft" engineering solutions.

The northeastern coastline of Pulau Tekong accounts for

90 HECTARES

of pristine mangrove forest.

SOFT APPROACH

This involves planting multiple species of native mangrove saplings, grown from propagules collected from all over Singapore, instead of the conventional single-species planting, thereby retaining our native mangrove gene pool.

HARD APPROACH

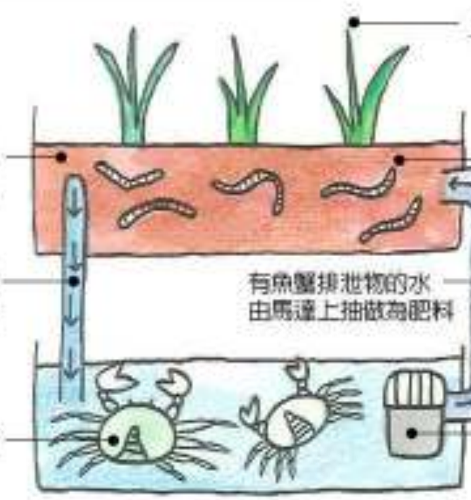
This involves installing biodegradable sacks filled with marine clay in erosion notches and stones of various sizes along the coast, and rigorous tracking of the various initiatives' outcomes.

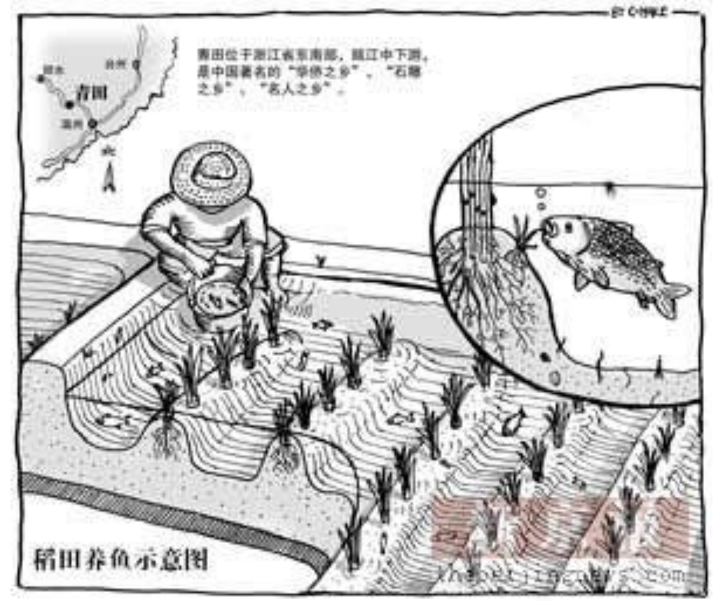
Green Engineering

Pulau Tekong, Singapore


Replanting Mangroves
2
Biodegradable
Bags
Biodegradable Rings

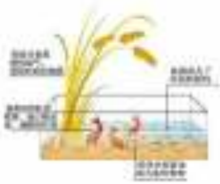
Rice – Animals Co-cultivation





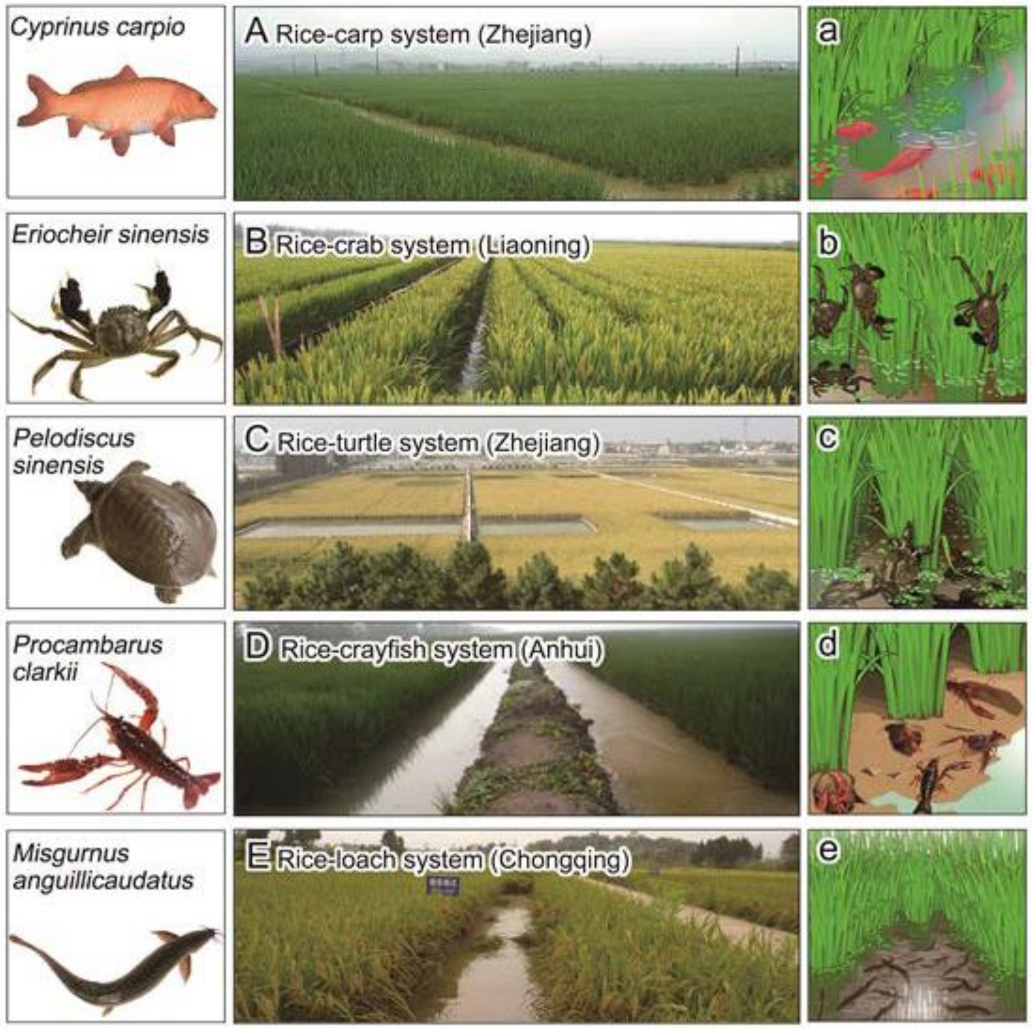
Prof Xin Chen, Zhejiang University

Rice – Fish Co-cultivation

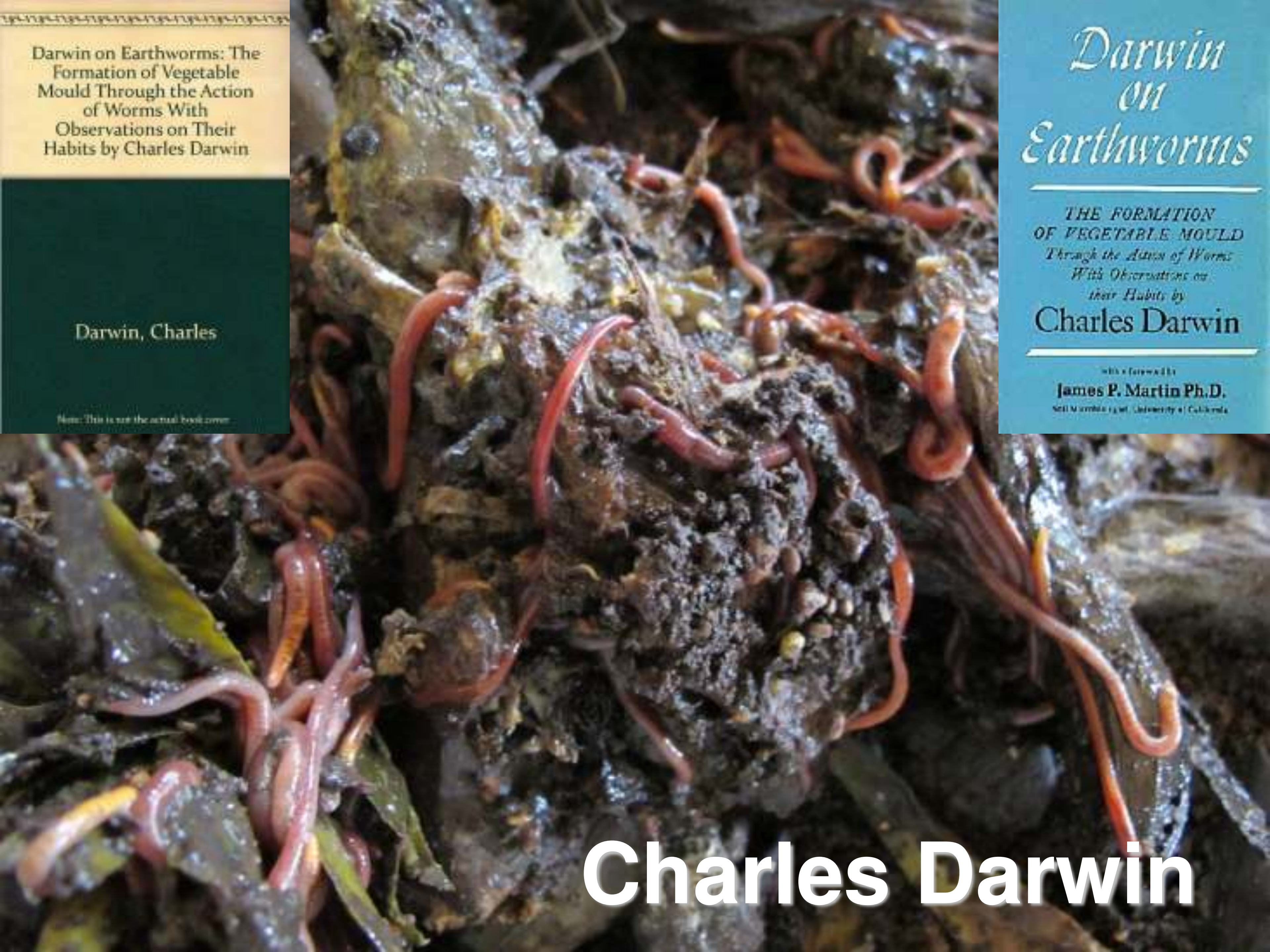


Xie et al (2011) PNAS

Are there natural Biostimulants in animal waste?




Earthworms
(vermi-compost)
Natural Soil Fertility



Charles Darwin

Earthworms (vermi-compost)

Perionyx excavatus **and** ***Eisenia foetida*** **at 65:35 ratio**

Large-scale Biostimulants' usage & Soil Re-constitution

Past Successful Track Record

Lampung, Sumatra, Indonesia

PT Great Giant Pineapple

Types of Fertilizers

- Chemical (NPK)

- Traditional (manure)
- Organic/**Green**

Traditional, Organic/Green Fertilizers

- Composts, Vermi-compost (earthworms)
- Liquid/pellet microbial applications
- Humo-organic

Biostimulants

Plant biostimulants are diverse substances and microorganisms used to enhance plant growth.

Biostimulants

Eight categories (Calvo et al. 2014)

- – Microbial inoculants
- – Humic acids (including Fulvic acids)
- – Protein hydrolysates & amino acids (including MicroProteins)
- – Seaweed extracts
- – Complex organic materials (including phytohormones)
- – Beneficial chemical elements & Inorganic salts (including phosphite)
- – Chitin and chitosan derivatives
- – Anti-transpirants


MARSCHNER REVIEW

Agricultural uses of plant biostimulants

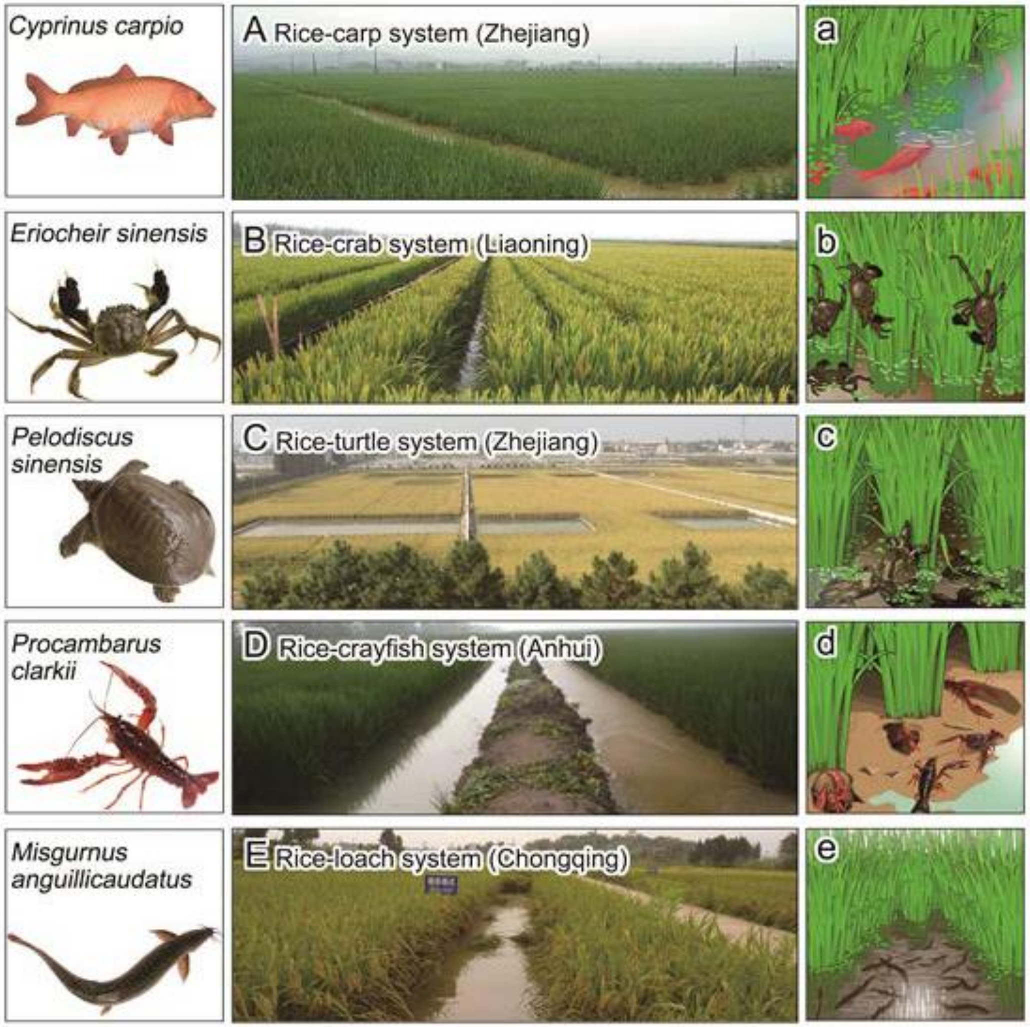
Pamela Calvo · Louise Nelson · Joseph W. Kloepper

Abstract

Introduction

Plant & Soil (2014) Marschner Review

Are there natural **Biostimulants** in animal waste?



Dr Markus Langeland
(SLU Uppsala)

SCIENTIFIC REPORTS

OPEN Can the co-cultivation of rice and fish help sustain rice production?

Vermicompost tea – a leachate

● This is the first mass spectrometric and therefore unequivocal evidence for the presence of CKs in VT: namely **trans-Zeatin** (**tZ**), **N^6-Isopentenyladenine** (**iP**) and **N^6-Isopentenyladenosine** (**iPR**), and were determined to be present at 0.06, 3.33, & 0.02 pmol mL^{-1}, respectively.

● The successful detection and quantitation of CKs in VT provided direct evidence to explain the growth efficacy of applying VT to enhance plant growth and development.

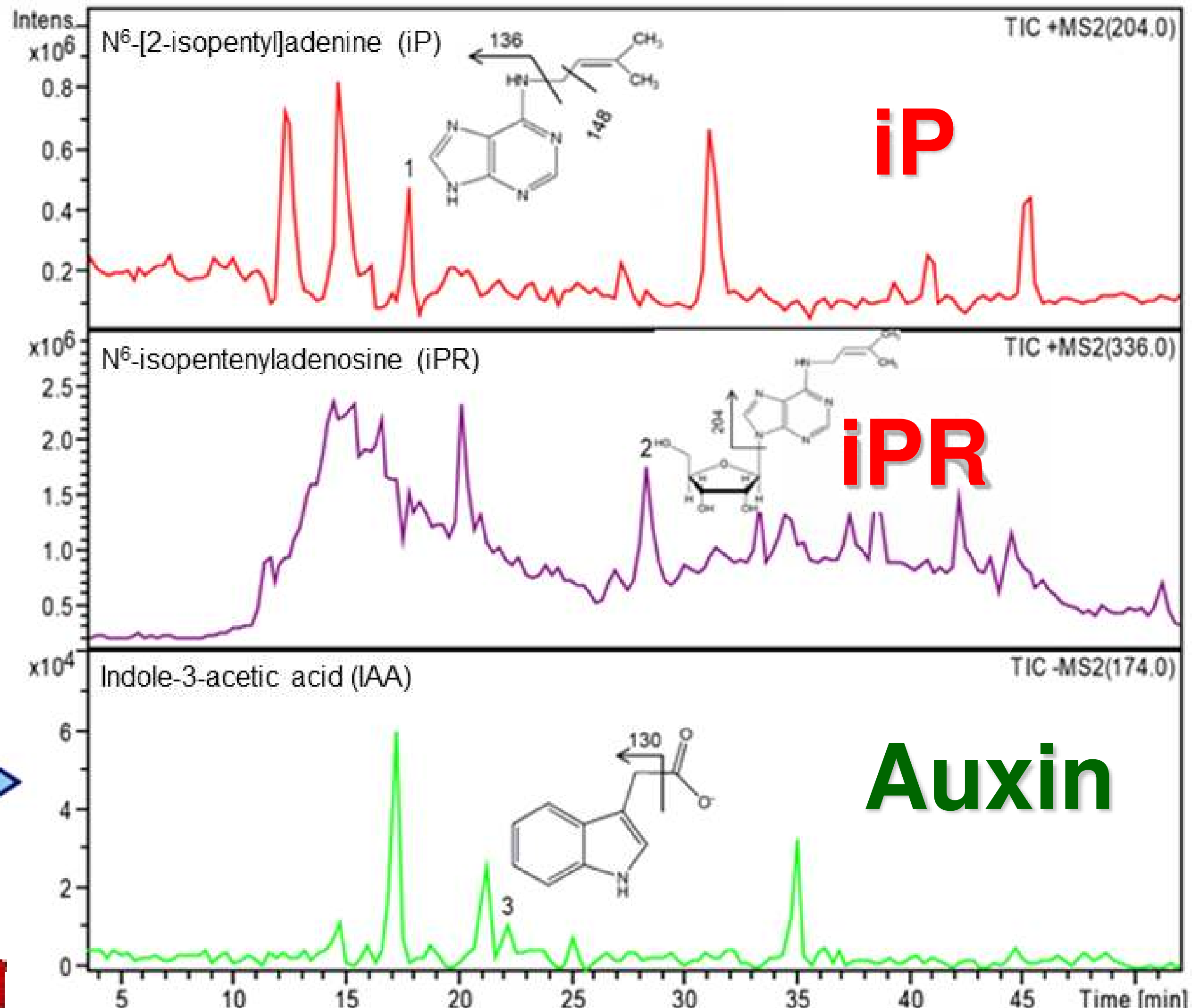
● We postulated that iP is a good reflection of the microbial origin for CKs present in the VT due to its importance in CK biosynthesis pathways and high abundance provided by microorganisms.

Zhang et al. 2014, Biol Fert Soils

Vermicomposts

1.UAE
2.SPE

LC-MS analysis



UAE - Ultra-Sound Assisted Extraction

Zhang et al. 2015, Talanta

Vermicompost tea – Other Research Groups

Plant Growth Regul (2015) 75:483–492
DOI 10.1007/s10725-014-0011-0

ORIGINAL PAPER

Evidence of phytohormones and phenolic acids variability in garden-waste-derived vermicompost leachate, a well-known plant growth stimulant

Adeyemi O. Aremu · Wendy A. Stirk · Manoj G. Kulkarni · Danuše Tarkowská · Veronika Turečková · Jiří Gruz · Michaela Šubrtová · Aleš Pěnčík · Ondřej Novák · Karel Doležal · Miroslav Strnad · Johannes Van Staden

Received: 7 October 2014 / Accepted: 10 December 2014 / Published online: 18 December 2014

Abstract Cytokinins, auxins, abscisic acid, gibberellins (GAs) and brassinosteroids (BRs) as well as the phenolic acid content in three batches of vermicompost leachate (VCL) were quantified using ultra high performance liquid chromatography tandem mass spectrometry. N^6-isopentenyladenine formed the major (60 %) proportion of the CK content while dihydrozeatin had the lowest (<0.02 %) concentration. Indole-3-acetic acid ranged from approximately 0.55–0.77 pmol/mL. A total of 18 GAs including bioactive forms and metabolic end products were observed in the VCL samples. Castasterone had the highest (3,900–4,200 fg/mL) concentration while brassinolide was the lowest (1–5 fg/mL) abundant BRs found. Phenolic acids quantified were protocatechuic acid (3–3.6 μg/mL), *p*-hydroxybenzoic acid (2.5–2.8 μg/mL), *p*-coumaric acid (1–1.7 μg/mL) and ferulic acid (0–4 μg/mL). These results provide an indication of the rich diversity in natural PGRs and phytochemicals in VCL which may inevitably contribute to the numerous favourable physiological responses elicited by VCL application to plants.

Keywords Abscisic acid · Biostimulant · Brassinosteroids · Cytokinins · Gibberellins · Phenolics

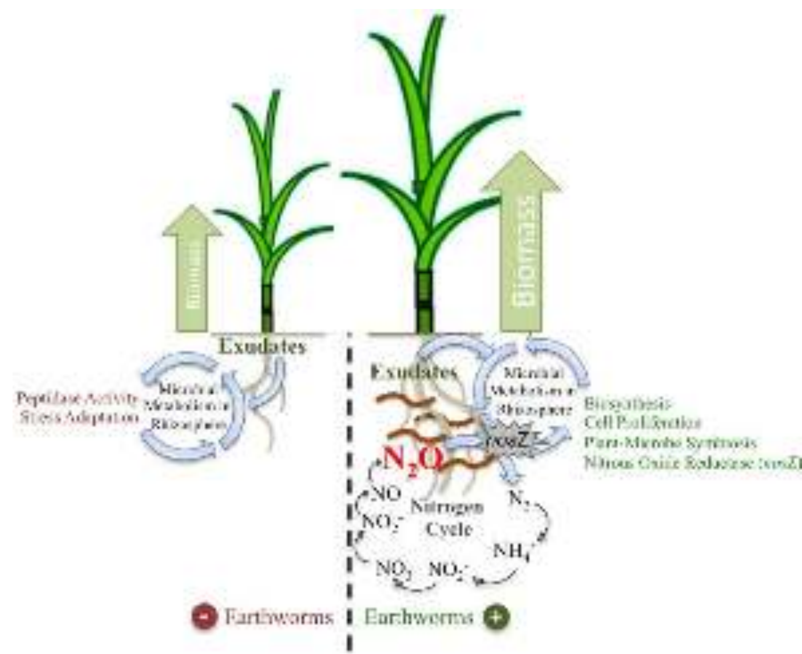
Abbreviations

ABA	Abscisic acid
BRs	Brassinosteroids
CKs	Cytokinins
cZ	*cis*-Zeatin
cZ9G	*cis*-Zeatin-9-glucoside
cZOG	*cis*-Zeatin-*O*-glucoside
cZR	*cis*-Zeatin riboside
cZRMP	*cis*-Zeatin riboside-5′-monophosphate
cZROG	*cis*-Zeatin-*O*-glucoside riboside
DHZ	Dihydrozeatin
DHZ9G	Dihydrozeatin-9-glucoside
DHZOG	Dihydrozeatin-*O*-glucoside
DHZR	Dihydrozeatin riboside
DHZRMP	Dihydrozeatin riboside-5′-monophosphate
DHZROG	Dihydrozeatin-*O*-glucoside riboside
GAs	Gibberellins
IAA	Indole-3-acetic acid
IAC	Immunoaffinity chromatography

In addition to **Auxins** and **Cytokinins**

+ Gibberellins

+ Brassinosteroids

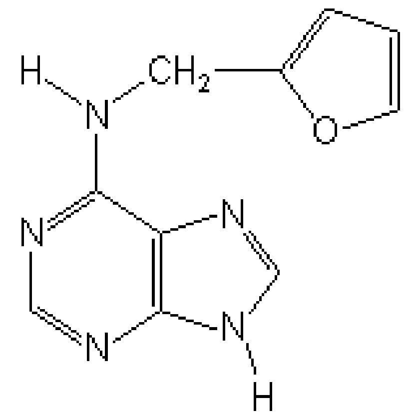


ELSEVIER

Biochemical and Biophysical Research Communications

Volume 279, Issue 1, 9 December 2000, Pages 69-73

Kinetin



Regular Article

Identification of 6-Furfuryladenine (Kinetin) in Human Urine

Jan Barciszewski [a, 1], Michal Mielcarek [a], Maciej Stobiecki [a], Gunhild Siboska [b], Brian F.C. Clark [b]

Show more

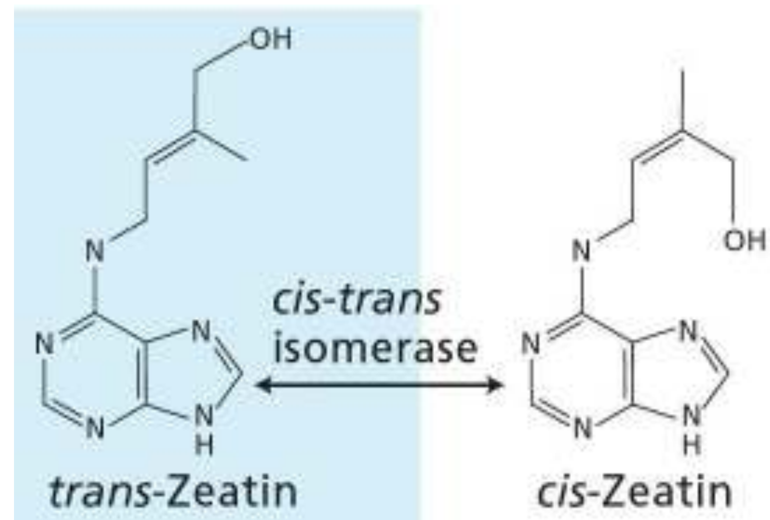
https://doi.org/10.1006/bbrc.2000.3928

Abstract

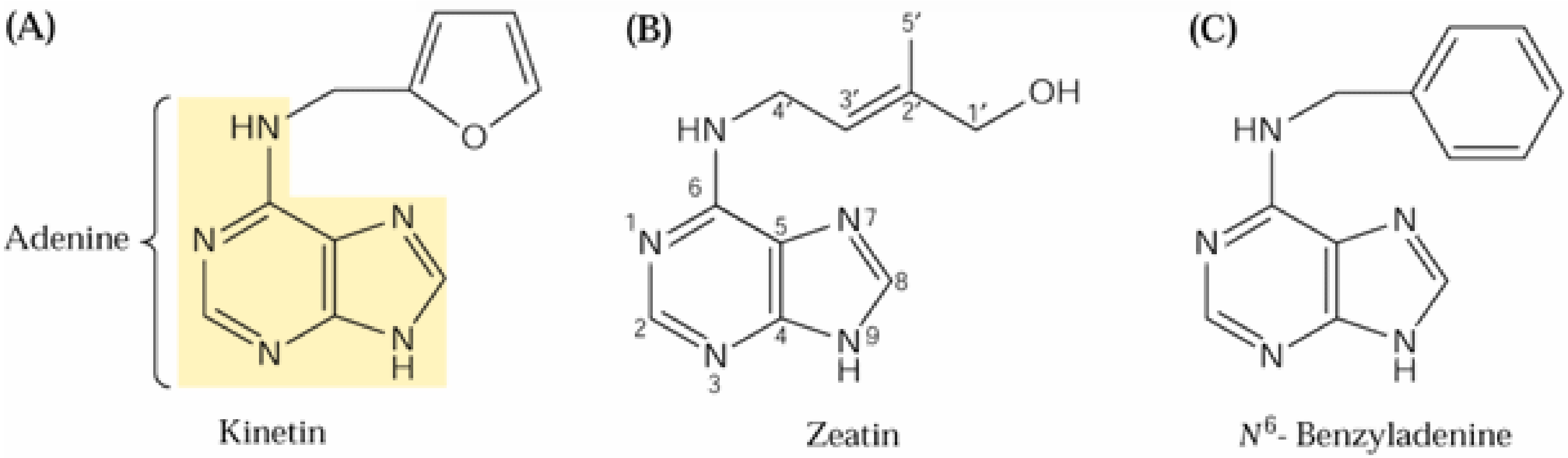
In contrast to the current view of kinetin (K, N^6-furfuryladenine) as an unnatural and synthetic cytokinin, recently it has been identified in plant DNA and plant extract. Here we describe identification of K in human urine using

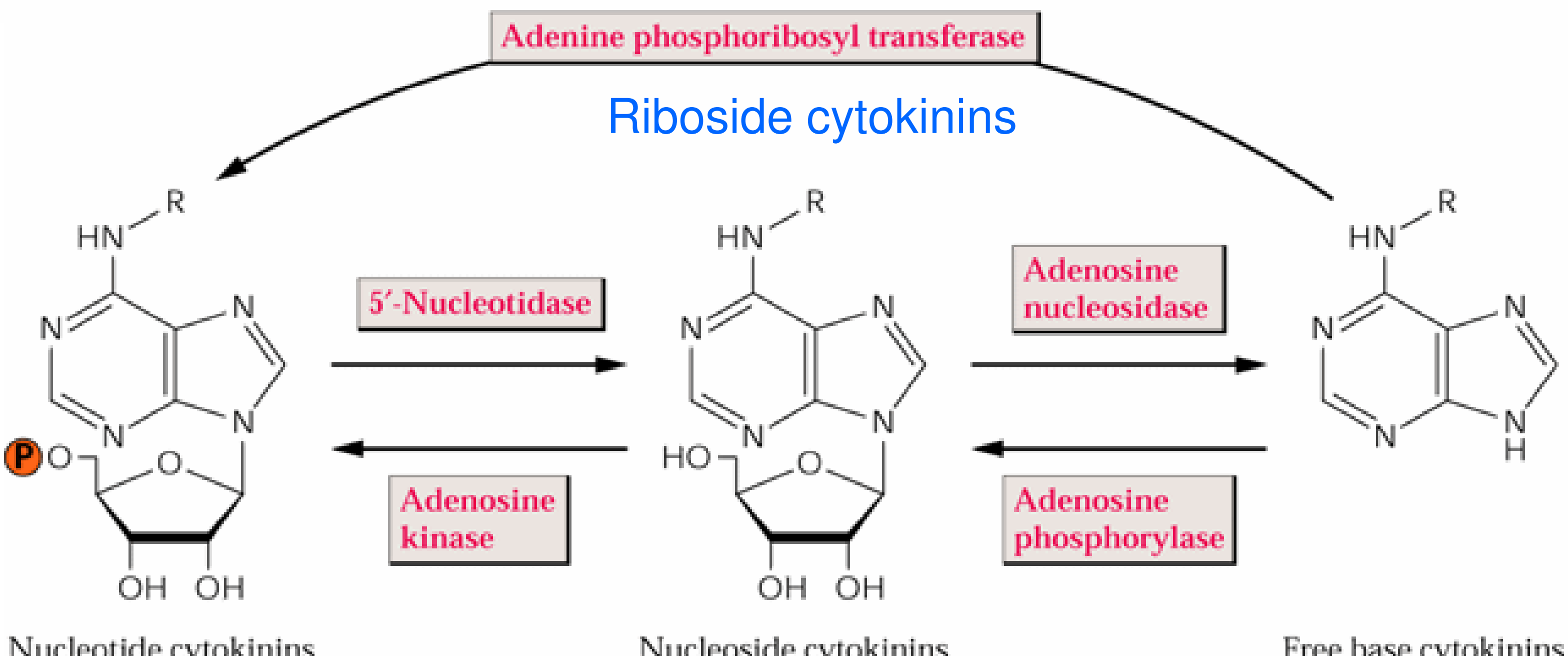
?

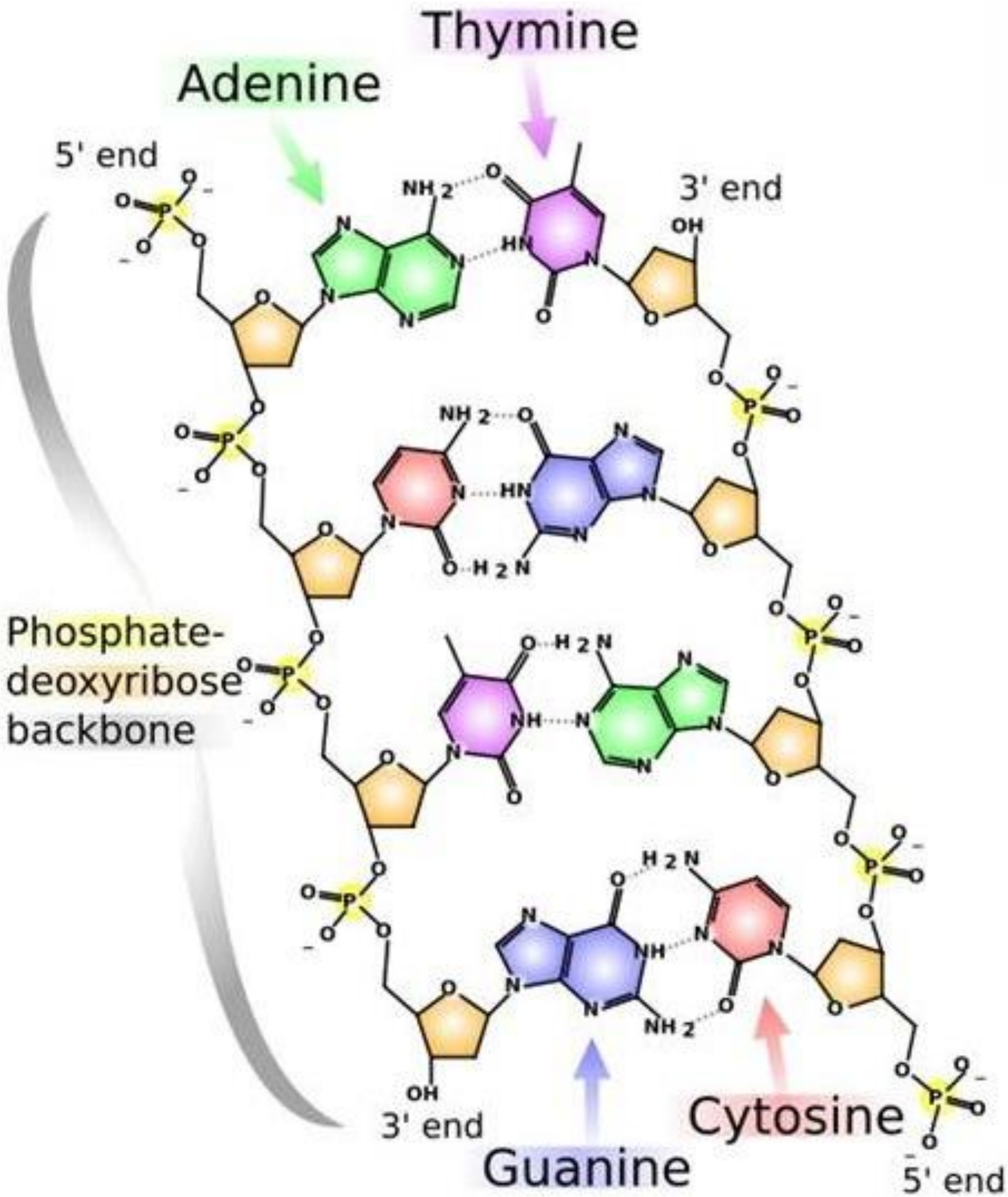
?



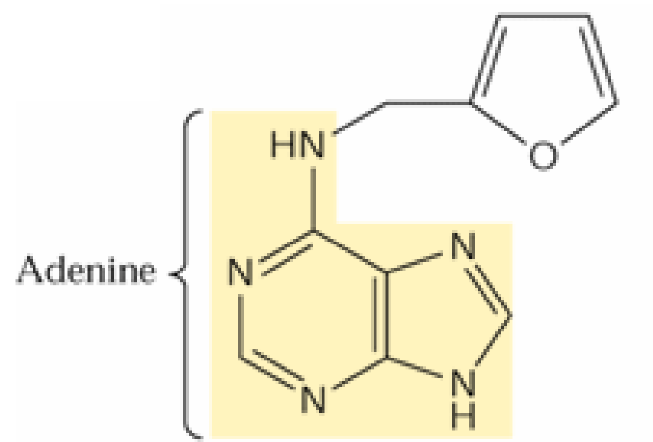
Cytokinin types







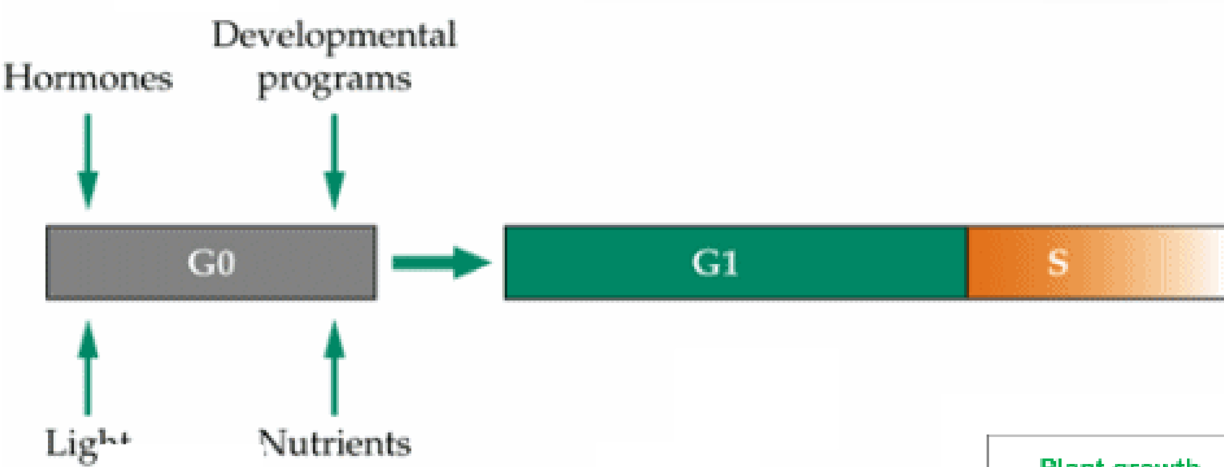
Components of the DNA

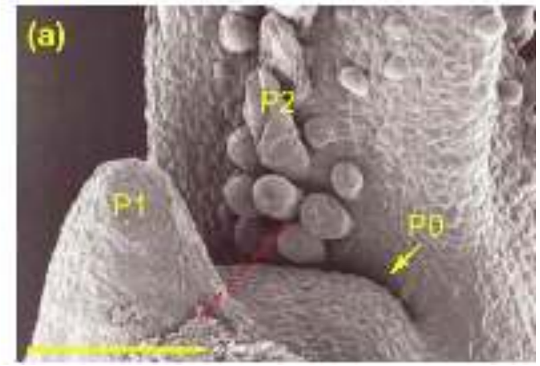


Kinetin

How Phytohormones drive the Cell Cycle?

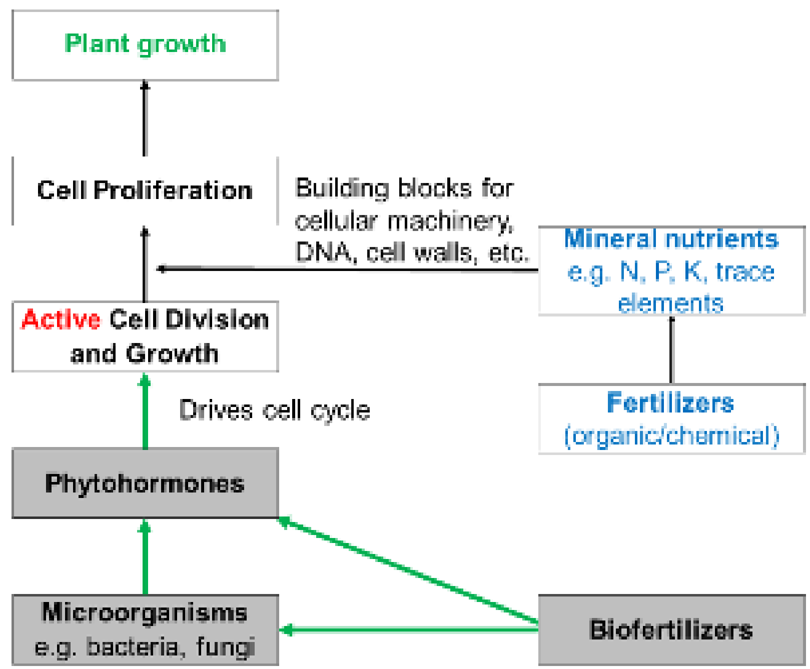
(A)





(B)

(C)



PNAS PNAS PNAS PNAS

Plants can use protein as a nitrogen source without assistance from other organisms

Chanyarat Paungfoo-Lonhienne*, Thierry G. A. Lonhienne†, Doris Rentsch‡, Nicole Robinson*, Michael Christie†, Richard I. Webb§, Harshi K. Gamage*, Bernard J. Carroll†, Peer M. Schenk*, and Susanne Schmidt*¶

*School of Integrative Biology, †ARC Centre of Excellence for Integrative Legume Research, School of Molecular and Microbial Sciences, and School of Land Crop and Food Sciences, and §Centre for Microscopy and Microanalysis, University of Queensland, Queensland 4072, Australia; and ‡Institute of Plant Sciences, University of Bern, 3013 Bern, Switzerland

Edited by Peter Vitousek, Stanford University, Stanford, CA, and approved January 25, 2008 (received for review December 21, 2007)

Nitrogen is quantitatively the most important nutrient that plants acquire from the soil. It is well established that plant roots take up nitrogen compounds of low molecular mass, including ammonium, nitrate, and amino acids. However, in the soil of natural ecosystems, nitrogen occurs predominantly as proteins. This complex organic form of nitrogen is considered to be not directly available to plants. We examined the long-held view that plants depend on specialized symbioses with fungi (mycorrhizas) to access soil protein and studied the woody heathland plant *Hakea actites* and the herbaceous model plant *Arabidopsis thaliana*, which do not form mycorrhizas. We show that both species can use protein as a nitrogen source for growth without assistance from other organisms. We identified two mechanisms by which roots access protein. Roots exude proteolytic enzymes that digest protein at the root surface and possibly in the apoplast of the root cortex. Intact protein also was taken up into root cells most likely via endocytosis. These findings change our view of the spectrum of nitrogen sources that plants can access and challenge the current paradigm that plants rely on microbes and soil fauna for the breakdown of organic ı

nitrogen ı
soil protei

New Ideas, Original Thinking?

Soil organic matter contains nitrogen predominantly as protein, which is considered a nitrogen source exclusively microbes and animals (1, 2). Despite the importance of pro in soils, little research has been carried out to elucidate the

(13), (*ii*) most other heathland plants have mycorrhizal symbioses and/or form symbioses with N_2-fixing microbes (13), and (*iii*) *Hakea* forms cluster roots that have a role in the acquisition of organic nitrogen (14). We further hypothesized that *Arabidopsis thaliana* is unable to use protein as a nitrogen source because it does not form cluster roots and grows in ruderal habitats that typically contain inorganic nitrogen. With the aid of fluorescent proteins, we show that both plant species, in the absence of microbes, can use protein as a nitrogen source.

Results

Axenically Cultivated *H. actites* and *A. thaliana* Use Externally Supplied Protein as a Nitrogen Source for Growth. Grown with protein as the sole nitrogen source, *Hakea* seedlings produced significantly more root biomass and had a greater nitrogen content in roots than plants grown without nitrogen (Fig. 1 *A* and *B*). Shoot biomass and shoot nitrogen content, as well as total plant biomass and nitrogen content, were similar in *Hakea* grown without nitrogen or with protein, and best shoot and root growth

3). *Arabi-*
of growth
reater dry
t nitrogen

(Fig. 1 *C* and *D*). *Arabidopsis* grown with a low amount of inorganic nitroge
ted more
grown wit
ed with a mixture of protein and a low amount of inorganic

PNAS 2008

Ascophyllum

Kelp

Gunapaselam

(Fermented Fish waste)

Kunapajala

(Fermented animal waste, bones. etc)

Water Urea Gunapaselam

Phytohormones

Yong et al. 2009, Molecules

NTU Dr Ge Liya

Coconut water

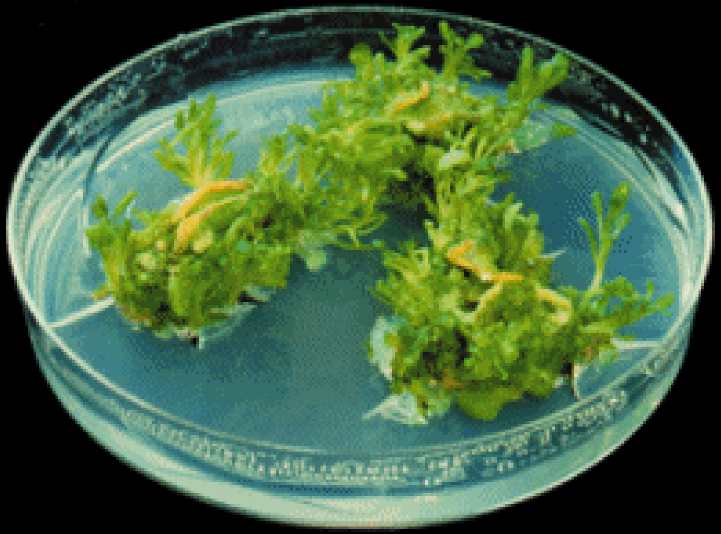
NANYANG TECHNOLOGICAL UNIVERSITY

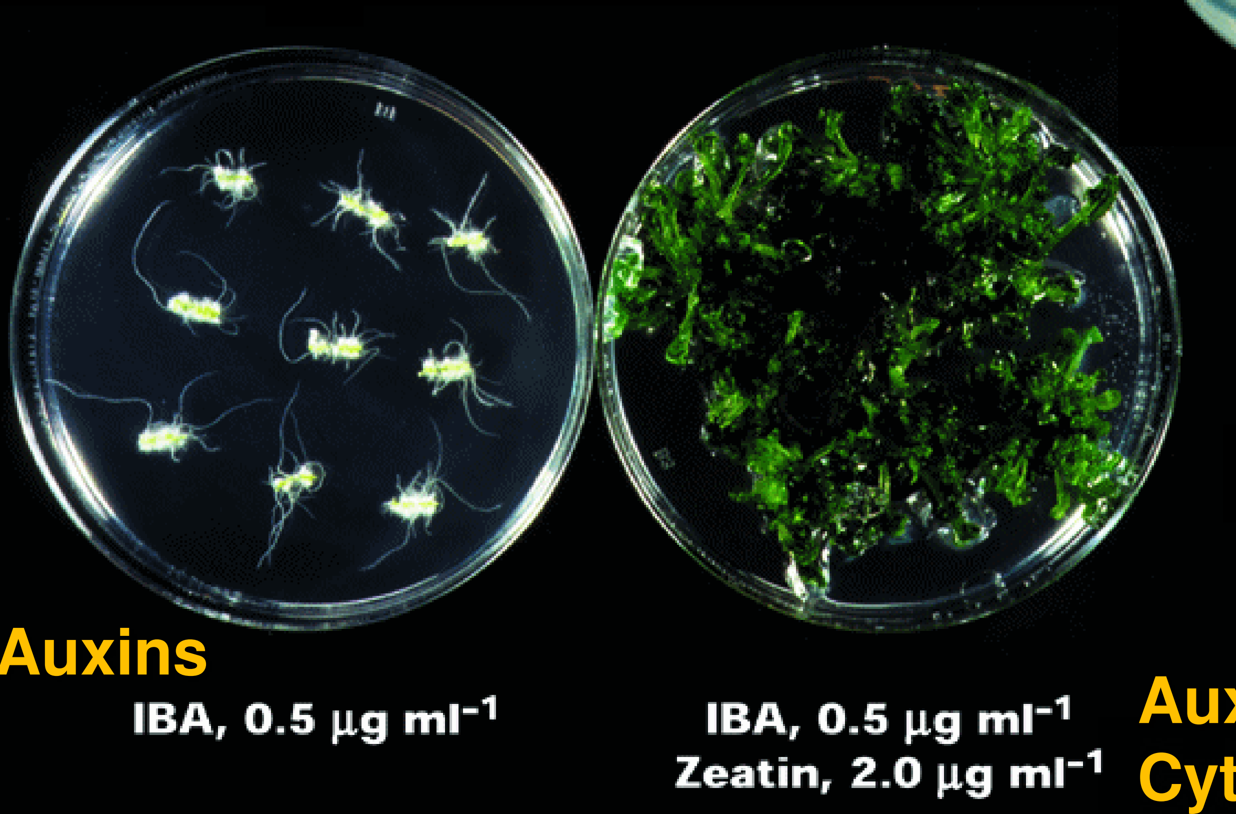
Insights from Tissue Culture

Analogy – Reductionist approach?

Plant Tissue Culture

Mineral Nutrients + Full complement of phytohormones





Auxins

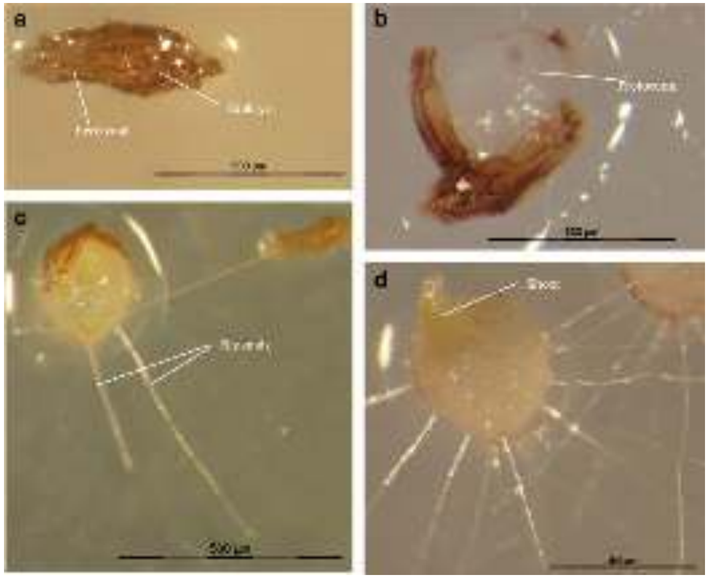
Auxins + Cytokinins

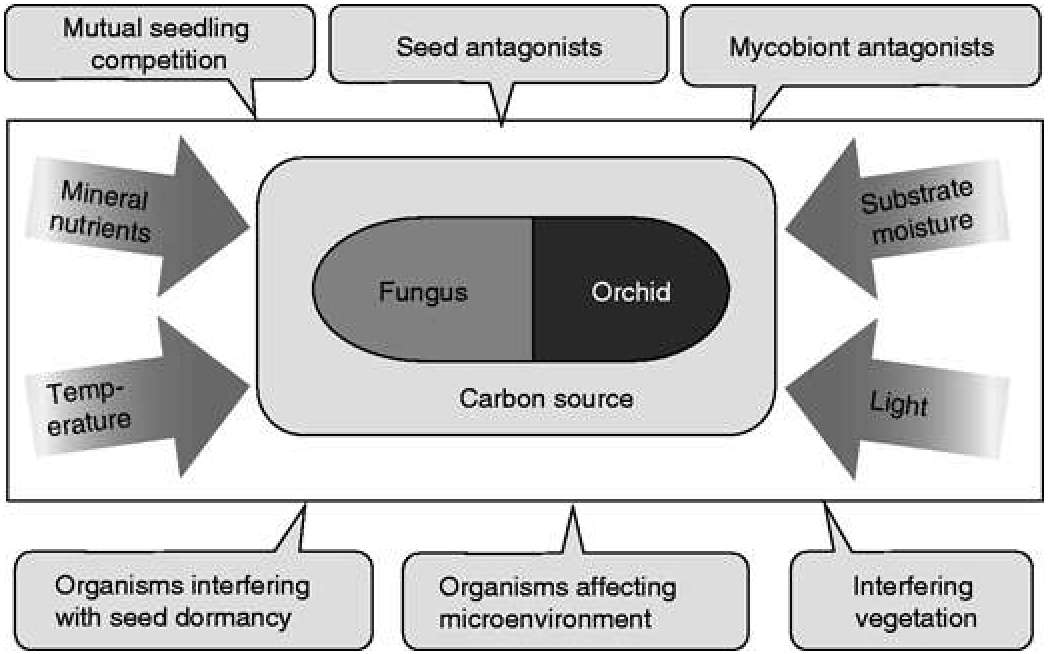
Mine Site Restoration =
Facilitated (Natural) Succession?

Ecological Restoration

Goldfields,
WA, Australia

Importance of Microbe-Plant interactions





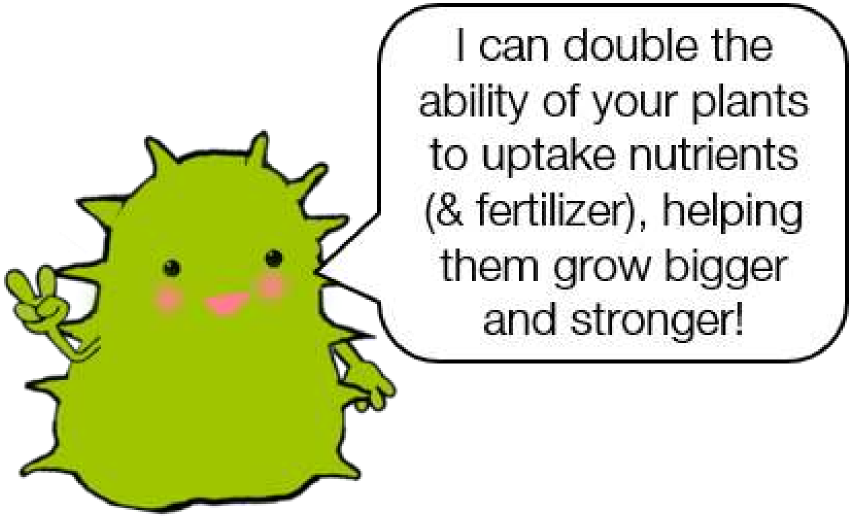
Rasmussen, Dixon, et al (2015)

Cynorkis purpurea, a terrestrial

orchid

Rafter et al (2016)

Importance of Microbe-Plant interactions



What do the

Microbes "give" to the **Plants**?

Phytohormones help coordinate growth, development, & responses to stimuli

- **Phytohormones** are chemical signals that modify or control one or more specific physiological processes within a plant
- **Phytohormones** are produced in very low concentration, but a minute amount can greatly affect growth and development of a plant organ
- In general, **Phytohormones** control plant growth and development by affecting the division, elongation, and differentiation of cells
- They have **multiple**, **overlapping**, **&** **interacting functions**

Table 39.1

Table 39.1 Overview of Plant Hormones

Hormone	Where Produced or Found in Plant	Major Functions
AUXINS	Shoot apical meristems and young leaves are the primary sites of auxin synthesis. Root apical meristems also produce auxin, although the root depends on the shoot for much of its auxin. Developing seeds and fruits contain high levels of auxin, but it is unclear whether it is newly synthesized or transported from maternal tissues.	Stimulates stem elongation (low concentration only); promotes the formation of lateral and adventitious roots; regulates development of fruit; enhances apical dominance; functions in phototropism and gravitropism; promotes vascular differentiation; retards leaf abscission.
CYTOKININS	These are synthesized primarily in roots and transported to other organs, although there are many minor sites of production as well.	Regulate cell division in shoots and roots; modify apical dominance and promote lateral bud growth; promote movement of nutrients into sink tissues; stimulate seed germination; delay leaf senescence.
GIBBERELLINS	Meristems of apical buds and roots, young leaves, and developing seeds are the primary sites of production.	Stimulate stem elongation, pollen development, pollen tube growth, fruit growth, and seed development and germination; regulate sex determination and the transition from juvenile to adult phases.
BRASSINOSTEROIDS	These compounds are present in all plant tissues, although different intermediates predominate in different organs. Internally produced brassinosteroids act near the site of synthesis.	Promote cell expansion and cell division in shoots; promote root growth at low concentrations; inhibit root growth at high concentrations; promote xylem differentiation and inhibit phloem differentiation; promote seed germination and pollen tube elongation.
ABSCISIC ACID (ABA)	Almost all plant cells have the ability to synthesize abscisic acid, and its presence has been detected in every major organ and living tissue; may be transported in the phloem or xylem.	Inhibits growth; promotes stomatal closure during drought stress; promotes seed dormancy and inhibits early germination; promotes leaf senescence; promotes desiccation tolerance.
STRIGOLACTONES	These carotenoid-derived hormones and extracellular signals are produced in roots in response to low phosphate conditions or high auxin flow from the shoot.	Promote seed germination, control of apical dominance, and the attraction of mycorrhizal fungi to the root.
ETHYLENE	This gaseous hormone can be produced by most parts of the plant. It is produced in high concentrations during senescence, leaf abscission, and the ripening of some types of fruits. Synthesis is also stimulated by wounding and stress.	Promotes ripening of many types of fruit, leaf abscission, and the triple response in seedlings (inhibition of stem elongation, promotion of lateral expansion, and horizontal growth); enhances the rate of senescence; promotes root and root hair formation; promotes flowering in the pineapple family.

Karrikins

Plant tissue cultures and Phytohormones

– **cytokinins** in coconut water

Dendrobium orchids

Electrophoresis 2006, 27, 2171–2181

Liya Ge[1]
Jean Wan Hong Yong[1]
Swee Ngin Tan[1]
Eng Shi Ong[2]

[1]Natural Sciences and Science Education Academic Group, Nanyang Technological University, Singapore, Singapore
[2]Applied Science School, Temasek Polytechnic, Singapore, Singapore

Research Article

Determination of cytokinins in coconut (*Cocos nucifera* L.) water using capillary zone electrophoresis-tandem mass spectrometry

The applicability of CZE in combination with MS and MS/MS methods for the simultaneous separation and determination of 12 cytokinins was investigated for the first time. Cytokinins were first completely separated by CZE within less than 20 min using a

Liya Ge[1]
Jean Wan Hong Yong[1]
Swee Ngin Tan[1]
Lin Hua[2]
Eng Shi Ong[3]

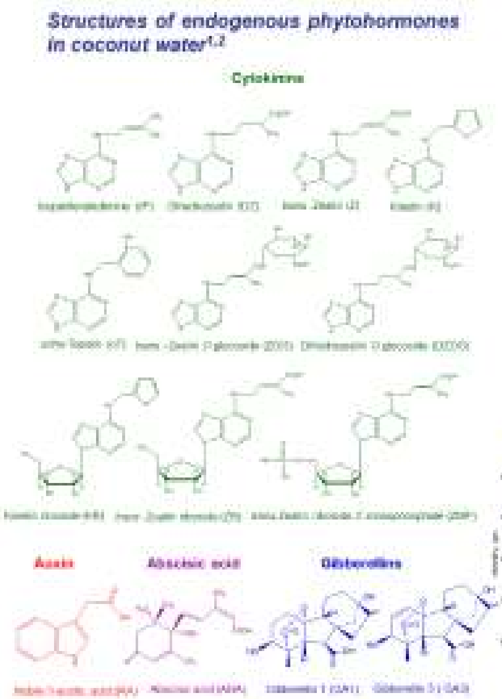
[1]Natural Sciences and Science Education Academic Group, Nanyang Technological University, Singapore, Republic of Singapore
[2]Genome Institute of Singapore, Biopolis, Singapore, Republic of Singapore
[3]Department of Community, Occupational, and Family Medicine, Yong Loo Lin School of Medicine, National University of Singapore, Singapore, Republic of Singapore

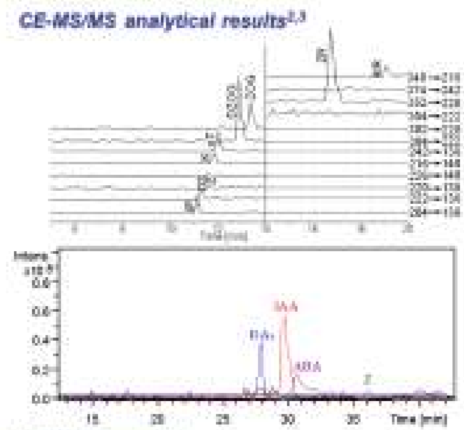
Research Article

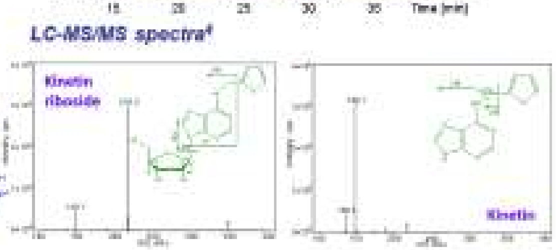
Analyses of gibberellins in coconut (*Cocos nucifera* L.) water by partial filling-micellar electrokinetic chromatography-mass spectrometry with reversal of electroosmotic flow

In this paper, we present the results of simultaneous screening of eight gibberellins (GAs) in coconut (Cocos nucifera L.) water by MEKC directly coupled to ESI-MS detection. During the development of MEKC-MS, partial filling (PF) was used to prevent the micelles from reaching the mass spectrometer as this is detrimental to the MS signal, and a cationic surfactant, cetyltrimethylammonium hydroxide, was added to the electrolyte to reverse the EOF. On the basis of the resolution of the neighboring peaks, different pa-

Several Phytohormones are found in young coconut water especially cytokinins, auxins and gibberellins.







Naturally-occurring phytohormones identified in coconut water[1-4]

Phytohormones		Estimated original concentration (× 10⁻³ μM)
Cytokinins	isopentenyladenine	0.35
	dihydrozeatin	0.14
	trans-zeatin	0.09
	kinetin	0.31
	ortho-topolin	0.28
	dihydrozeatin O-glucoside	45.8
	trans-zeatin O-glucoside	49.7
	trans-zeatin riboside	76.2
	kinetin riboside	0.33
	trans-zeatin riboside-5'-monophosphate	19.2
	14-O-{3-O-[β-D-galactopyranosyl-(1→2)-α-D-galactopyranosyl-(1→3)-α-L-arabinofuranosyl]-4-O-(α-L-arabinofuranosyl)-β-D-galactopyranosyl}-trans-zeatin riboside	Present
Gibberellins	gibberellin 1	16.7
	gibberellin 3	17.8
Auxin	indole-3-acetic acid	150.6
Abscisic acid	Abscisic acid	65.2

Coconut water

NANYANG TECHNOLOGICAL UNIVERSITY


Mass
Micropropagation


ORKIDE
49:-


IKEA

Bacterial cultures' cytokinin levels

Table IV. *Concentration of Cytokinins in the Culture Supernatants of the Strains IC3342 and ANU240*

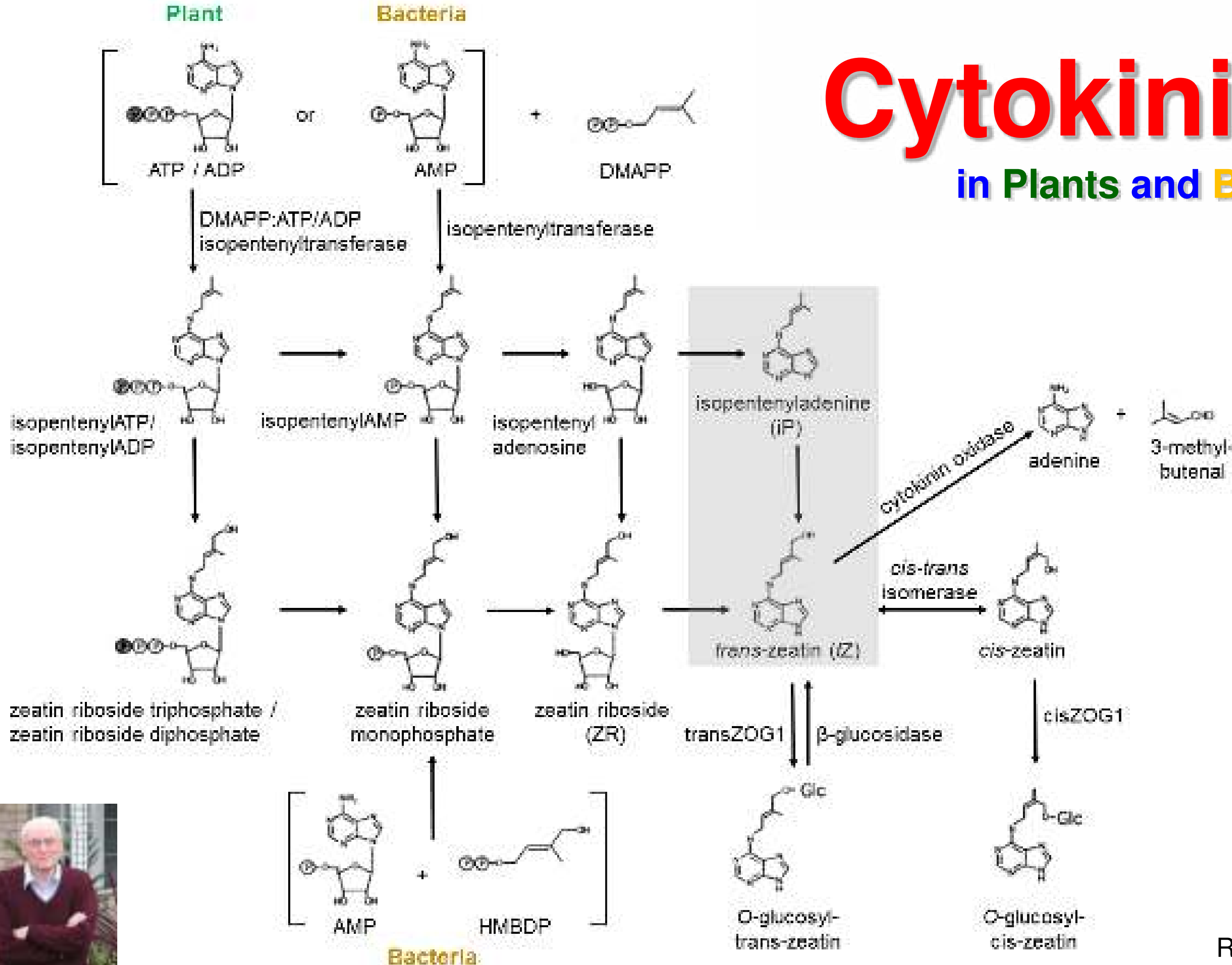
The values in parentheses were determined by GC-MS; the other values were obtained by RIA.

Cytokinins	Concentration in the Culture Supernatants of	
	ANU240	IC3342
	ng/L	
Z	83 (105)	2,188 (2,410)
DZ	54	133
ZR	9	7
DZR	8	9
cis-Z	166	176
cis-ZR	37	2
iP	5,191 (7,128)	41,420 (44,356)
iPA	123	329

Upadhyaya et al (1991) Plant Physiology

Cytokinin types

in Plants and Bacteria



RIKEN Prof. H. Sakakibara

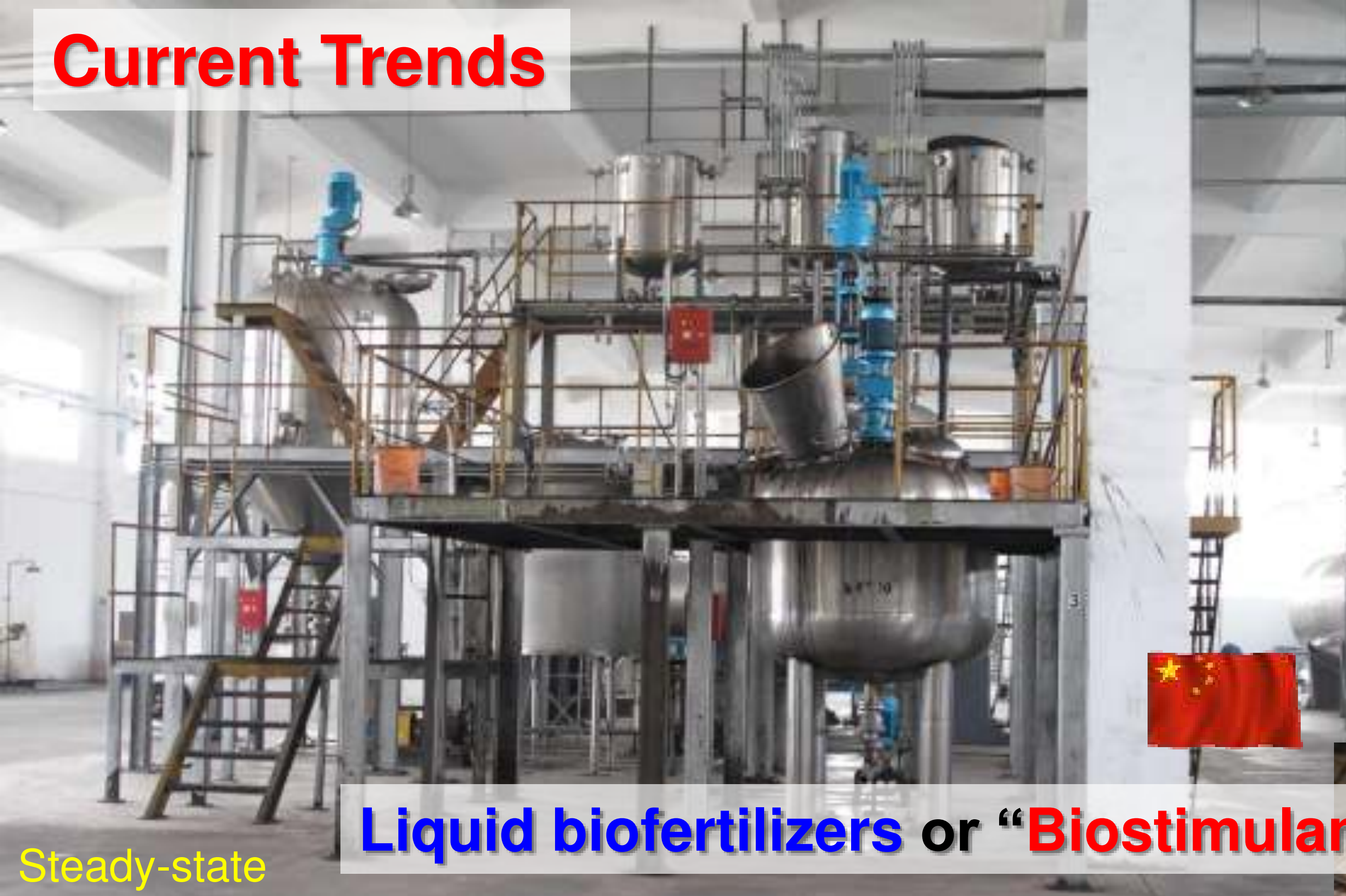
ANU Prof. Stuart Letham

Wong et al. (2015) Springer

Figure 5. A model for cytokinins biosynthesis and metabolic pathway in plants and bacteria. In plants, the isopentenyl moiety from dimethylallyl diphosphate (DMAPP) is transferred to ATP/ ADP while the bacterial pathways starts off with AMP. Bacteria cytokinin biosynthesis may also start by transferring isopentenyl moiety from 1-hydroxy-2-methyl-2-(E)-butenyl 4-diphosphate (HMBDP) to AMP. Active cytokinins are shaded.

Adapted from: Frébort et al. (2011); Haberer and Kieber (2002); Kakimoto (2003); Sakakibara (2006) and Tarkowski et al. (2009).

Current Trends



Liquid biofertilizers or "**Biostimulants**"

Past Successful Track Record

Fundamental Question:

Why add "HORMONE" to a standard NPK and TE (trace elements) chemical fertilizer mixture?

Is this becoming more common in the Agri-Horti industries?

Is Fish Waste a GOOD Fertilizer?

- Measure the essential nutrients (Marco & micro nutrients, trace elements)
- Determine the natural biostimulants in the fish waste sludge and aquaponics.


Available online at www.sciencedirect.com
SCIENCE DIRECT
Aquaculture 230 (2004) 125–135
Aquaculture
www.elsevier.com/locate/aqua-online

Performance evaluation of rice–fish integration system in rainfed medium land ecosystem

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Received 22 October 2002; received in revised form 13 May 2003; accepted 15 May 2003

Rice yield increased 4.9 to 8.6 % with **fishes**

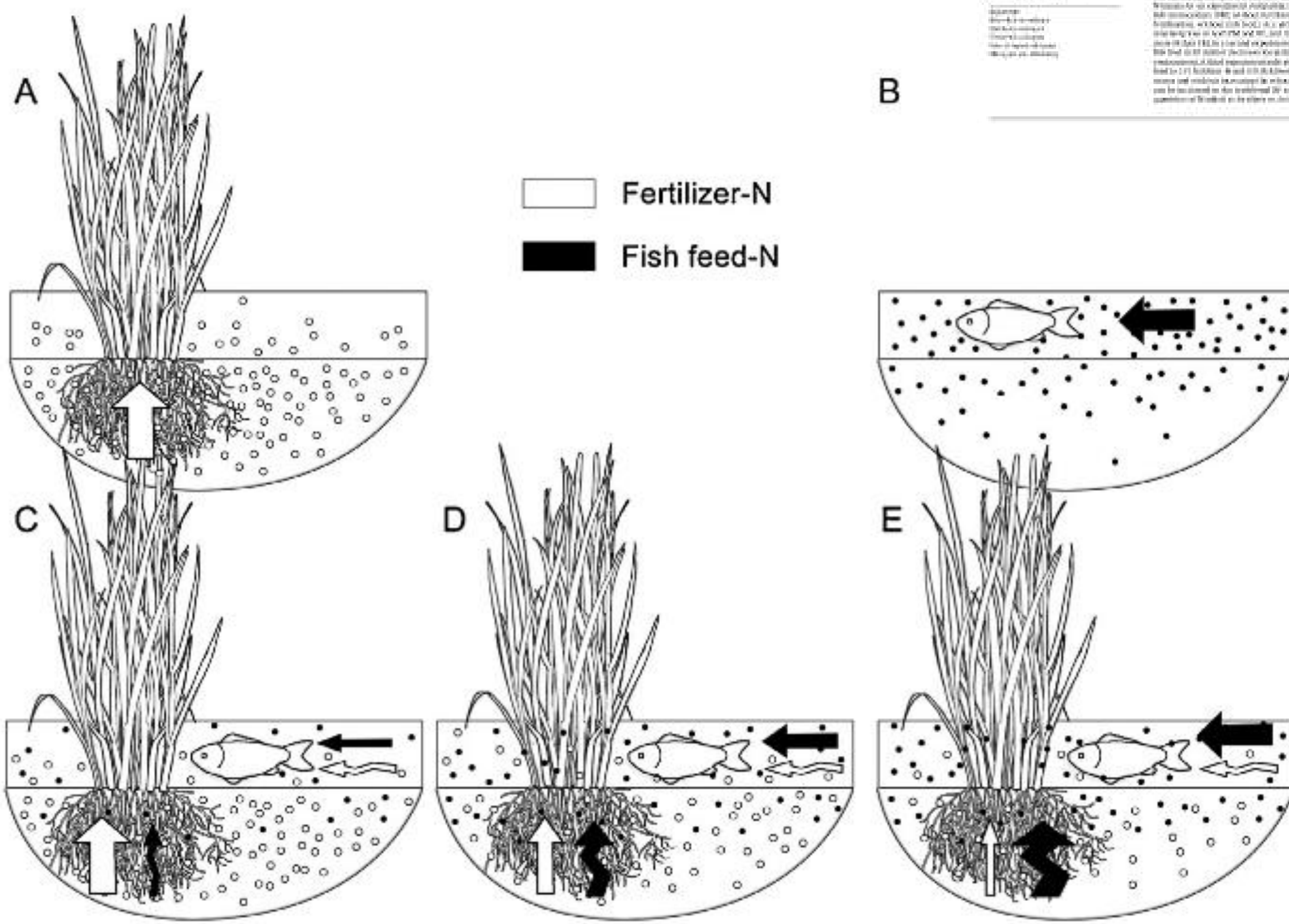
An experiment in India indicated a 4.9–8.6% increase in rice yield under rice–fish culture, and the increase was associated with an increased number of panicles and an increased number of filled grains per panicle (Mohanty et al., 2004).

Ashikari et al (2005) Science

Connections to a typical Cytokinin effect!


Agriculture, Ecosystems and Environment

The productivity of traditional rice–fish co-culture can be increased without increasing nitrogen loss to the environment



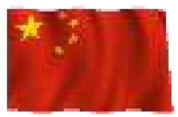

Agriculture, Ecosystems and Environment

The productivity of traditional rice–fish co-culture can be increased without increasing nitrogen loss to the environment

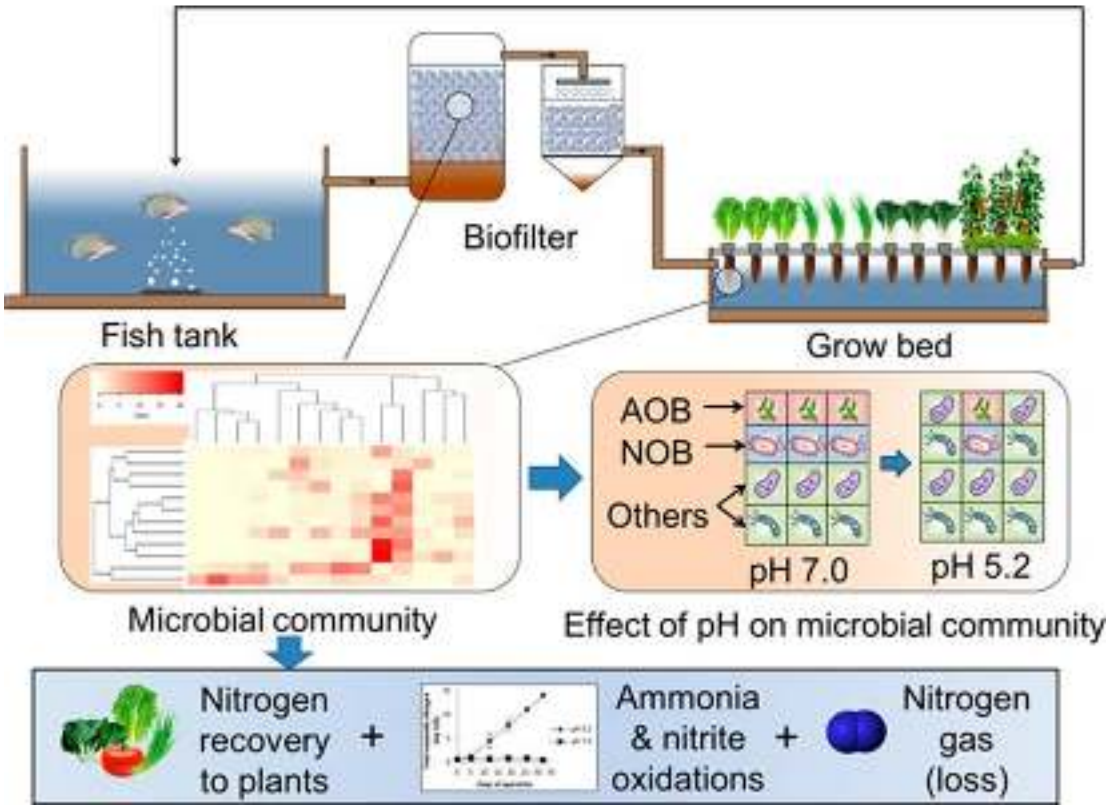
Table 1
Yields of rice and fish in the three experiments.

Experiments and treatments	Rice yield (t ha^{-1})		Fish yield (kg ha^{-1})	
	Grain	Straw	Gross	Net
Experiment 1				
RM	6.19 ± 0.17a	4.42 ± 0.12a		
FM			414.49 ± 37.53a	302.49 ± 37.53a
RF	6.29 ± 0.26a	4.43 ± 0.18a	484.45 ± 70.90a	372.45 ± 70.90a
Experiment 2				
RM	4.87 ± 0.38a	3.50 ± 0.24a		
FM60			1274.75 ± 90.65b	1163.06 ± 90.65b
RF30	4.97 ± 0.38a	3.58 ± 0.32a	685.75 ± 54.38c	629.91 ± 54.38c
RF60	5.20 ± 0.43a	3.79 ± 0.52a	1190.75 ± 104.43b	1079.06 ± 104.43bc
RF90	5.22 ± 0.40a	3.75 ± 0.25a	1578.25 ± 243.85b	1410.72 ± 243.85b
RF120	4.98 ± 0.23a	3.59 ± 0.23a	2159.00 ± 199.54a	1935.62 ± 199.54a
Experiment 2				
RF25%	5.67 ± 0.09a	3.84 ± 0.10a	655.62 ± 75.08b	338.37 ± 70.71b
RF44%	5.36 ± 0.12a	3.49 ± 0.24a	829.01 ± 34.84ab	516.26 ± 37.22ab
RF63%	5.37 ± 0.29a	3.21 ± 0.07a	1024.20 ± 73.82a	689.65 ± 79.07a

Values are means ± S.E. Numbers with different letters are statistically different based on LSD ($P \leq 0.05$). In experiment 1: RM (rice monoculture), RF (rice–fish co-culture), and FM (fish monoculture). In experiment 2: RM (rice monoculture); FM60 (fish monoculture, 60 fish plot^{-1}); RF30, RF60, RF90, and RF120 (rice–fish co-culture with 30, 60, 90, and 120 fish plot^{-1}, respectively). In experiment 3: RF25% (RF with 75% fertilizer-N and 25% feed-N); RF44% (RF with 56% fertilizer-N and 44% feed-N); RF63% (RF with 37% fertilizer-N and 63% feed-N).

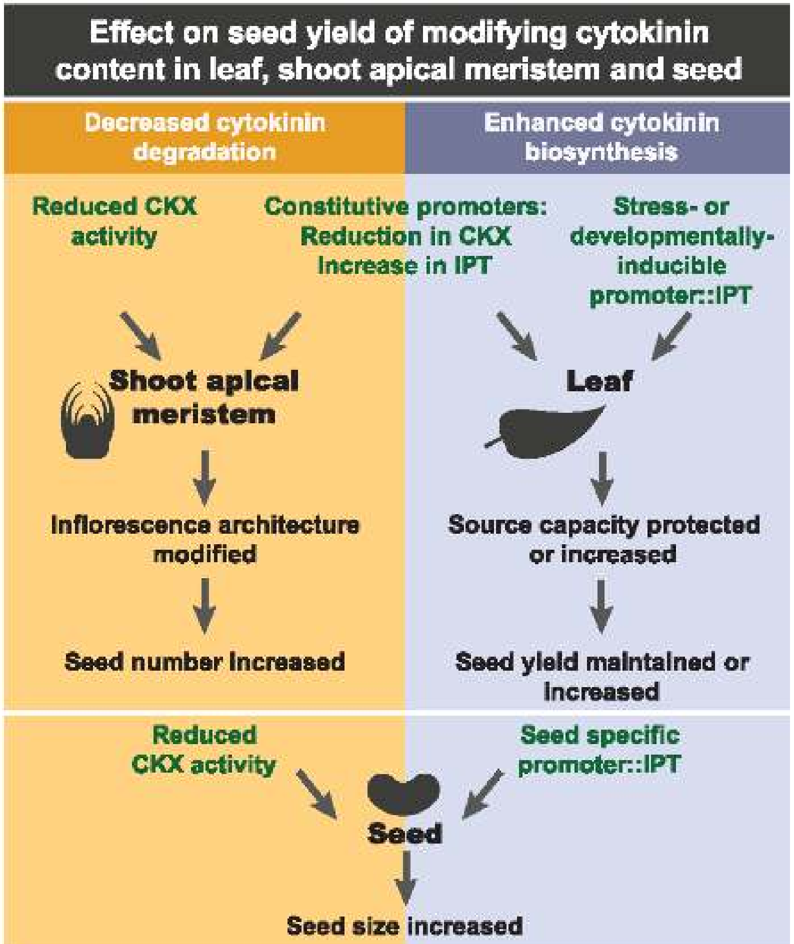


Aquaponics



A better experimental system to measure natural Biostimulants in animal waste?

Published in: Sumeth Wongkiew; Mee-Rye Park; Kartik Chandran; Samir Kumar Khanal; *Environ. Sci. Technol.* 52, 12728-12739.
DOI: 10.1021/acs.est.8b04177



Journal of Experimental Botany, Vol. 67, No. 3 pp. 593–606, 2016
doi:10.1093/jxb/erv461 Advance Access publication 1 November 2015

REVIEW PAPER

Cytokinin: a key driver of seed yield

Paula Elizabeth Jameson[1,*] **and Jiancheng Song**[1,2]

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[2] School of Life Sciences, Yantai University, Yantai 264005, China

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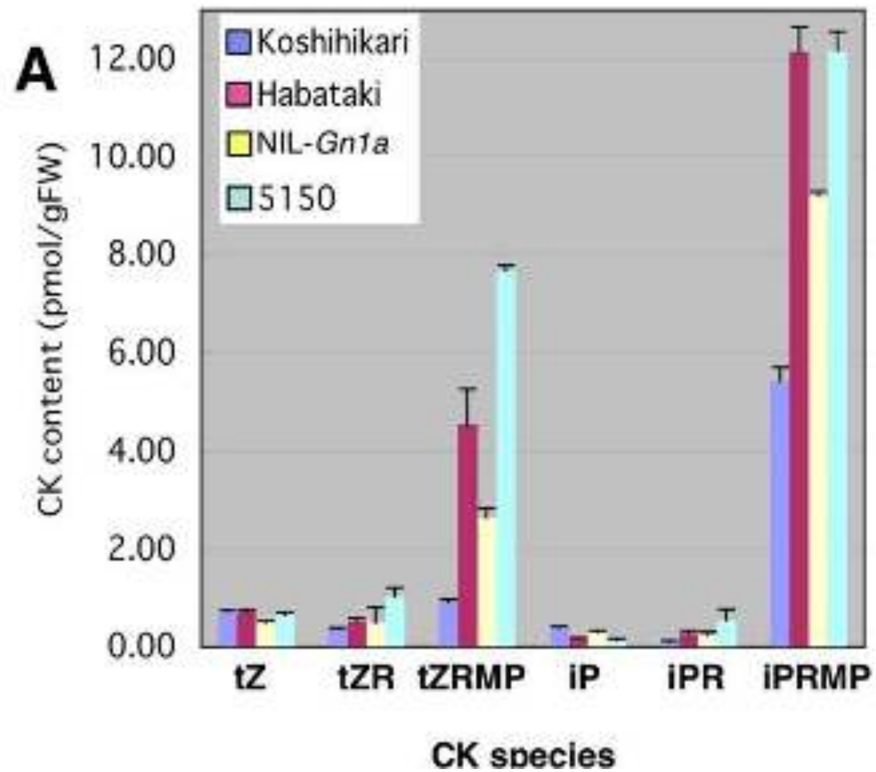
Higher cytokinin levels (within limits), more grains

Cytokinin Oxidase Regulates Rice Grain Production

Motoyuki Ashikari,[1*] Hitoshi Sakakibara,[2*] Shaoyang Lin,[3] Toshio Yamamoto,[3] Tomonori Takashi,[3] Asuka Nishimura,[3] Enrique R. Angeles,[3] Qian Qian,[4] Hidemi Kitano,[1] Makoto Matsuoka[1]†

Most agriculturally important traits are regulated by genes known as quantitative trait loci (QTLs) derived from natural allelic variations. We here show that a QTL that increases grain productivity in rice, *Gn1a*, is a gene for cytokinin oxidase/dehydrogenase (OsCKX2), an enzyme that degrades the phytohormone cytokinin. Reduced expression of *OsCKX2* causes cytokinin accumulation in inflorescence meristems and increases the number of reproductive organs, resulting in enhanced grain yield. QTL pyramiding to combine loci for grain number and plant height in the same genetic background generated lines exhibiting both beneficial traits. These results provide a strategy for tailormade crop improvement.



Ashikari et al (2005) Science

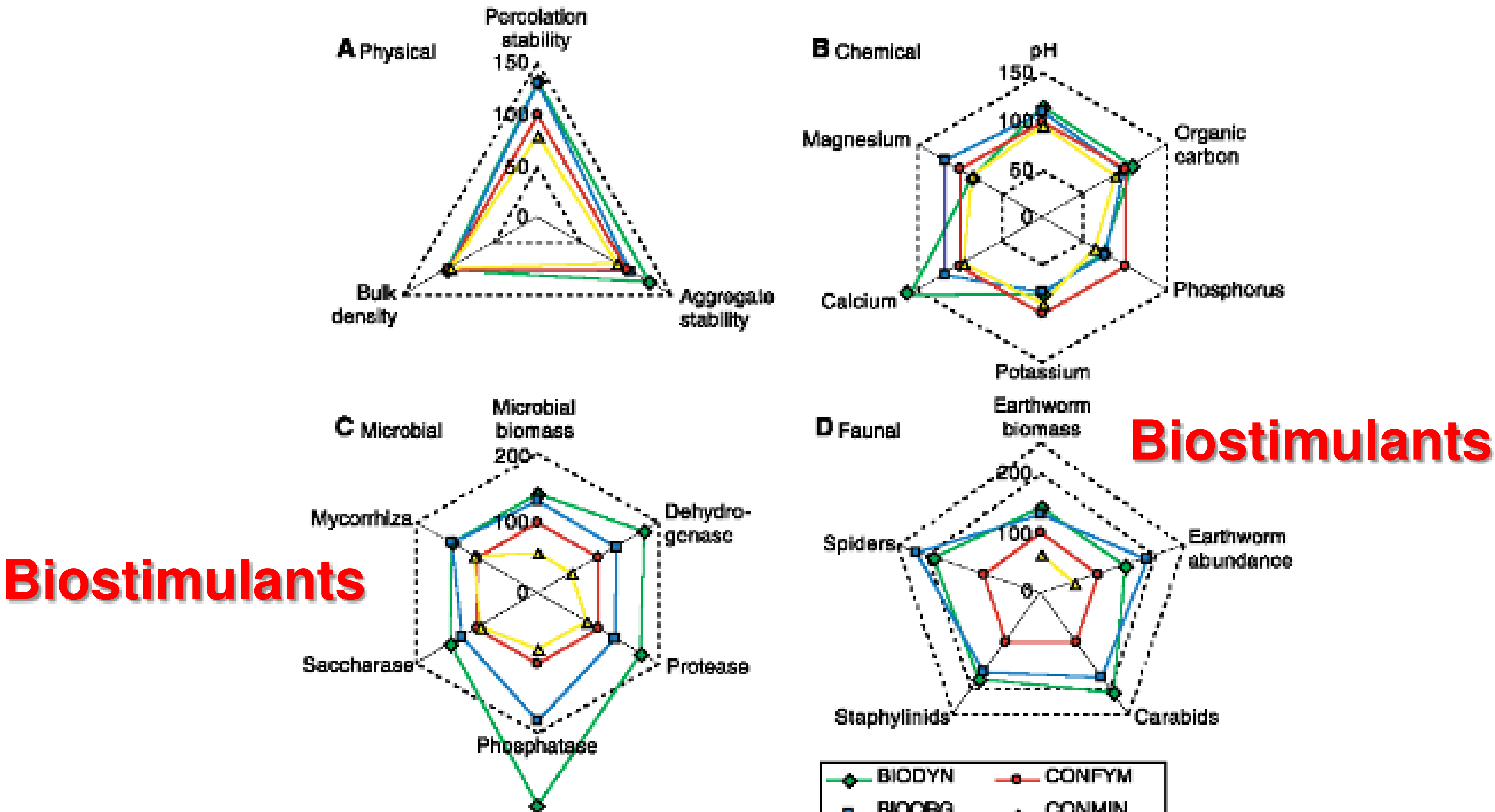
Bridging the divide between Conventional & Organic mode of cultivation

A-NPK

A refers to the **A**ctive ingredients or **A**ctive compounds present in any given fertilizers/soils.

A is not just any phytohormones like cytokinins, but including the other phytohormones like auxins, gibberellins, karrikins, etc., MicroProteins, protein hydrolysates, and their stabilizing ("chelating") associates like humic and fulvic acids, etc.

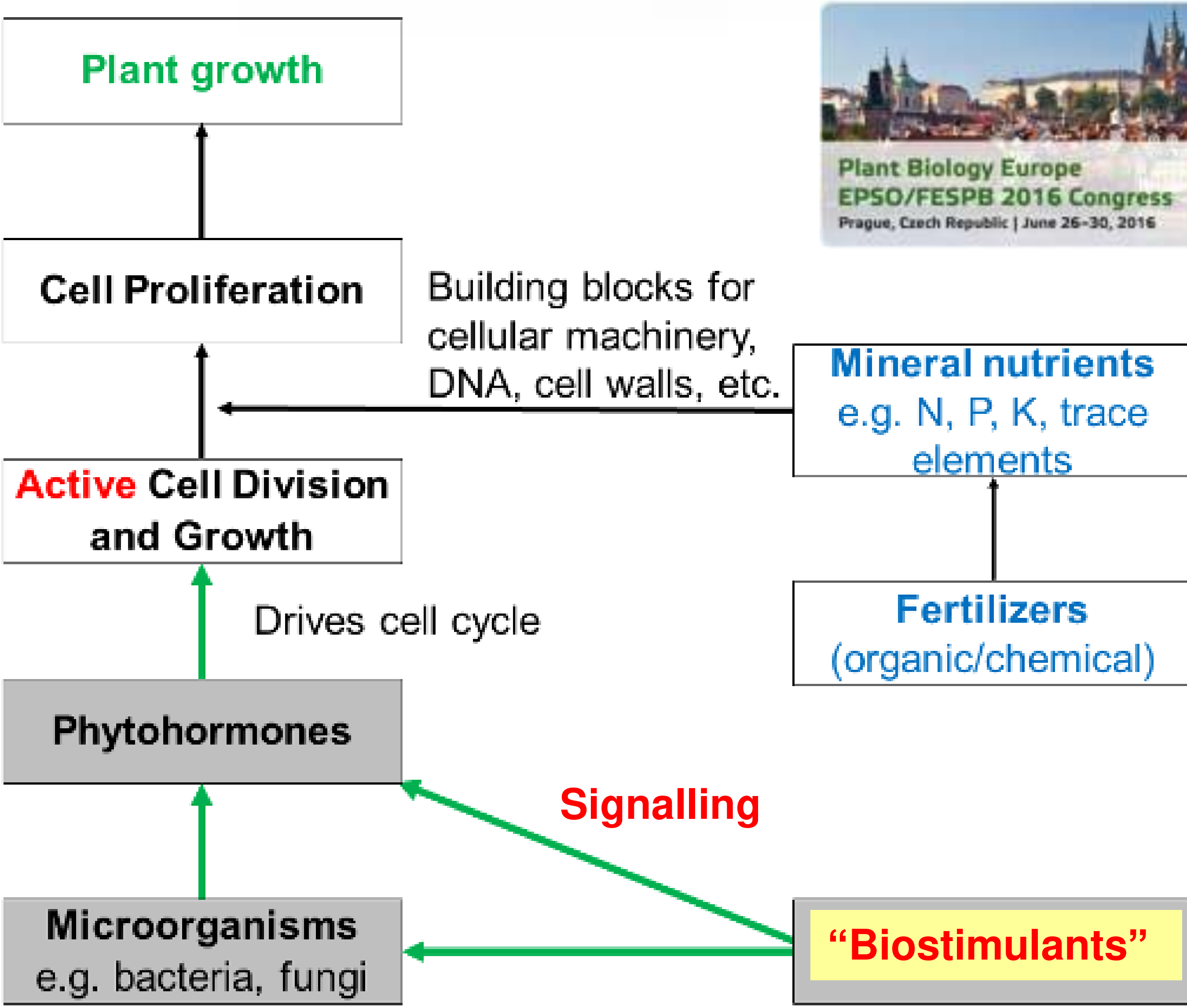
Organic plant production



Mäder et al (2002) Science

Figure 2 Physical, chemical, and biological soil properties in soils of the DOK farming systems. Analyses were done within the plough horizon (0 to 20 cm) except for soil fauna. Results are presented relative to CONFYM (= 100%) in four radial graphs. Absolute values for 100% are as follows. (**A**) Percolation stability, 43.3 ml min^{-1}; aggregate stability, 55% stable aggregates > 250 µm; bulk density, 1.23 g cm^{-3}. (**B**) pH(H_2O), 6.0; organic carbon, 15.8 g C_{org} kg^{-1}; phosphorus, 21.4 mg P kg^{-1}; potassium, 97.5 mg K kg^{-1}; calcium, 1.7 g Ca kg^{-1}; magnesium, 125 mg Mg kg^{-1}. (**C**) Microbial biomass, 285 mg C_{mic} kg^{-1}; dehydrogenase activity, 133 mg TPF kg^{-1} h^{-1}; protease activity, 238 mg tyrosine kg^{-1} h^{-1}; alkaline phosphatase, 33 mg phenol kg^{-1} h^{-1}; saccharase, 526 mg reduced sugar kg^{-1} h^{-1}; mycorrhiza, 13.4% root length colonized by mycorrhizal fungi. (**D**) Earthworm biomass, 183 g m^{-2}; earthworm abundance, 247 individuals m^{-2}; carabids, 55 individuals; staphylinids, 23 individuals; spiders, 33 individuals. Arthropods have not been determined in the CONMIN system because of the field trial design. Significant effects were found for all parameters except for bulk density, C_{org}, and potassium (analysis of variance; $P < 0.05$). For methods, see table S3.

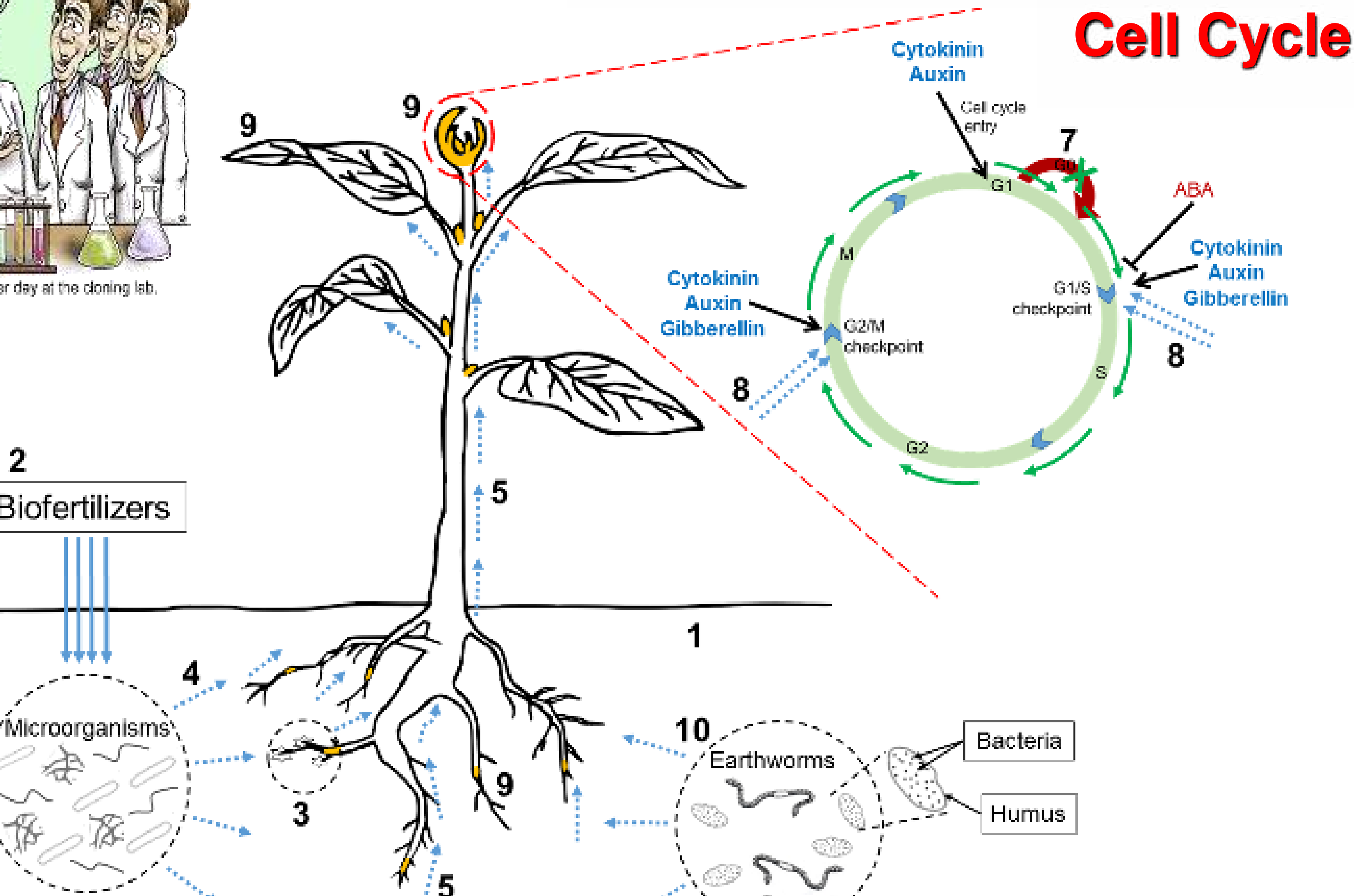
New paradigm for Plant Nutrition



Wong et al. (2019) Wiley
Wong et al. (2015) Springer
Wong et al. (2016) Acta Horticulturae

Conceptual Model

Another day at the cloning lab.

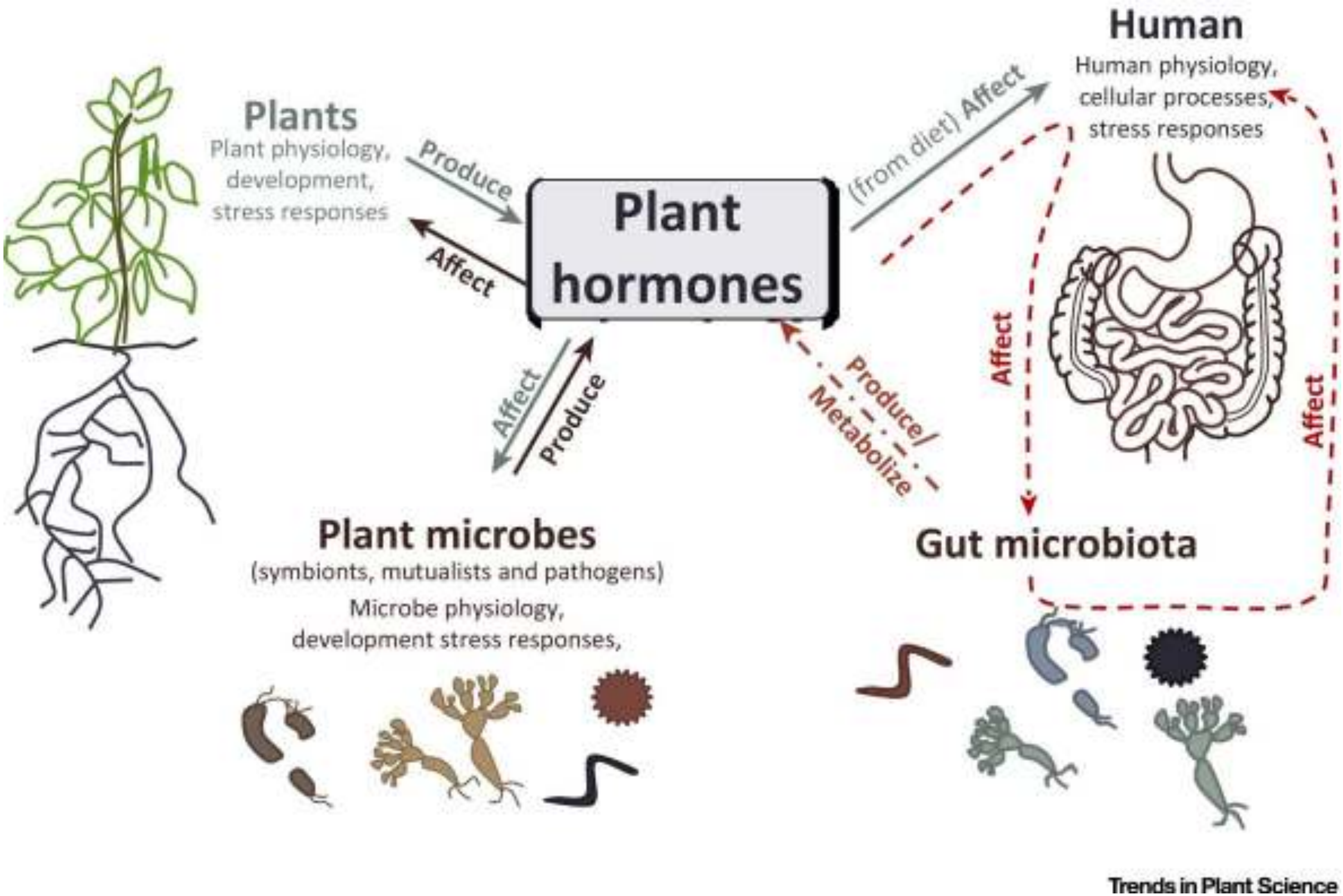


Wong et al. (2019) Wiley
Wong et al. (2015) Springer
Wong et al. (2016) Acta Horticulturae

What is a GOOD Fertilizer?

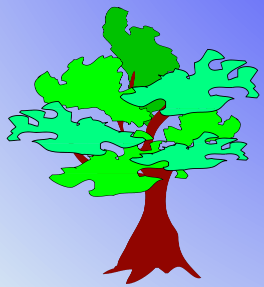
- Essential nutrients (Marco & micro nutrients, trace elements)
- Improves soil structure & holds water
- Promote plant cell division leading to cell proliferation (hormones, etc - biostimulants)

Increasing body of evidence to show that **phytohormones** affect **human health** through the **diet** and **microbes**



Chanclud and Lacombe, Trends Pl Sci (2017)

"The true voyage of discovery lies not in finding new landscapes, but in having new eyes."



- Marcel Proust

Thank You!

Hortikulturell produktionsfysiologi (HPF),
Institutionen för biosystem och teknologi

Horticultural Production Physiology,
Department of Biosystems and Technology

SLU

Swedish University of Agricultural Sciences

Acknowledgments

ARC Centre for Mine Site Restoration

An Industrial Transformation Training Centre

THE UNIVERSITY OF WESTERN AUSTRALIA

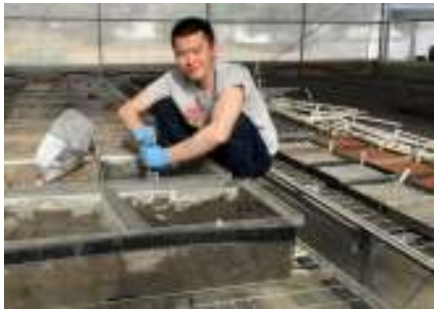
Curtin University of Technology

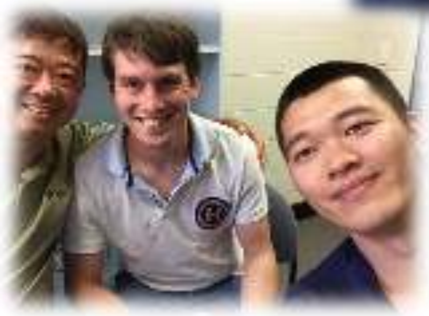
Australian Government

Australian Research Council

KINGS PARK & Botanic Garden · SER · bhpbilliton · CLIFFS · Hanson · KARARA · SMC

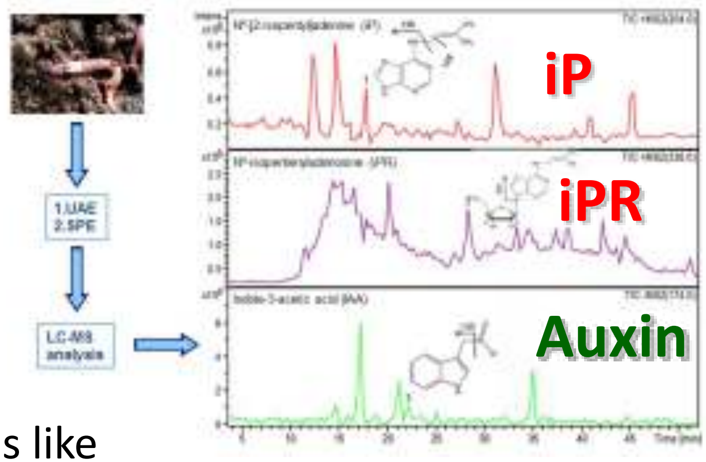
Thank You!

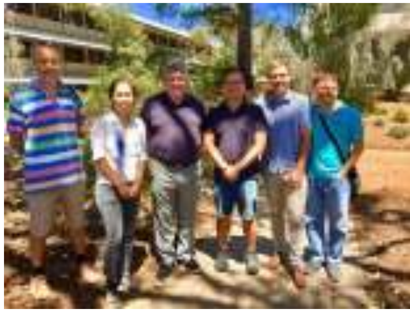




Multi-disciplinary & collaborative research
give significant cost-savings!!!
Insightful research outcomes – better papers too

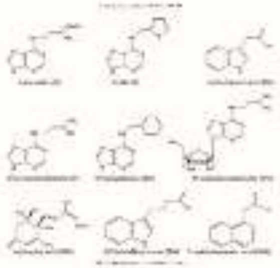
Advanced "analytical tools"





GCMS

New tools like **Soil Biological Functionality Assessment** & **Rhizosphere Competency**

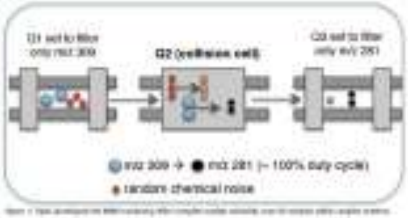


UPLC

GCMS

ELISA & SPA

Note SPA: **S**cintillation **P**roximity **A**ssay



Triple-Quad LCMS

LCMS/MS

Effects of chemical fertilizers or/and organic fertilizers on Tomato photosynthesis

Cell Cycle Control & Cytokinins

Planta (1996) 200: 2–12

Planta
© Springer-Verlag 1996

Cytokinin controls the cell cycle at mitosis by stimulating the tyrosine dephosphorylation and activation of $p34^{cdc2}$-like H1 histone kinase

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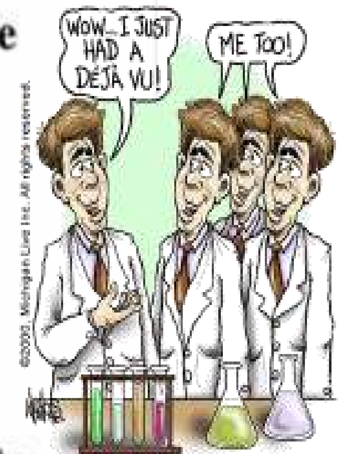
Received: 27 October 1995/Accepted: 8 January 1996

Abstract. In excised pith parenchyma from *Nicotiana tabacum* L. cv. Wisconsin Havana 38, auxin (naphthalene-1-acetic acid) together with cytokinin (6-benzylamino-purine) induced a greater than 40-fold increase in a $p34^{cdc2}$-like protein, recoverable in the $p13^{suc1}$-binding fraction, that had high H1 histone kinase activity, but enzyme induced without cytokinin was inactive. In suspension-cultured *N. plumbaginifolia* Viv., cytokinin (kinetin) was stringently required only in late G2 phase of the cell division cycle (cdc) and cells lacking kinetin arrested in G2 phase with inactive $p34^{cdc2}$-like H1 histone kinase. Control of the Cdc2 kinase by inhibitory tyrosine phosphorylation was indicated by high phosphotyrosine

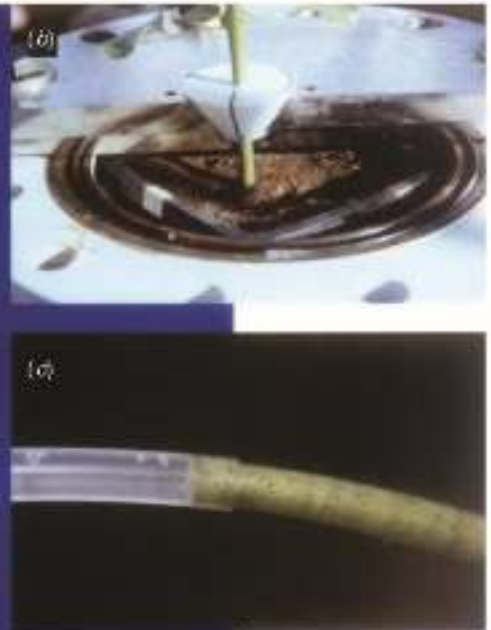
Introduction

Cell cycle control can be exercised by interaction of the key cell division cycle (cdc) catalyst $p34^{cdc2}$ (the 34-kDa product of the *cdc2* gene) with different cyclin subunits that direct its protein kinase activity to specific substrates (Peeper et al. 1993), by cyclin dependent kinase inhibitor (CKI) proteins (Pines 1995) and by enzymes that control its enzyme activity through phosphorylation (Gould and Nurse 1987; Millar et al. 1991), so providing a likely universal mitotic control (Nurse 1990).

In plants we have noted changes in the level of $p34^{cdc2}$-like protein that are consistent with an hypothesis



Another day at the cloning lab.




ANU Graham Farquhar & Chin Wong

Importance of Roots-derived Phytohormones

Using a **Root-pressure chamber** to obtain “snap-shots” of xylem sap for various analyses.

Yong et al (2000, 2010)

Agriculture, Ecosystems and Environment 224 (2016) 116–122

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Rice-soft shell turtle coculture effects on yield and its environment

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TURTLE POO

for

rice

cultivation!

Table 1
Turtle and rice yields in a 2-year field experiment with rice monoculture (RM), rice-turtle coculture (RT), and turtle monoculture (TM) in China. The turtle is *Pelodiscus sinensis*.

	Treatment		
Yields	RM	RT	TM
Rice (ton ha^{-1})			
Grain yield	7.67 ± 0.15^a	7.46 ± 0.26^a	
Straw yield	4.67 ± 0.04^b	4.98 ± 0.09^a	
Turtle (ton ha^{-1})			
Gross yield		1.56 ± 0.01^a	1.48 ± 0.03^a
Net yield		1.15 ± 0.01^a	1.09 ± 0.03^a

Values are means ± SE ($n = 4$). Means in a row followed by different letters are significantly different ($P < 0.05$).

Chinese soft-shelled turtle (*Pelodiscus sinensis*)