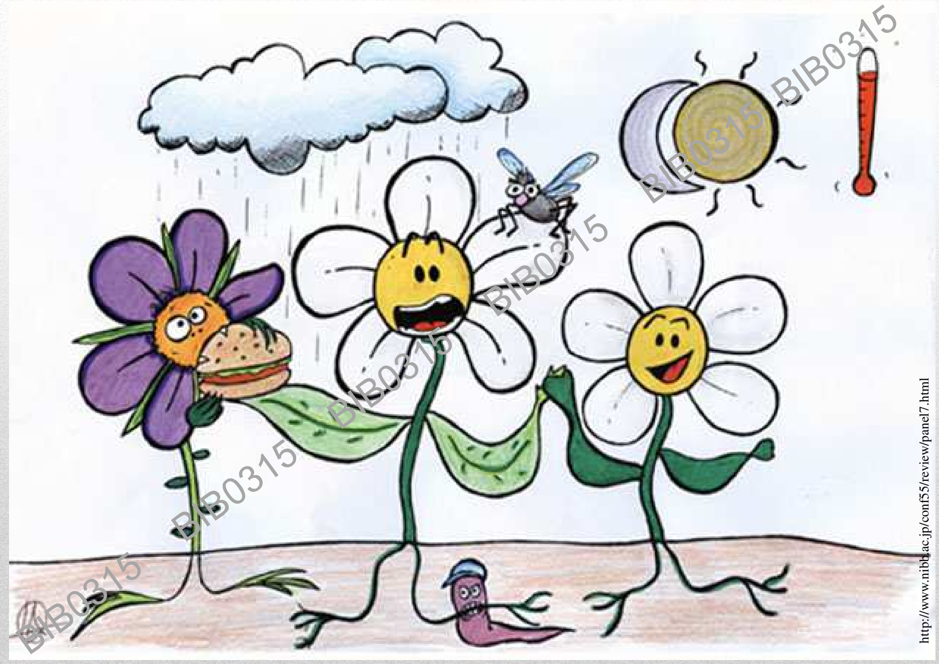
BIB 315 – Metabólitos vegetais: origem, diversidade e aplicações

Interação planta-ambiente (biótico e abiótico)

Déborah Santos
dyacsan@ib.usp.br



http://www.nibb.ac.jp/conf55/review/panel7.html

762 Planta (2015) 242:761–771

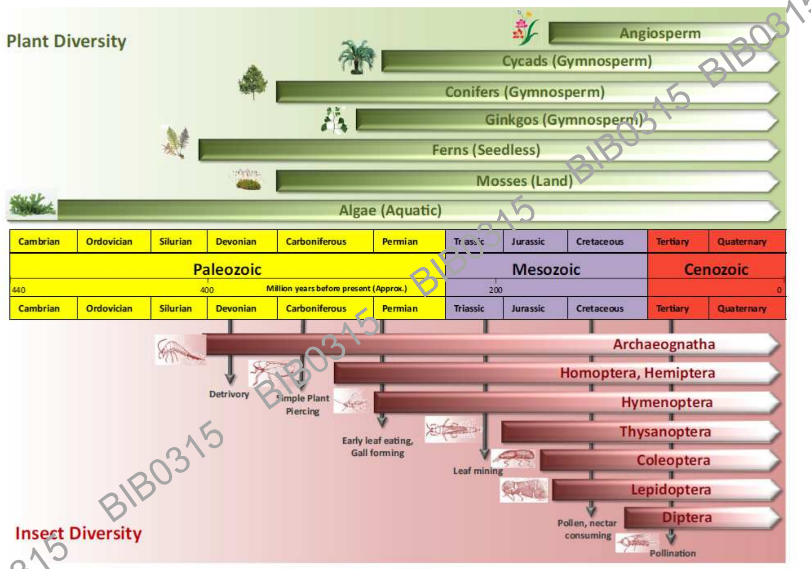
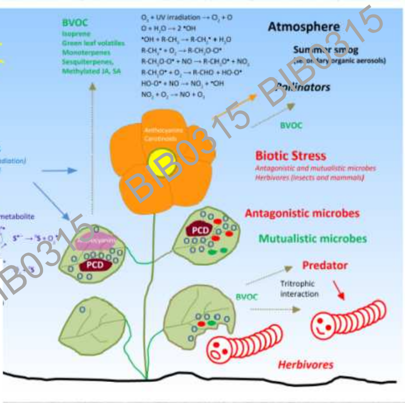
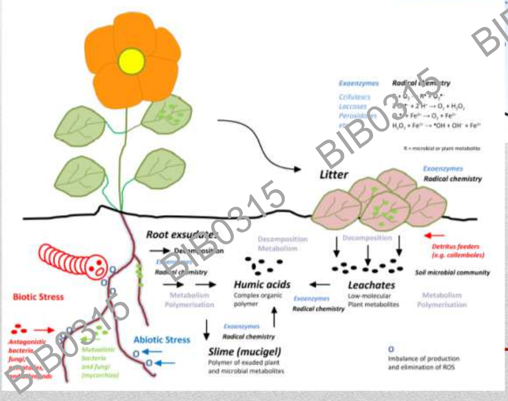

Plant Diversity
Angiosperm
Cycads (Gymnosperm)
Conifers (Gymnosperm)
Ginkgos (Gymnosperm)
Ferns (Seedless)
Mosses (Land)
Algae (Aquatic)
Cambrian
Ordovician
Silurian
Devonian
Carboniferous
Permian
Triassic
Jurassic
Cretaceous
Tertiary
Quaternary
Paleozoic
Mesozoic
Cenozoic
440
400
Million years before present (Approx.)
200
0
Archaeognatha
Homoptera, Hemiptera
Hymenoptera
Thysanoptera
Coleoptera
Lepidoptera
Diptera
Detrivory
Simple Plant Piercing
Early leaf eating, Gall forming
Leaf mining
Pollen, nectar consuming
Pollination
Insect Diversity

Fig. 1 Plant and insect evolution and various feeding habits developed by insects throughout the evolutionary timescale. Plant evolution and diversity is shown in the *upper half*, whereas insect orders and their evolution is given in the *lower half*. *Arrows* directed towards the lower side show insect feeding habits during respective time periods. The information on the evolutionary time scale and insect feeding habits was gathered from Niklas et al. (1983), Tahvanainen and Niemela (1987), and references therein

Fonte: Mishra et al. 2015.

Como as plantas se
adequam a essas situações?


BVOC
Isoprene
Green leaf volatiles
Monoterpenes
Sesquiterpenes
Methylated JA, SA
Atmosphere
Summer smog
(secondary organic aerosols)
Pollinators
BVOC
Abiotic Stress
Light (daily change in irradiation)
Temperature (day–night)
Draught
Reducing secondary metabolite
Biotic Stress
Antagonistic and mutualistic microbes
Herbivores (insects and mammals)
PCD
Antagonistic microbes
Mutualistic microbes
Predator
Tritrophic interaction
BVOC
Herbivores


Exoenzymes
Radical chemistry
Cellulases
Laccases
Peroxidases
Litter
Exoenzymes
Radical chemistry
Root exsudates
Decomposition
Radical chemistry
Decomposition
Metabolism
Decomposition
Detritus feeders (e.g. collemboles)
Soil microbial community
Biotic Stress
Metabolism
Polymerisation
Humic acids
Complex organic polymer
Exoenzymes
Radical chemistry
Leachates
Low-molecular Plant metabolites
Metabolism
Polymerisation
Abiotic Stress
Exoenzymes
Radical chemistry
Slime (mucigel)
Polymer of exuded plant and microbial metabolites
Imbalance of production and elimination of ROS
Mutualistic bacteria and fungi (mycorrhiza)

METABÓLITOS SECUNDÁRIOS

Hadacek, F, Bachmann, G, Engelmeier, D, Chobot, V. 2011. Dose Response: 79-116.

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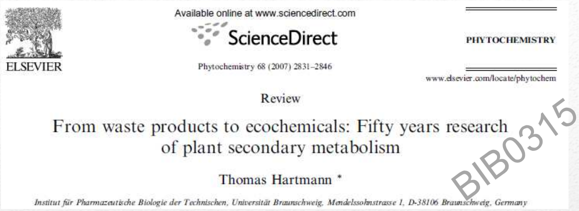


Available online at www.sciencedirect.com

ScienceDirect

Phytochemistry 68 (2007) 2831–2846

PHYTOCHEMISTRY

www.elsevier.com/locate/phytochem

Review

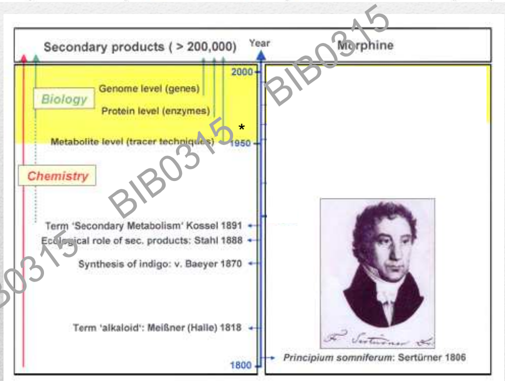
From waste products to ecochemicals: Fifty years research of plant secondary metabolism

Thomas Hartmann *

Institut für Pharmazeutische Biologie der Technischen, Universität Braunschweig, Mendelssohnstrasse 1, D-38106 Braunschweig, Germany

* Frankel 1959
Ehrlich & Raven 1964

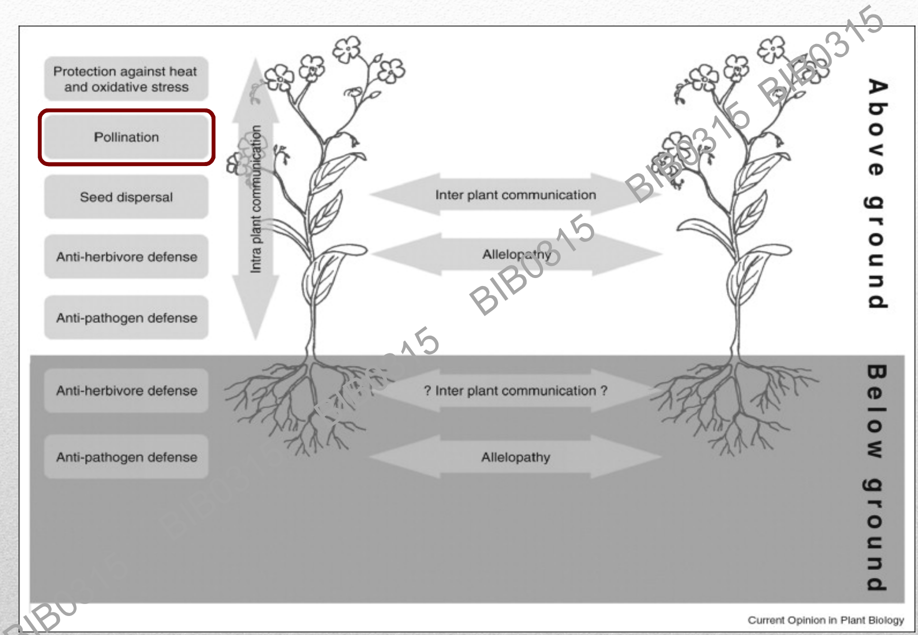
Harborne 1971
1^rst^ Symposium of Phytochemical Society – Phytochemical Ecology


Secondary products (> 200,000)
Year
Morphine
2000
Biology
Genome level (genes)
Protein level (enzymes)
*
Metabolite level (tracer techniques)
1950
Chemistry
Term 'Secondary Metabolism' Kossel 1891
Ecological role of sec. products: Stahl 1888
Synthesis of indigo: v. Baeyer 1870
Term 'alkaloid': Meißner (Halle) 1818
1800
Principium somniferum: Sertürner 1806

Friedrich Sertürner
morfina

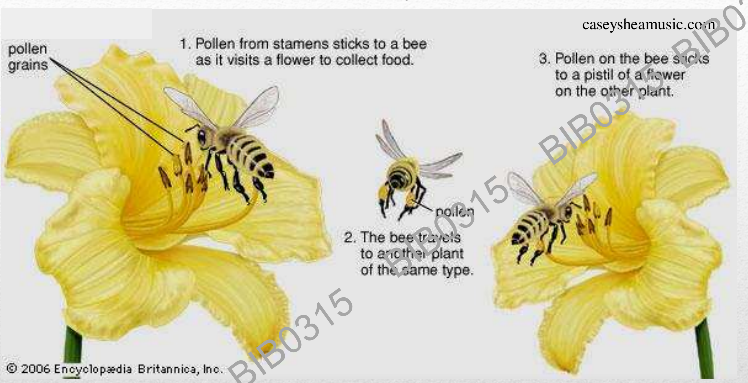
BIB0315

BIB 315 – Metabólitos vegetais: origem, diversidade e aplicações 2016


Protection against heat and oxidative stress
Pollination
Seed dispersal
Anti-herbivore defense
Anti-pathogen defense
Intra plant communication
Inter plant communication
Allelopathy
Above ground
Anti-herbivore defense
Anti-pathogen defense
? Inter plant communication ?
Allelopathy
Below ground
Current Opinion in Plant Biology

Sybille B Unsicker , Grit Kunert , Jonathan Gershenzon. **Protective perfumes: the role of vegetative volatiles in plant defense against herbivores.** Current Opinion in Plant Biology Volume 12, Issue 4 **2009** 479 – 485.

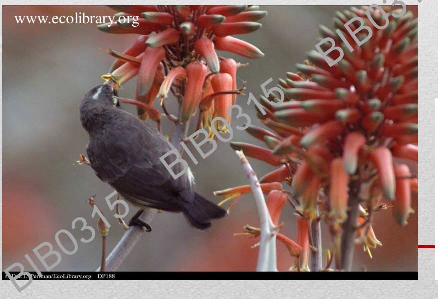
POLINIZAÇÃO


caseysheamusic.com
pollen grains
1. Pollen from stamens sticks to a bee as it visits a flower to collect food.
2. The bee travels to another plant of the same type.
pollen
3. Pollen on the bee sticks to a pistil of a flower on the other plant.
© 2006 Encyclopædia Britannica, Inc.

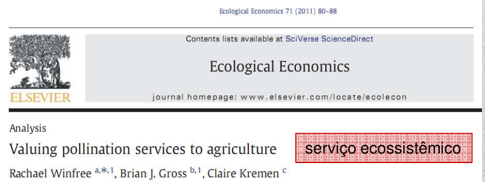
wallpaperist.net

POLINIZAÇÃO

orchidcrazeme.blogspot.com


www.ecolibrary.org

- ✓a reprodução sexuada em alguns grupos de plantas envolve a polinização
- ✓a polinização, em especial a cruzada, amplia e garante a variabilidade genética dos vegetais
- ✓relação benéfica aos envolvidos
  animal – néctar e pólen
  planta – transferência do pólen


Ecological Economics 71 (2011) 80–88

Contents lists available at SciVerse ScienceDirect

Ecological Economics

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

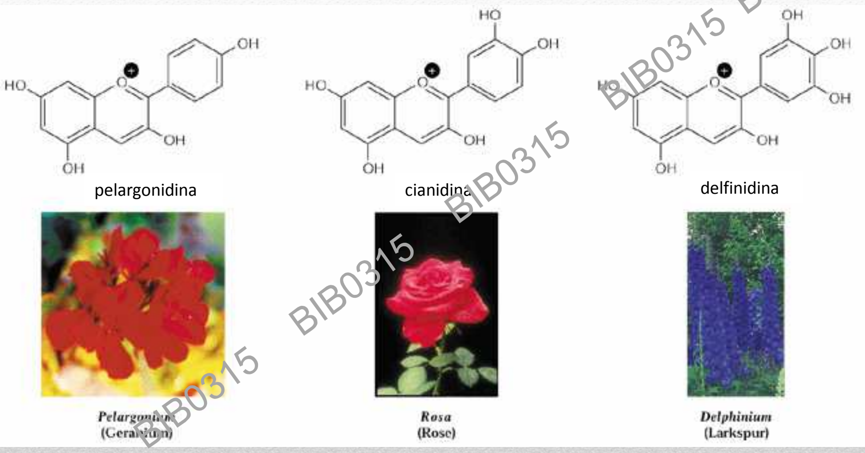
ELSEVIER

Analysis

Valuing pollination services to agriculture

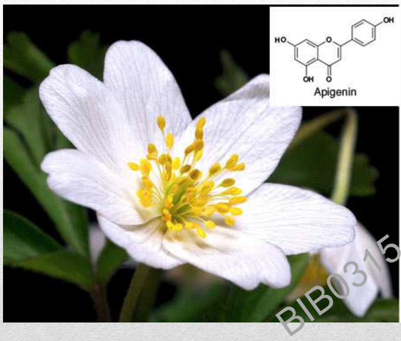
Rachael Winfree a,*,1, Brian J. Gross b,1, Claire Kremen c

serviço ecossistêmico

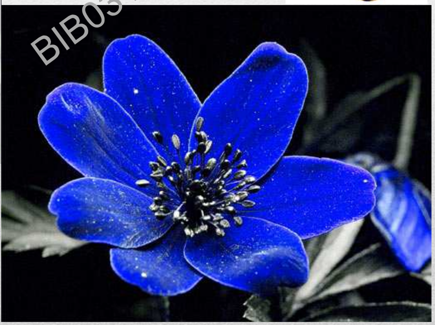

pelargonidina
cianidina
delfinidina
Pelargonium
(Geranium)
Rosa
(Rose)
Delphinium
(Larkspur)

BIB0315

visão humana



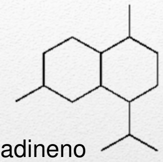
visão abelha



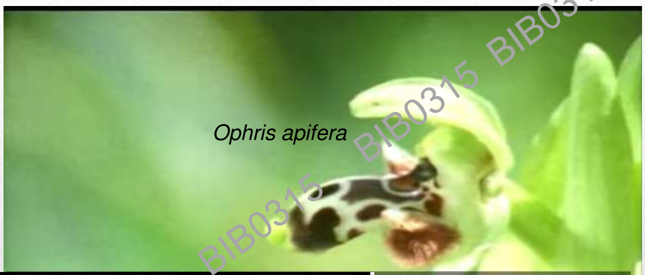
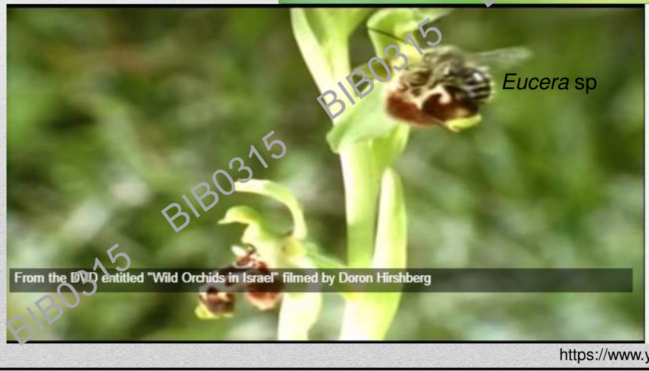
http://www.dailymail.co.uk/sciencetech/article-473897/A-bees-eye-view-How-insects-flowers-differently-us.html

BIB0315

Wild Orchids of Israel: Seduction of the Long-horned Bee 8mm to DVD by CinePost



cadineno

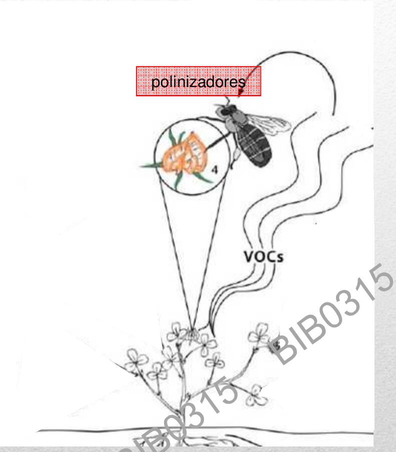



Ophris apifera

Eucera sp

Hirshberg
From the DVD entitled "Wild Orchids in Israel" filmed by Doron Hirshberg

https://www.youtube.com/watch?v=yFftHXbjEQA



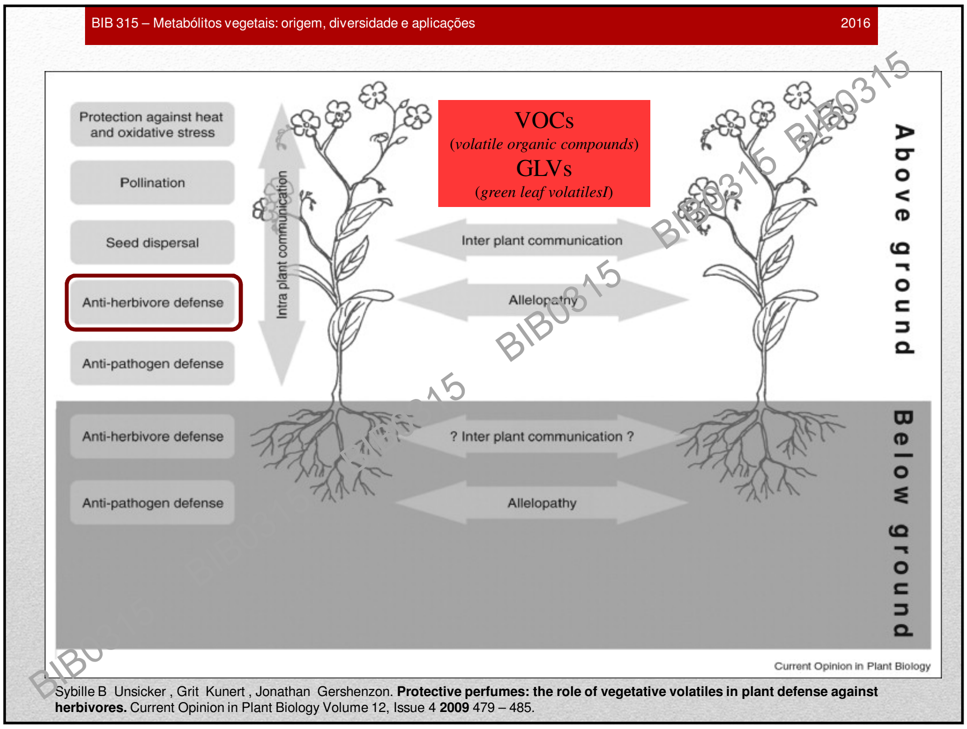
polinizadores
4
VOCs

VOCs
volatile organic compounds
(terpenoides)

http://meioambiente.culturamix.com/ecologia/flora/polinizacao-por-abelhas

© Gregorio CECCANTINI

Mithöfer, A, Boland, W, Maffei, ME. 2009. Ann. Plant Rev. 34: 261-291 (modificada)



BIB 315 – Metabólitos vegetais: origem, diversidade e aplicações 2016

VOCs
(volatile organic compounds)
GLVs
(green leaf volatilesl)

Protection against heat and oxidative stress
Pollination
Seed dispersal
Anti-herbivore defense
Anti-pathogen defense
Intra plant communication
Inter plant communication
Allelopathy
Above ground
Anti-herbivore defense
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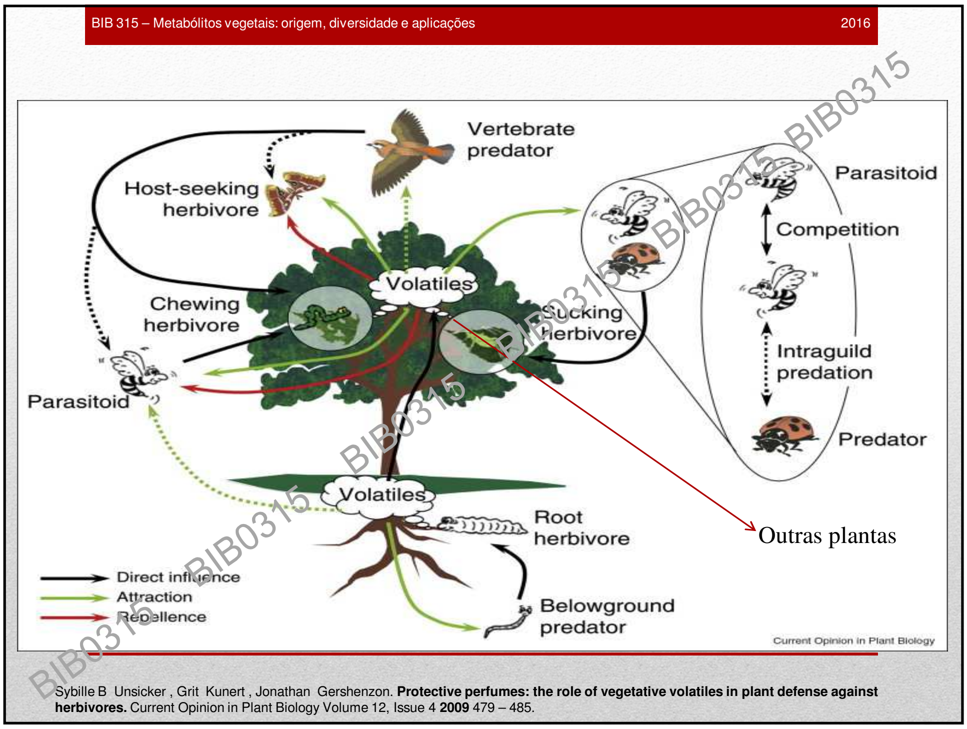

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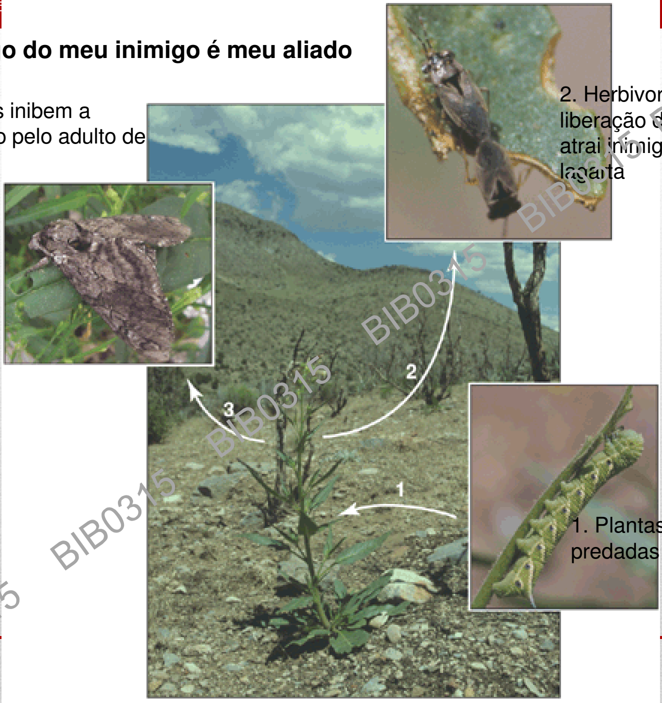
Vertebrate predator
Host-seeking herbivore
Parasitoid
Competition
Volatiles
Chewing herbivore
Sucking herbivore
Intraguild predation
Parasitoid
Predator
Volatiles
Root herbivore
Outras plantas
Direct influence
Attraction
Repellence
Belowground predator
Current Opinion in Plant Biology

BIB0315

Sybille B Unsicker , Grit Kunert , Jonathan Gershenzon. **Protective perfumes: the role of vegetative volatiles in plant defense against herbivores.** Current Opinion in Plant Biology Volume 12, Issue 4 **2009** 479 – 485.

O inimigo do meu inimigo é meu aliado



3. Voláteis inibem a oviposição pelo adulto de *Manduca*

2. Herbivoria induz liberação de voláteis que atrai inimigos naturais da lagarta

1. Plantas de tabaco predadas pela lagarta

Sabelis et al. 2001. Science 291: 2104-5

PLANTAS - formas distintas de percepção de um ataque:

1. Presença de receptores específicos para sinais químicos;
2. Reconhecimento de processos de danos locais.

HERBIVORIA

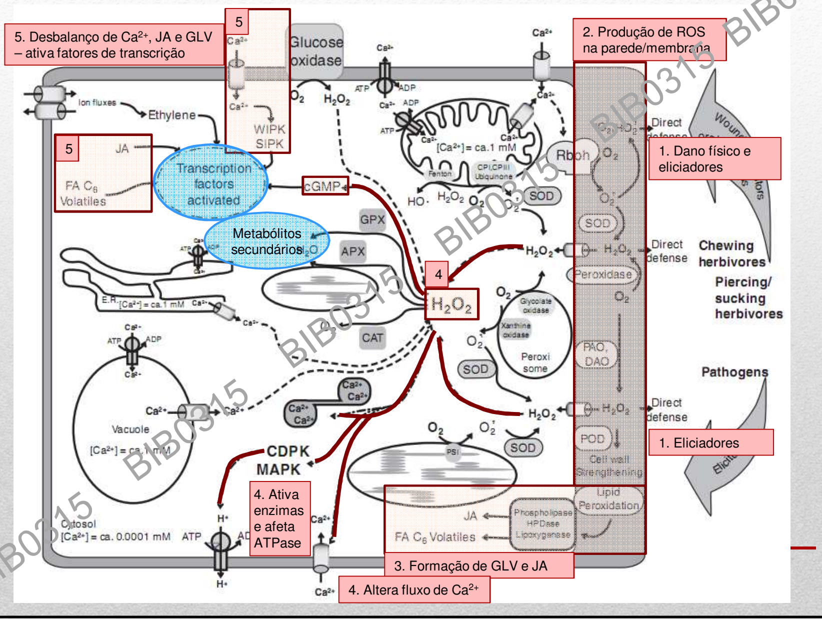
a. Injúria (dano) mecânico;
b. Secreções orais do herbívoro.

http://www.imagejuicy.com/

Larva da borboleta monarca (*Danaus plexippus*) se alimentando de folhas de *Asclepias syriaca*

COMO ACONTECE ESSA PERCEPÇÃO ?

Modelo do desencadeamento de resposta em planta frente ao ataque de herbívoros e patógenos


Glucose oxidase
Ion fluxes
Ethylene
WIPK SIPK
JA
FA C6 Volatiles
Transcription factors activated
Metabólitos secundários
cGMP
GPX
APX
CAT
SOD
Rboh
HO·
H_2O_2
O_2
Fenton
E.R. $[Ca^{2+}]$ = ca. 1 mM
Vacuole $[Ca^{2+}]$ = ca. 1 mM
Cytosol $[Ca^{2+}]$ = ca. 0.0001 mM
ATP ADP
Ca^{2+}
H^+
CDPK MAPK
Glycolate oxidase
Xanthine oxidase
Peroxisome
PSI
Peroxidase
PAO, DAO
POD
Cell wall Strengthening
Lipid Peroxidation
Phospholipase HPLase Lipoxygenase
Direct defense
Wounding
Chewing herbivores
Piercing/ sucking herbivores
Pathogens
Elicitors

5. Desbalanço de Ca^{2+}, JA e GLV – ativa fatores de transcrição

5

2. Produção de ROS na parede/membrana

1. Dano físico e eliciadores

5

4

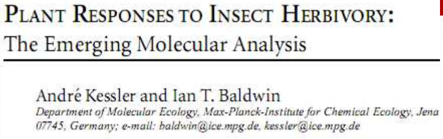
1. Eliciadores

4. Ativa enzimas e afeta ATPase

3. Formação de GLV e JA

4. Altera fluxo de Ca^{2+}

Mithöfer, A, Boland, W, Maffei, ME. 2009. Ann. Plant Rev. 34: 261-291



PLANT RESPONSES TO INSECT HERBIVORY: The Emerging Molecular Analysis

André Kessler and Ian T. Baldwin
Department of Molecular Ecology, Max-Planck-Institute for Chemical Ecology, Jena 07745, Germany; e-mail: baldwin@ice.mpg.de, kessler@ice.mpg.de

a. Dano mecânico + secreção larva: amplifica a síntese de JA

b. Dano mecânico + secreção larva: leva a síntese de VOCs

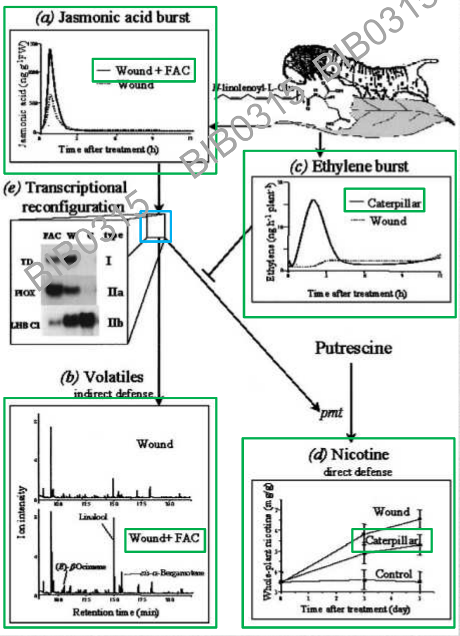
c. Herbivoria: síntese etileno

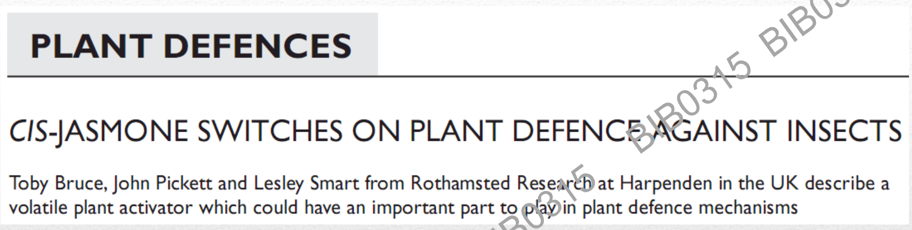
d. Etileno – atenua efeito do (a) suprimindo transcritos relacionados com síntese nicotina – adaptação de herbívoros especialistas

e. Dano mecânico + secreção larva: rearranjo transcricional que afeta a expressão diferenciada de genes relacionados a defesa.

Annu. Rev. Plant Biol. 2002.53:299-328. Downloaded from www.annualreviews.org by Universidade de São Paulo (USP) on 06/13/13. For personal use only.

Nicotiana attenuata x *Manduca* sp





PLANT DEFENCES

CIS-JASMONE SWITCHES ON PLANT DEFENCE AGAINST INSECTS

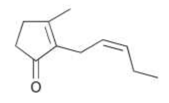
Toby Bruce, John Pickett and Lesley Smart from Rothamsted Research at Harpenden in the UK describe a volatile plant activator which could have an important part to play in plant defence mechanisms

Pesticide Outlook – June 2003

Substâncias voláteis induzidas em plantas injuriadas:

1. Repelente de insetos fitófagos.
2. Defesa indireta – atração de predador ou parasita do fitófago.
3. Sinais entre plantas – indução de mecanismos de defesa em plantas vizinhas antes do ataque dos herbívoros.

cis-Jasmone



BIB0315

Trigo (*Triticum aestivum*) x afídeo (*Sitobion avenae*)

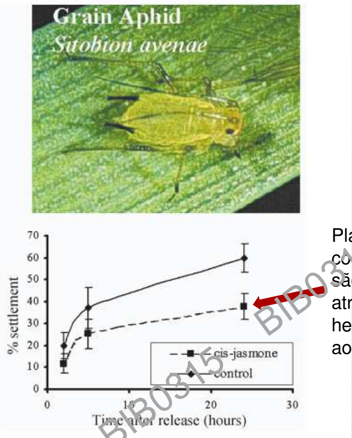


Figure 1 **Settlement of *S. avenae* in simulator bioassay**

Plantas tratadas com sinalizador são menos atrativas ao herbívoro e mais ao seu parasita

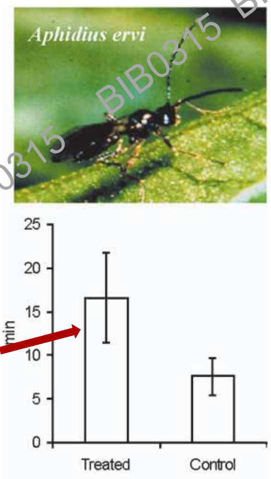


Figure 2 **Time spent foraging by *Aphidius ervi* on *cis*-jasmone and control wheat seedlings.**

BIB0315

Figure 3 **Field application of *cis*-jasmone**

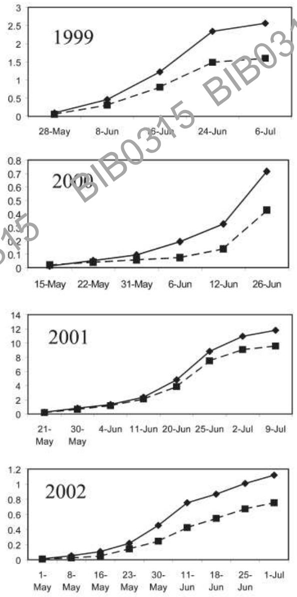


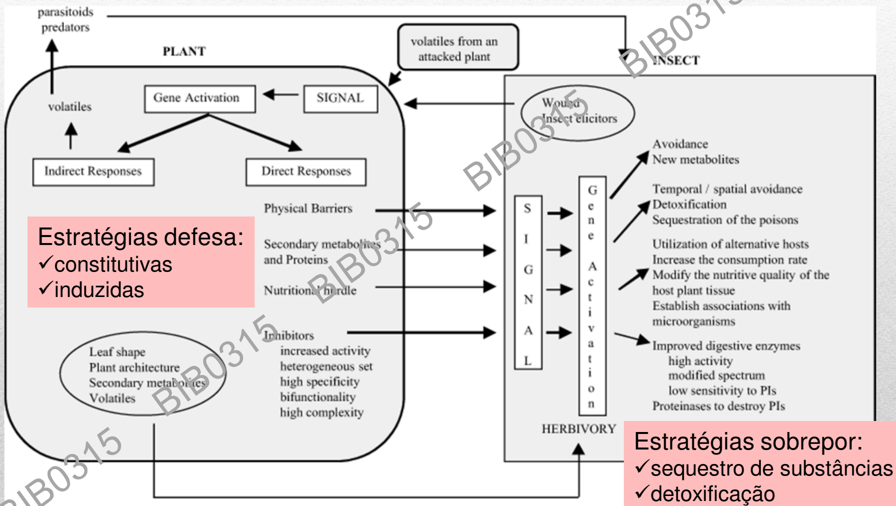
Figure 4 **Cumulative Cereal Aphid Counts in Field Plot Trials with *cis*-jasmone treatment 1999–2002 (control: ——; *cis*-jasmone: - - -)**

Braz. J. Plant Physiol., 14(2):71-81, 2002

MINIREVIEW

Plant-insect interactions: an evolutionary arms race between two distinct defense mechanisms

Marcia O. Mello and Marcio C. Silva-Filho*


parasitoids
predators
PLANT
volatiles from an attacked plant
INSECT
volatiles
Gene Activation
SIGNAL
Wound
Insect elicitors
Indirect Responses
Direct Responses
Avoidance
New metabolites
Temporal / spatial avoidance
Detoxification
Sequestration of the poisons
Physical Barriers
Secondary metabolites and Proteins
Nutritional hurdle
Utilization of alternative hosts
Increase the consumption rate
Modify the nutritive quality of the host plant tissue
Establish associations with microorganisms
Inhibitors
increased activity
heterogeneous set
high specificity
bifunctionality
high complexity
Improved digestive enzymes
high activity
modified spectrum
low sensitivity to PIs
Proteinases to destroy PIs
Leaf shape
Plant architecture
Secondary metabolites
Volatiles
SIGNAL
Gene Activation
HERBIVORY

Estratégias defesa:
- ✓constitutivas
- ✓induzidas

Estratégias sobrepor:
- ✓sequestro de substâncias
- ✓detoxificação
- ✓assoc com microrganismos

Figure 1. Interactions between plants and insects.

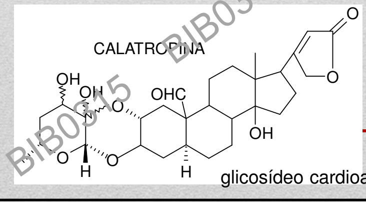
Estratégias defesa nos insetos: sequestro de substâncias

monarca x *Asclepias* x pássaro

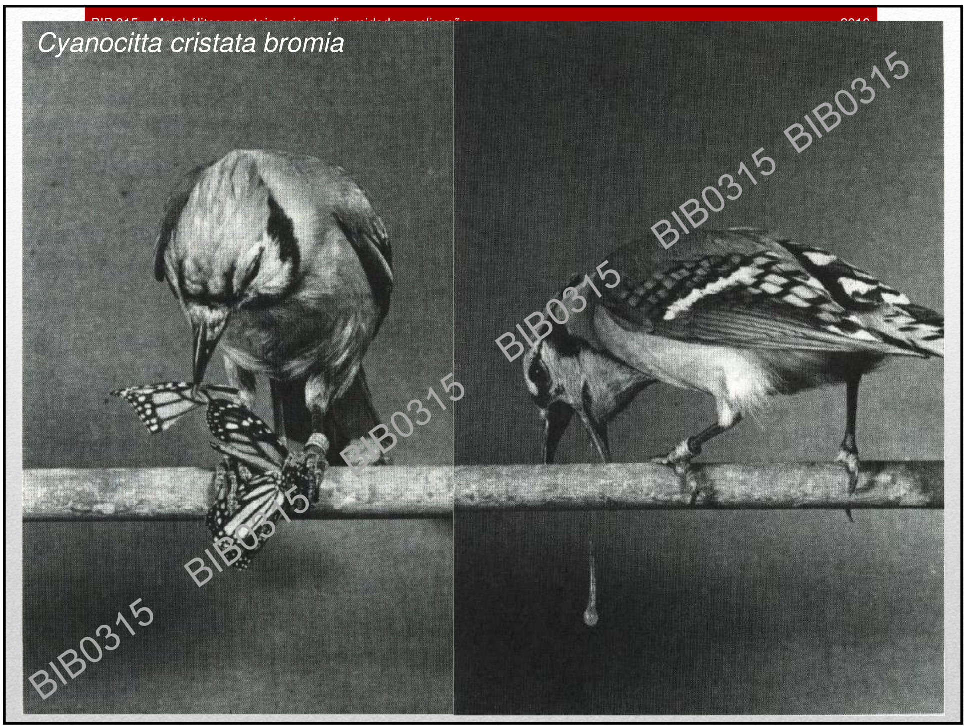
Asclepias curassavica - Apocynaceae

Danaus plexippus - monarca

Cyanocitta cristata bromia



glicosídeo cardioativo



Cyanocitta cristata bromia

Atta sexdens rubropilosa Forel

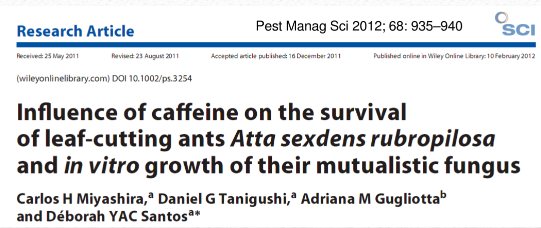
Leucoagaricus gongylophorus (Möller) Singer

Emerson Alonso

Paulo Affonso

Adriana Gugliotta

Laboratório de Fitoquímica (IB
BIB0315 BIB0315

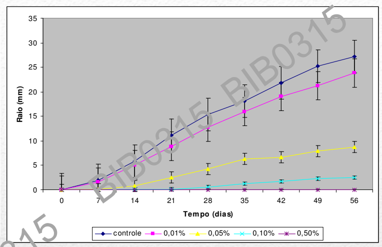

Research Article Pest Manag Sci 2012; 68: 935–940 SCI

Received: 25 May 2011 Revised: 23 August 2011 Accepted article published: 16 December 2011 Published online in Wiley Online Library: 10 February 2012

(wileyonlinelibrary.com) DOI 10.1002/ps.3254

Influence of caffeine on the survival of leaf-cutting ants *Atta sexdens rubropilosa* and *in vitro* growth of their mutualistic fungus

Carlos H Miyashira,[a] Daniel G Tanigushi,[a] Adriana M Gugliotta[b] and Déborah YAC Santos[a]*



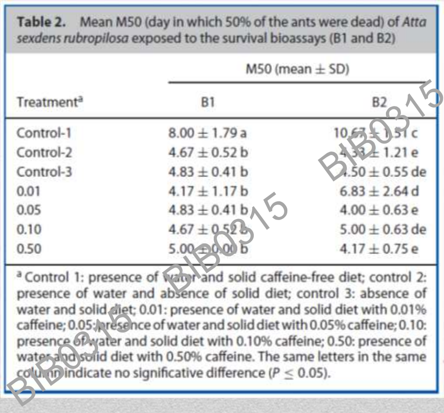
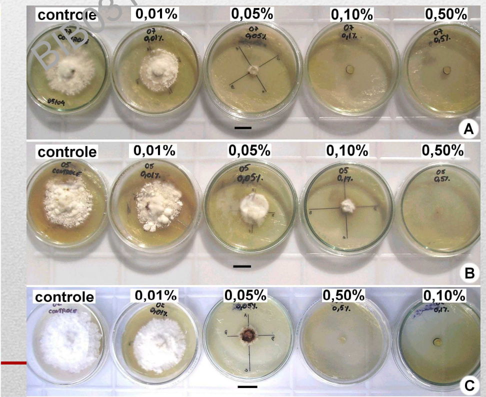
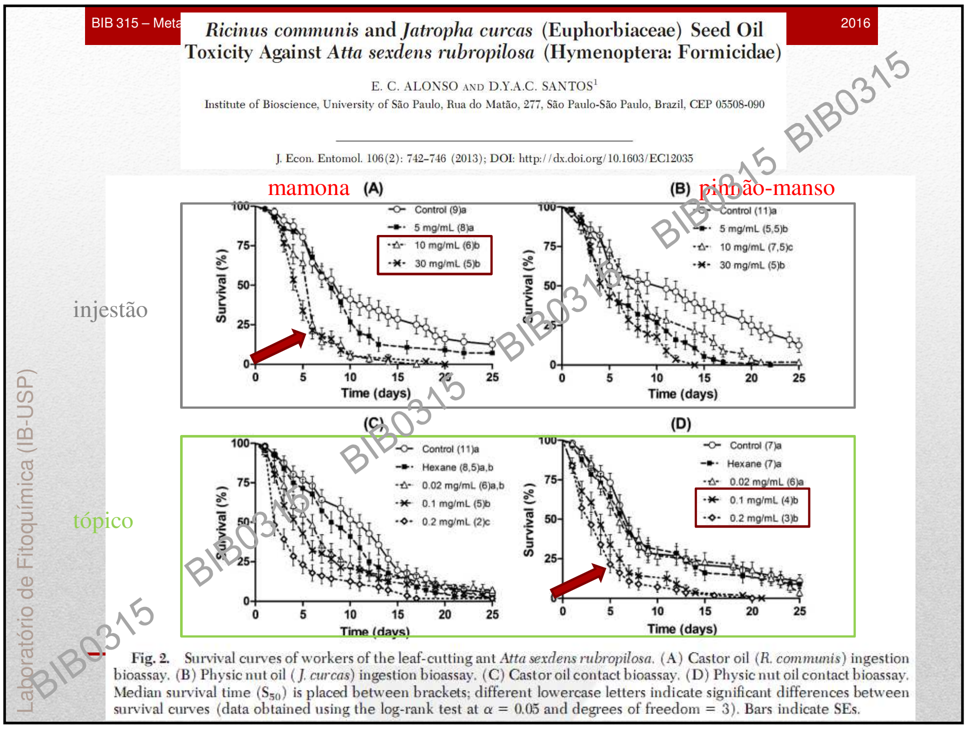


Table 2. Mean M50 (day in which 50% of the ants were dead) of *Atta sexdens rubropilosa* exposed to the survival bioassays (B1 and B2)

	M50 (mean ± SD)	
Treatment[a]	B1	B2
Control-1	8.00 ± 1.79 a	10.67 ± 1.51 c
Control-2	4.67 ± 0.52 b	4.33 ± 1.21 e
Control-3	4.83 ± 0.41 b	4.50 ± 0.55 de
0.01	4.17 ± 1.17 b	6.83 ± 2.64 d
0.05	4.83 ± 0.41 b	4.00 ± 0.63 e
0.10	4.67 ± 0.52 b	5.00 ± 0.63 de
0.50	5.00 ± 0.00 b	4.17 ± 0.75 e

[a] Control 1: presence of water and solid caffeine-free diet; control 2: presence of water and absence of solid diet; control 3: absence of water and solid diet; 0.01: presence of water and solid diet with 0.01% caffeine; 0.05: presence of water and solid diet with 0.05% caffeine; 0.10: presence of water and solid diet with 0.10% caffeine; 0.50: presence of water and solid diet with 0.50% caffeine. The same letters in the same column indicate no significative difference ($P \leq 0.05$).





Ricinus communis and *Jatropha curcas* (Euphorbiaceae) Seed Oil Toxicity Against *Atta sexdens rubropilosa* (Hymenoptera: Formicidae)

E. C. ALONSO AND D.Y.A.C. SANTOS[1]
Institute of Bioscience, University of São Paulo, Rua do Matão, 277, São Paulo-São Paulo, Brazil, CEP 05508-090

J. Econ. Entomol. 106(2): 742–746 (2013); DOI: http://dx.doi.org/10.1603/EC12035

mamona

pinhão-manso

injestão

tópico

(A)
Control (9)a
5 mg/mL (8)a
10 mg/mL (6)b
30 mg/mL (5)b
Survival (%)
Time (days)
(B)
Control (11)a
5 mg/mL (5,5)b
10 mg/mL (7,5)c
30 mg/mL (5)b
(C)
Control (11)a
Hexane (8,5)a,b
0.02 mg/mL (6)a,b
0.1 mg/mL (5)b
0.2 mg/mL (2)c
(D)
Control (7)a
Hexane (7)a
0.02 mg/mL (6)a
0.1 mg/mL (4)b
0.2 mg/mL (3)b
0
5
10
15
20
25
50
75
100

Fig. 2. Survival curves of workers of the leaf-cutting ant *Atta sexdens rubropilosa*. (A) Castor oil (*R. communis*) ingestion bioassay. (B) Physic nut oil (*J. curcas*) ingestion bioassay. (C) Castor oil contact bioassay. (D) Physic nut oil contact bioassay. Median survival time (S_{50}) is placed between brackets; different lowercase letters indicate significant differences between survival curves (data obtained using the log-rank test at $\alpha = 0.05$ and degrees of freedom = 3). Bars indicate SEs.

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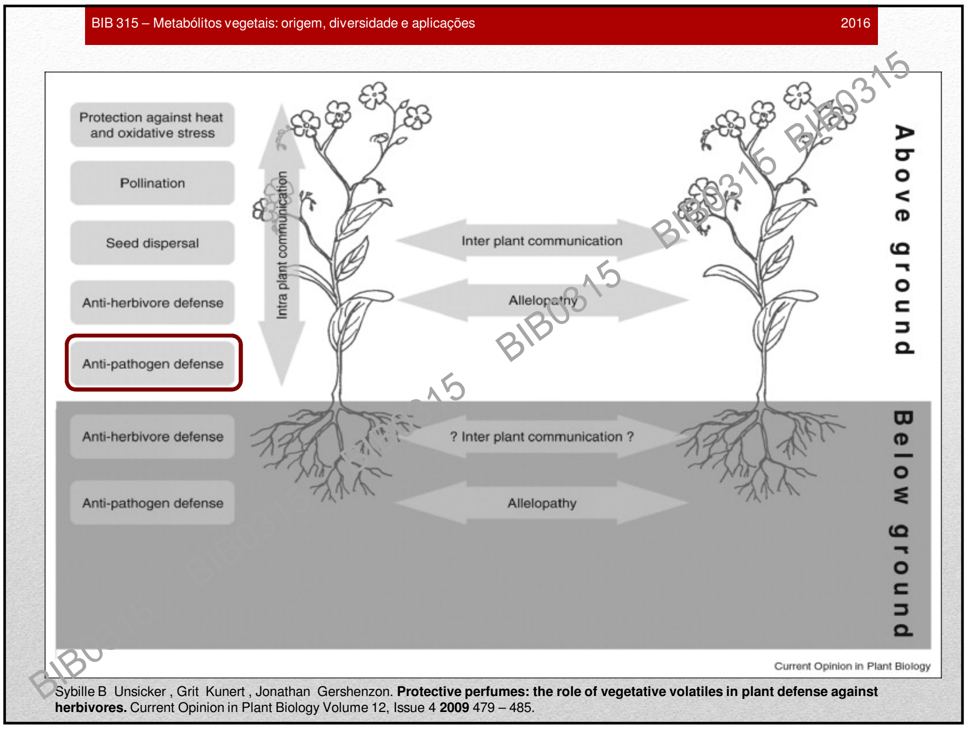

Protection against heat and oxidative stress
Pollination
Seed dispersal
Anti-herbivore defense
Anti-pathogen defense
Intra plant communication
Inter plant communication
Allelopathy
Anti-herbivore defense
Anti-pathogen defense
? Inter plant communication ?
Allelopathy
Above ground
Below ground
Current Opinion in Plant Biology

Sybille B Unsicker , Grit Kunert , Jonathan Gershenzon. **Protective perfumes: the role of vegetative volatiles in plant defense against herbivores.** Current Opinion in Plant Biology Volume 12, Issue 4 **2009** 479 – 485.

NPC Natural Product Communications
2011
Vol. 6
No. 8
1189 - 1192

Influence of Viral Infection on Essential Oil Composition of *Ocimum basilicum* (Lamiaceae)

Alice Nagai[a], Lígia M.L. Duarte[b] and Déborah Y.A.C. Santos[c,*]

[a]*São Paulo State University – Júlio de Mesquita Filho – Campus of Botucatu, Institute of Bioscience, Deparment of Botany, Botucatu-SP, Brazil, 18618-000*
[b]*Biological Institute, Research Center of Plant Sanity, Laboratory of Plant Virology, Av. Cons. Rodrigues Alves, 1252, São Paulo-SP, Brazil, 04014-002*
[c]*University of São Paulo, Institute of Bioscience, Department of Botany, R. do Matão, 277. São Paulo-SP, Brazil, 05508-090*

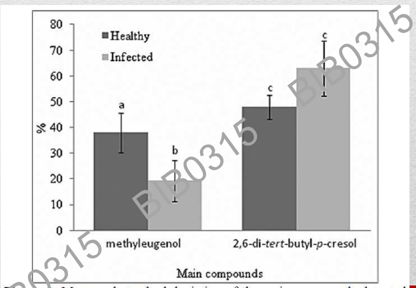

Figure 1: Mean and standard deviation of the main compounds detected in healthy and infected plants of *Ocimum basilicum* cv. Genovese. Different letters mean significant differences (p ≤ 0.05).

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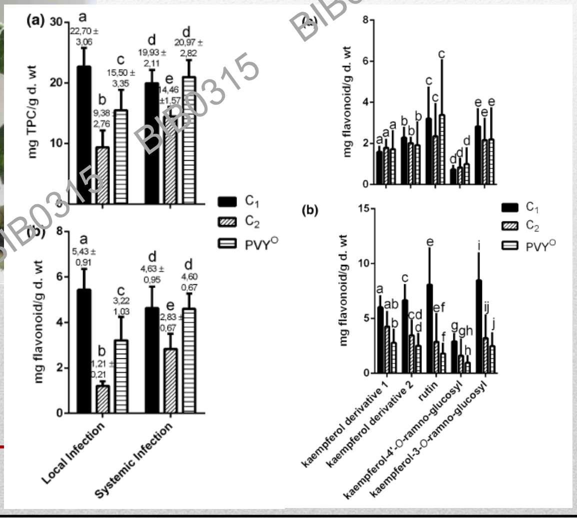
BIB0315 BIB0315 BIB0315 BIB0315 BIB0315 BIB0315

Potato virus Y infection affects flavonoid profiles of *Physalis angulata* L.

Alice Nagai[1] · Lígia M. L. Duarte[2] · Alexandre L. R. Chaves[2] · Déborah Y. A. C. dos Santos[1]

Braz. J. Bot online
DOI 10.1007/s40415-015-0181-7

Foto: Dr Marcelo Eiras



Laboratório de Fitoquímica (IB-USP)
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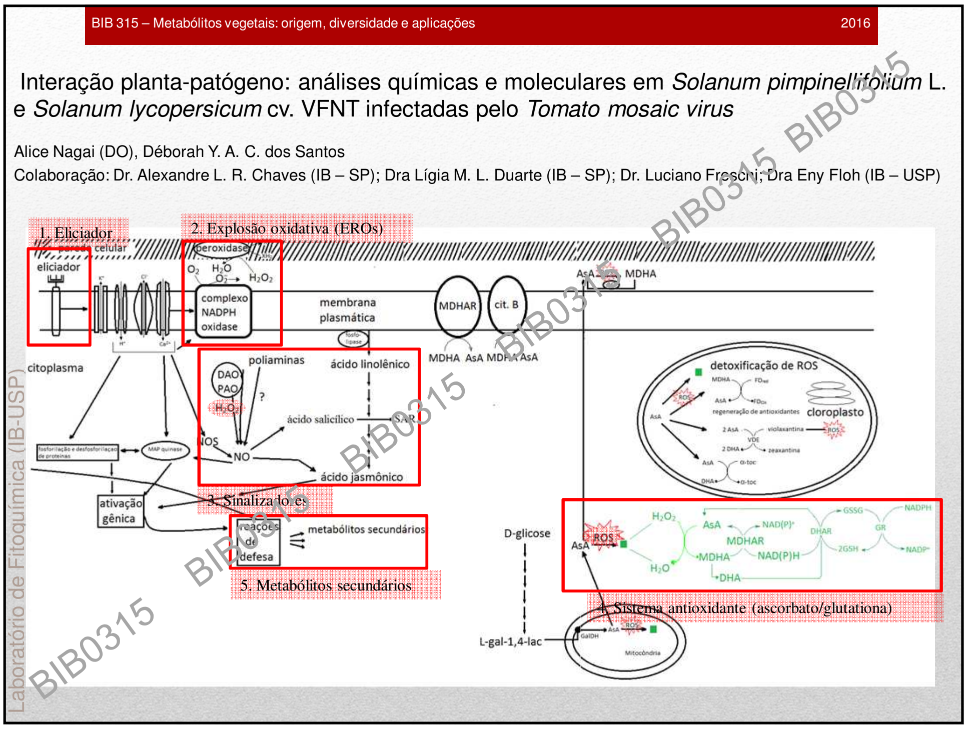


Interação planta-patógeno: análises químicas e moleculares em *Solanum pimpinellifolium* L. e *Solanum lycopersicum* cv. VFNT infectadas pelo *Tomato mosaic virus*

Alice Nagai (DO), Déborah Y. A. C. dos Santos

Colaboração: Dr. Alexandre L. R. Chaves (IB – SP); Dra Lígia M. L. Duarte (IB – SP); Dr. Luciano Freschi; Dra Eny Floh (IB – USP)

1. Eliciador

2. Explosão oxidativa (EROs)

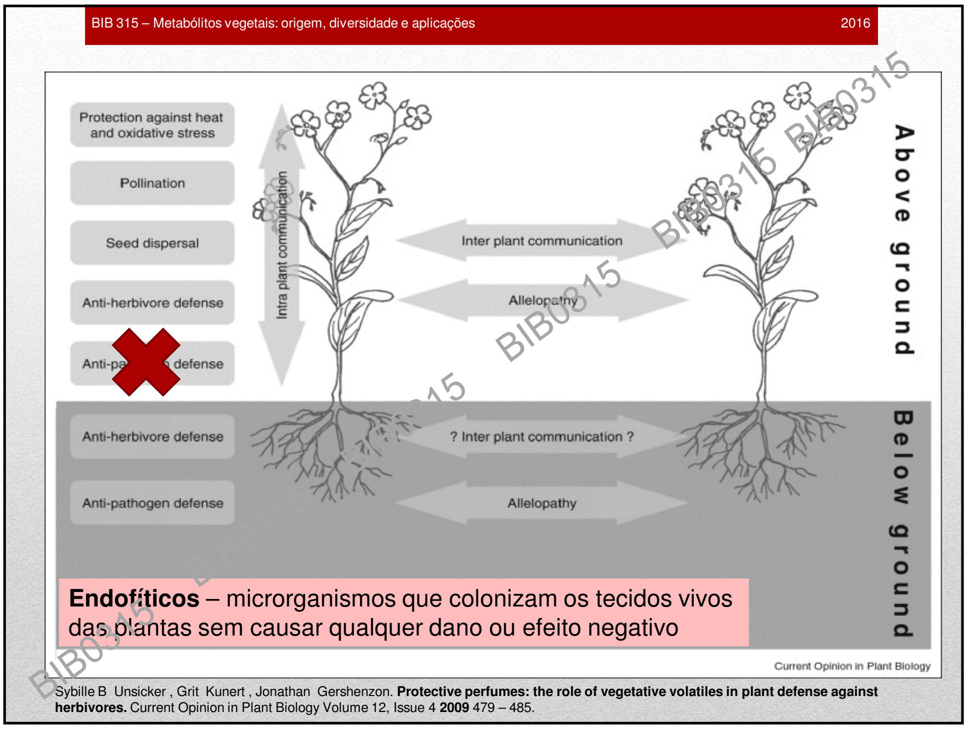
3. Sinalizadores

4. Sistema antioxidante (ascorbato/glutationa)

5. Metabólitos secundários

parede celular
eliciador
peroxidase
O_2
H_2O
O_2^-
H_2O_2
complexo NADPH oxidase
membrana plasmática
fosfo-lipase
MDHAR
cit. B
AsA
MDHA
MDHA AsA MDHA AsA
citoplasma
poliaminas
DAO
PAO
H_2O_2
?
ácido linolênico
ácido salicílico
SAR
NOS
NO
ácido jasmônico
fosforilação e desfosforilação de proteínas
MAP quinase
ativação gênica
reações de defesa
metabólitos secundários
detoxificação de ROS
MDHA
FD_{red}
AsA
FD_{ox}
ROS
regeneração de antioxidantes
cloroplasto
2 AsA
violaxantina
VDE
2 DHA
zeaxantina
α-toc
DHA
D-glicose
L-gal-1,4-lac
GalDH
Mitocôndria
ROS
H_2O_2
H_2O
AsA
MDHAR
NAD(P)+
NAD(P)H
MDHA
DHA
DHAR
GSSG
2GSH
GR
NADPH
NADP+

Laboratório de Fitoquímica (IB-USP)



Protection against heat and oxidative stress
Pollination
Seed dispersal
Anti-herbivore defense
Anti-pathogen defense
Intra plant communication
Inter plant communication
Allelopathy
Above ground
Anti-herbivore defense
Anti-pathogen defense
? Inter plant communication ?
Allelopathy
Below ground
Current Opinion in Plant Biology

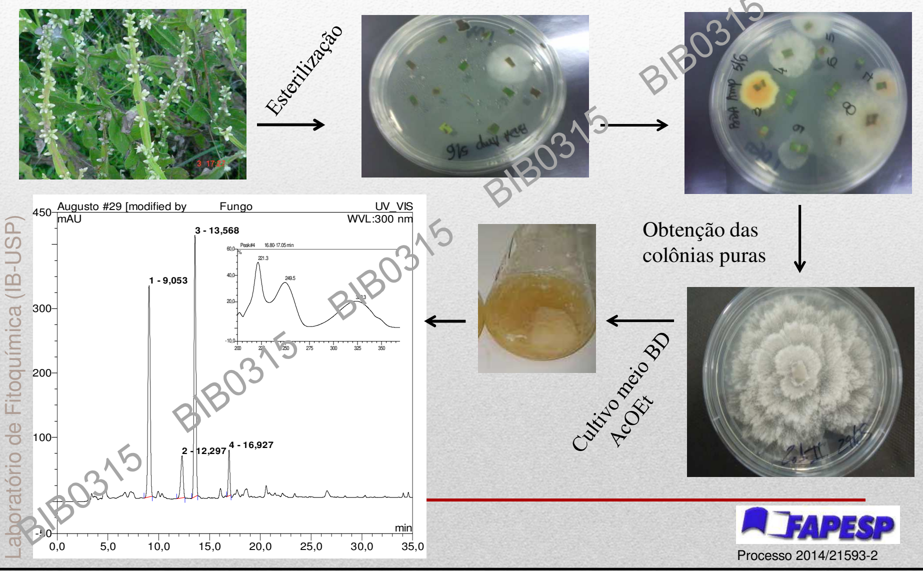
Endofíticos – microrganismos que colonizam os tecidos vivos das plantas sem causar qualquer dano ou efeito negativo

Sybille B Unsicker , Grit Kunert , Jonathan Gershenzon. **Protective perfumes: the role of vegetative volatiles in plant defense against herbivores.** Current Opinion in Plant Biology Volume 12, Issue 4 **2009** 479 – 485.

Pentacalia desiderabilis

Baccharis L. e fungos endofíticos associados: estudo químico e bioatividades

Prof. Marcelo José Pena Ferreira


Augusto #29 [modified by
Fungo
UV_VIS
WVL:300 nm
450
mAU
3 - 13,568
1 - 9,053
300
200
100
2 - 12,297
4 - 16,927
-10
min
0,0
5,0
10,0
15,0
20,0
25,0
30,0
35,0

Esterilização

Obtenção das colônias puras

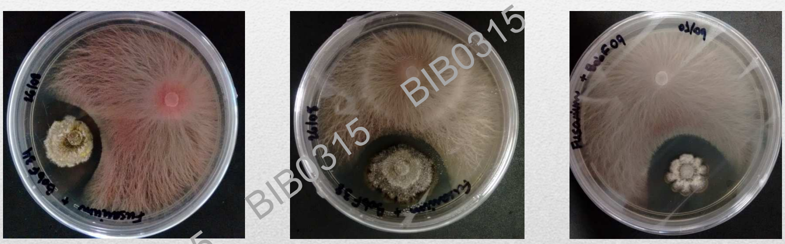
Cultivo meio BD AcOEt

Laboratório de Fitoquímica (IB-USP)

FAPESP
Processo 2014/21593-2

Exemplos da atividade antagônica (antibiose) entre os fungos endofíticos de *B. oblongifolia* e o fitopatógeno *Fusarium oxysporum*

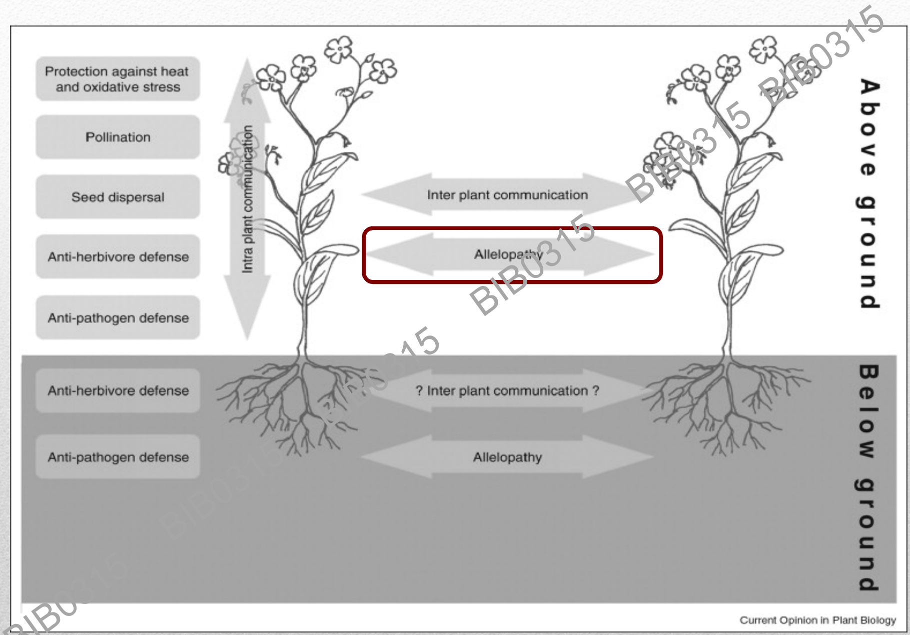
Luiza Cheliz Rodrigues (IC – Fapesp), Prof. Marcelo J. P. Ferreira



Fotos: Luiza Cheliz Rodrigues

Laboratório de Fitoquímica (IB-USP)

FAPESP
Processo 2016/05187-0


Protection against heat and oxidative stress
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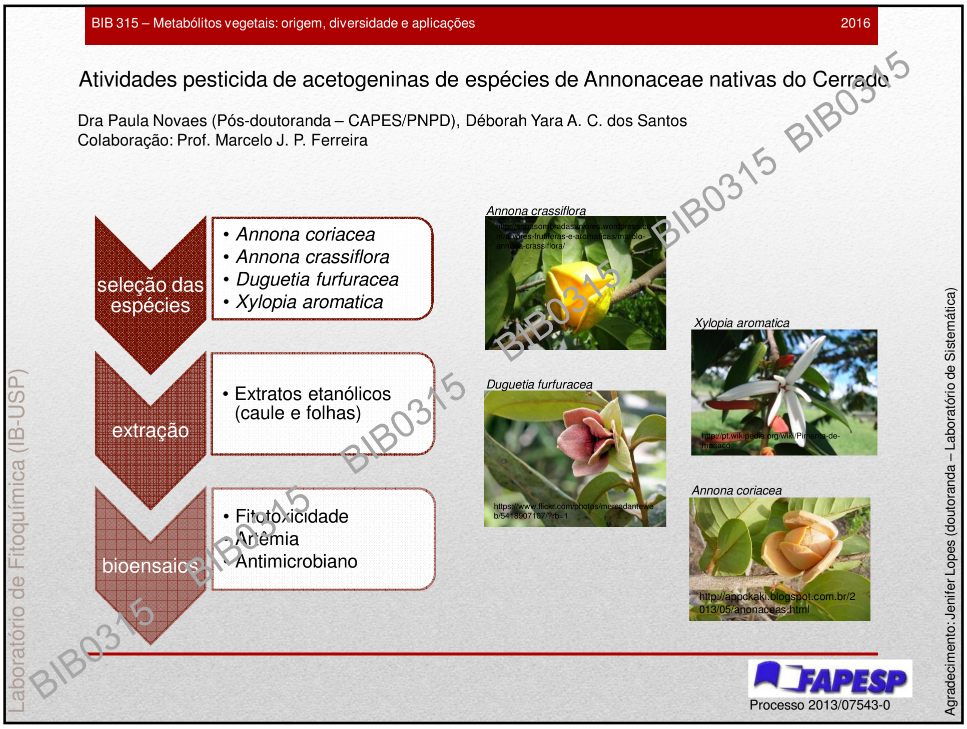
Sybille B Unsicker , Grit Kunert , Jonathan Gershenzon. **Protective perfumes: the role of vegetative volatiles in plant defense against herbivores.** Current Opinion in Plant Biology Volume 12, Issue 4 **2009** 479 – 485.



Atividades pesticida de acetogeninas de espécies de Annonaceae nativas do Cerrado

Dra Paula Novaes (Pós-doutoranda – CAPES/PNPD), Déborah Yara A. C. dos Santos
Colaboração: Prof. Marcelo J. P. Ferreira

seleção das espécies
- *Annona coriacea*
- *Annona crassiflora*
- *Duguetia furfuracea*
- *Xylopia aromatica*

extração
- Extratos etanólicos (caule e folhas)

bioensaios
- Fitotoxicidade
- Artêmia
- Antimicrobiano

Annona crassiflora
http://sobasombradasarvores.wordpress.com/arvores-frutiferas-e-aromaticas/marolo-annona-crassiflora/

Xylopia aromatica
http://pt.wikipedia.org/wiki/Pimenta-de-macaco

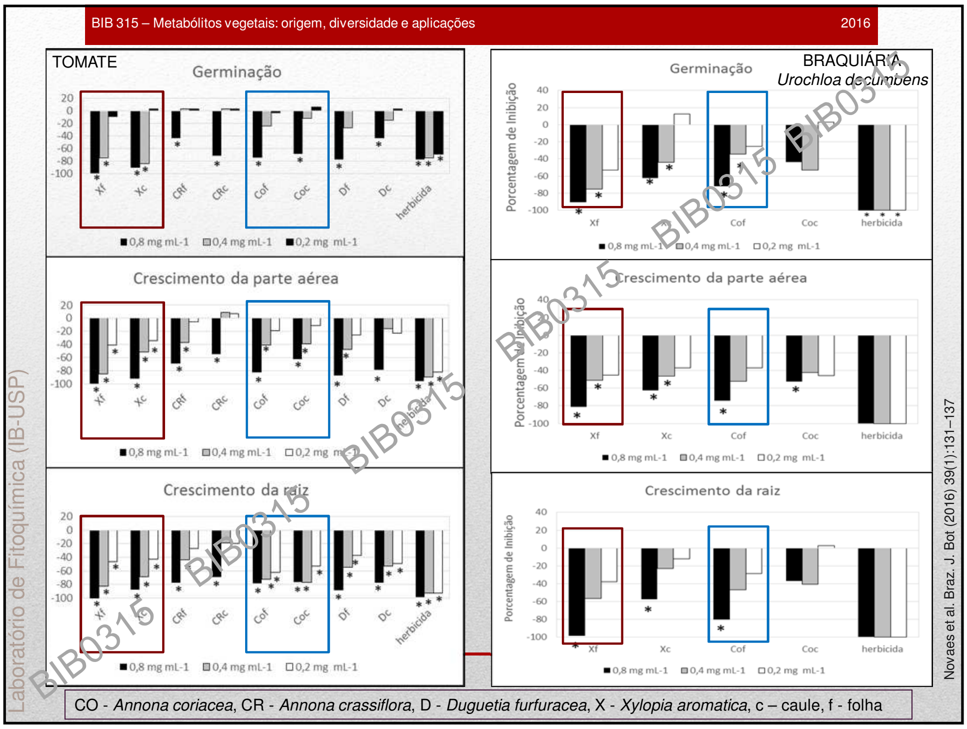
Duguetia furfuracea
https://www.flickr.com/photos/mercadanteweb/5418907107/?rb=1

Annona coriacea
http://appckaki.blogspot.com.br/2013/05/anonaceas.html

FAPESP
Processo 2013/07543-0

Agradecimento: Jenifer Lopes (doutoranda – Laboratório de Sistemática)

Laboratório de Fitoquímica (IB-USP)

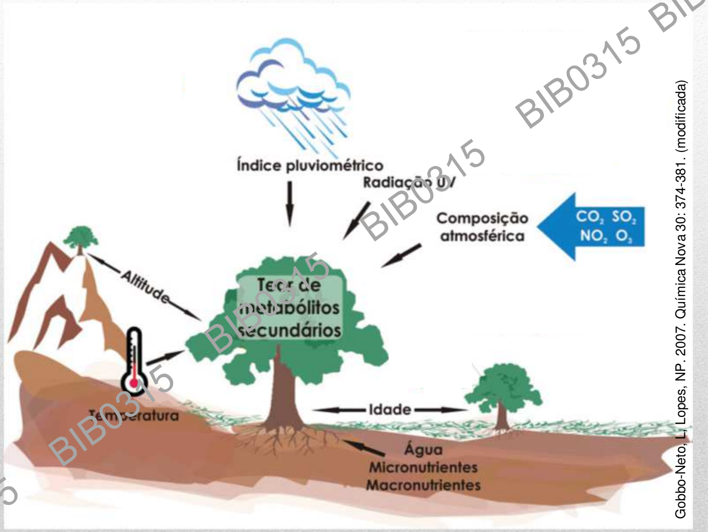


CO - *Annona coriacea*, CR - *Annona crassiflora*, D - *Duguetia furfuracea*, X - *Xylopia aromatica*, c – caule, f - folha

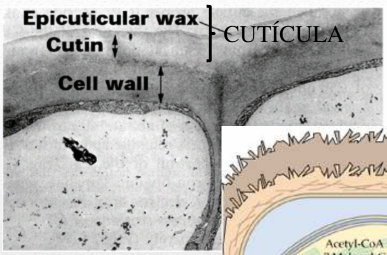
Novaes et al. Braz. J. Bot (2016) 39(1):131–137

Laboratório de Fitoquímica (IB-USP)

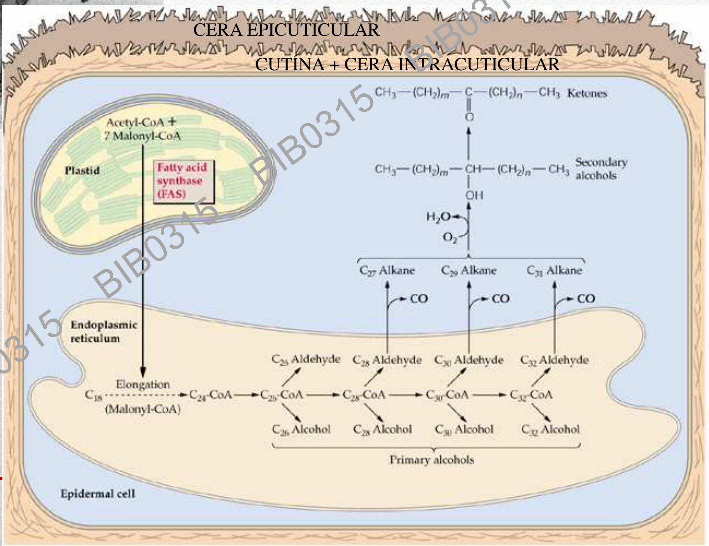
INTERAÇÃO PLANTA X FATORES ABIÓTICOS


Índice pluviométrico
Radiação UV
Composição atmosférica
CO, SO, NO, O
Altitude
Teor de metabólitos secundários
Temperatura
Idade
Água
Micronutrientes
Macronutrientes

Gobbo-Neto, L; Lopes, NP. 2007. Química Nova 30: 374-381. (modificada)


Epicuticular wax
Cutin
Cell wall
CUTÍCULA

- ✓Camada fotoprotetora
- ✓ Minimizar a adesão de resíduos nas superfícies das plantas
- ✓Limitar perda de água não estomática
- ✓ Mediação da interação das plantas com ambiente e herbívoros/patógenos
- ✓ Manutenção do correto desenvolvimento de vários órgãos


CERA EPICUTICULAR
CUTÍNA + CERA INTRACUTICULAR
CH3—(CH2)m—C—(CH2)n—CH3 Ketones
O
CH3—(CH2)m—CH—(CH2)n—CH3 Secondary alcohols
OH
H2O
O2
C27 Alkane
C29 Alkane
C31 Alkane
CO
CO
CO
Acetyl-CoA + 7 Malonyl-CoA
Plastid
Fatty acid synthase (FAS)
Endoplasmic reticulum
C25 Aldehyde
C28 Aldehyde
C30 Aldehyde
C32 Aldehyde
C18
Elongation
(Malonyl-CoA)
C24-CoA
C25-CoA
C28-CoA
C30-CoA
C32-CoA
C26 Alcohol
C28 Alcohol
C30 Alcohol
C32 Alcohol
Primary alcohols
Epidermal cell

Cera epicuticular influencia na dispersão da radiação;

Estrutura da superfície altera o ângulo de contato com líquidos; difusão

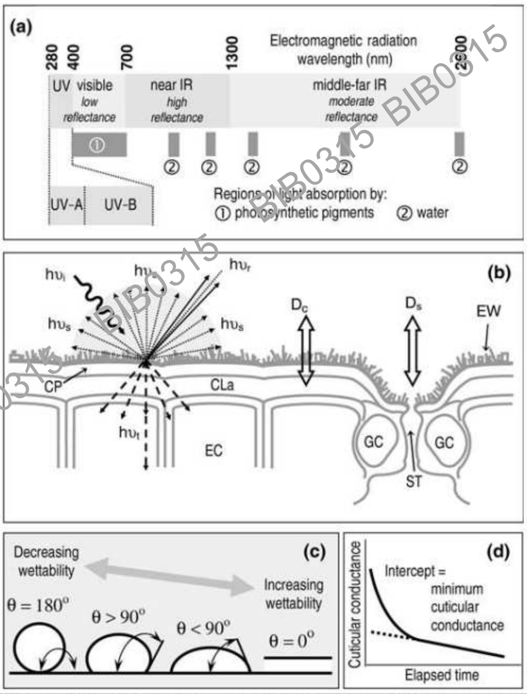
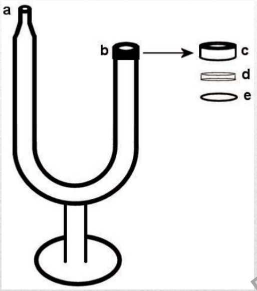

(a)
280
400
700
1300
2500
Electromagnetic radiation wavelength (nm)
UV visible low reflectance
near IR high reflectance
middle-far IR moderate reflectance
①
②
UV-A
UV-B
Regions of light absorption by:
① photosynthetic pigments
② water
(b)
hυ_i
hυ_r
hυ_s
hυ_t
D_c
D_s
EW
CP
CLa
EC
GC
ST
(c)
Decreasing wettability
Increasing wettability
θ = 180°
θ > 90°
θ < 90°
θ = 0°
(d)
Cuticular conductance
Intercept = minimum cuticular conductance
Elapsed time

Fig. 4 Leaf surface properties. (a) Wavelength distributions for radiation incident on plant leaves, absorption events and surface reflectivity. (b) Leaf cross-section showing incident ($h\upsilon_i$), reflected ($h\upsilon_r$), scattered ($h\upsilon_s$) and transmitted ($h\upsilon_t$) electromagnetic radiation, paths of stomatal (D_s) and cuticular (D_c) diffusion or transpiration. EW, epicuticular wax; CP, cuticle proper consisting of epicuticular wax, intracuticular wax and cutin; CLa, cuticular layer, consisting of intracuticular waxes, cutin and polysaccharides; EC, epidermal cells; GC, guard cells; ST, stomata. (c) Variation in leaf surface contact angle (θ) and wettability from spherical droplet to water film. (d) Variation of cuticular conductance with time following onset of water stress.

Shepherd & Griffiths. The effects of stress on plant cuticular waxes. New Phytologist (2006) 171: 469–499

BIB0315

Hidrofobicidade da cutícula depende da composição relativa das frações de hidrocarbonetos, álcoois e aldeídos (mais relacionada com as ceras)



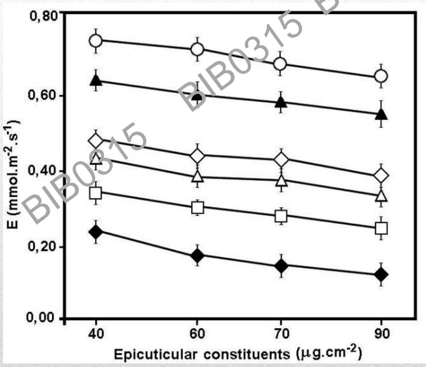
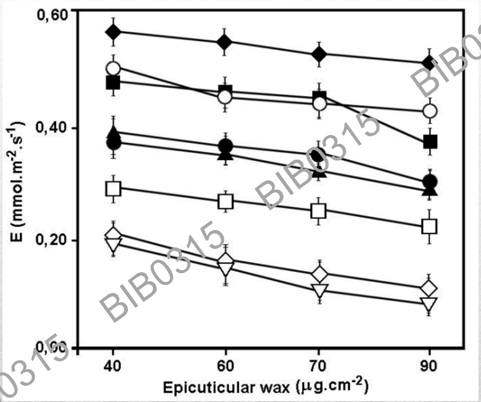


Fig. 3 – Evaporation rates (E) inWhatman paper discs impregnated with constituents separated fromfoliar epicuticularwaxes of species fromcaatinga and cerrado. Empty symbols correspond to triterpenoids. (○) ursolic acid, (▲) hentriacontan-16-one, (◇) lupeol, (△) lupeol + β-amyrin, (□) epifriedelinol, (◆)n-alkanes. Values correspond to means ± sd (n = 30), obtained at 25◦C and 65% relative humidity.

alcanos são mais eficientes que terpenóides como barreiras a perda de água

Oliveira & al. Epicuticular waxes from caatinga and cerrado species and their efficiency against water loss. Anais da Academia Brasileira de Ciências (2003) 75(4): 431-439

A composição de cada fração depende da espécie e afeta diretamente a condutância epidérmica e a estrutura da cera na superfície;



● cerrado

○ caatinga

Fig. 2 – Evaporation rates (*E*) in Whatman paper discs impregnated with foliar epicuticular waxes of species from caatinga (empty symbols) and cerrado (full symbols). (○) *Aspidosperma pyrifolium*, (◇) *Capparis yco*, (□) *Maytenus rigida*, (▽) *Ziziphus joazeiro*, (■) *Aristolochia esperanzae*, (▲) *Didymopanax vinosum*, (●) *Strychnos pseudoquina*, (♦) *Tocoyena formosa*. Values correspond to means ± sd (n = 30), obtained at 25◦C and 65% relative humidity.

BIB0315

Increased Accumulation of Cuticular Wax and Expression of Lipid Transfer Protein in Response to Periodic Drying Events in Leaves of Tree Tobacco[1[W]]

Kimberly D. Cameron, Mark A. Teece, and Lawrence B. Smart*

Faculty of Environmental and Forest Biology (K.D.C., L.B.S.) and Faculty of Chemistry (M.A.T.), State University of New York, College of Environmental Science and Forestry, Syracuse, New York 13210

Plant Physiology, January 2006, Vol. 140, pp. 176–183

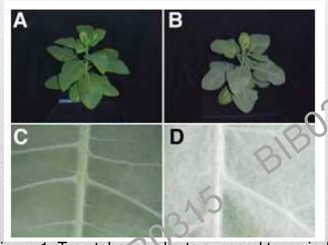


Figure 1. Tree tobacco plants exposed to periodic drying events. A, Well-watered plant. B, Plant exposed to three periodic drying events. C, Close-up of the adaxial surface of a fully expanded leaf from the plant in A. D, Close-up of the adaxial surface of a fully expanded leaf from the plant in B.

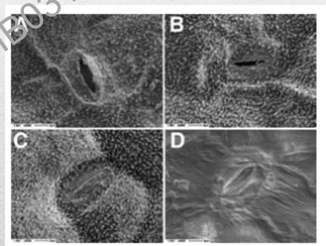


Figure 2. SEM of the adaxial surfaces of leaves from three tree tobacco plants after exposure to one drying event (A), two drying events (B), three drying events (C), and after removal of the CH2Cl2-soluble wax fraction (D). Magnification 32,000. Bar 5 5 mm.

Aumento na quantidade de cera nas plantas submetidas a seca

BIB0315

Aumento na tolerância a seca relacionado ao aumento de cera total

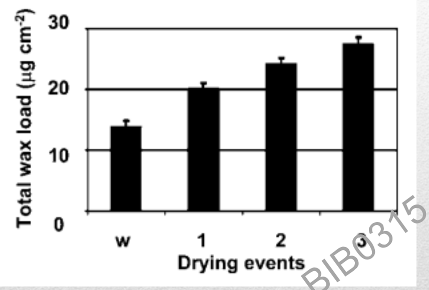


Figure 4. Total wax load in leaves of tree tobacco plants exposed to periodic drying events. The CH2Cl2-soluble fraction of the wax was extracted from fully expanded leaves exposed to periodic drying events. Bars represent the mean of two experiments. Error bars indicate the SE. w, Well-watered plants harvested before dehydration stress was applied.

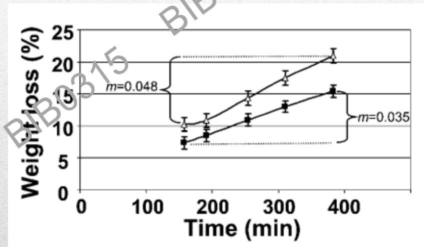
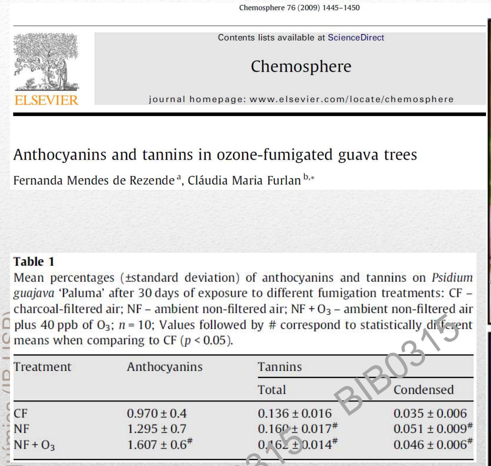


Figure 5. Rate of actual weight loss due to epidermal conductance from leaves excised from periodically dried (■) or well-watered (□) plants. Data represent one of three replicated experiments. Three leaves per plant from each of four well-watered and periodically dried plants were excised and immediately placed in a 30C incubator. Leaves were weighed after excision at approximately 150 min, 180 min, and at hourly increments thereafter. The percent of water loss was determined relative to the original leaf weight. Error bars indicate the mean SD across all time points. m 5 slope of the line.


Chemosphere 76 (2009) 1445–1450

Contents lists available at ScienceDirect

Chemosphere

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

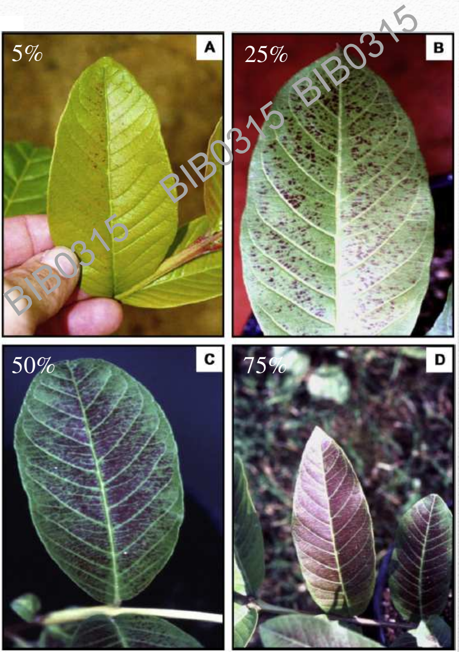
Anthocyanins and tannins in ozone-fumigated guava trees

Fernanda Mendes de Rezende[a], Cláudia Maria Furlan[b,*]

Table 1
Mean percentages (±standard deviation) of anthocyanins and tannins on *Psidium guajava* 'Paluma' after 30 days of exposure to different fumigation treatments: CF – charcoal-filtered air; NF – ambient non-filtered air; NF + O_3 – ambient non-filtered air plus 40 ppb of O_3; $n = 10$; Values followed by # correspond to statistically different means when comparing to CF ($p < 0.05$).

Treatment	Anthocyanins	Tannins	
		Total	Condensed
CF	0.970 ± 0.4	0.136 ± 0.016	0.035 ± 0.006
NF	1.295 ± 0.7	0.160 ± 0.017#	0.051 ± 0.009#
NF + O_3	1.607 ± 0.6#	0.162 ± 0.014#	0.046 ± 0.006#

Correlação entre porcentagem de injúrias foliares e teor de antocianinas.



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Tibouchina pulchra (Cham.) Cogn., a native Atlantic Forest species, as a bio-indicator of ozone: Visible injury

Cláudia M. Furlan [a,*], Regina M. Moraes [b], Patricia Bulbovas [b], Maria J. Sanz [c], Marisa Domingos [b], Antonio Salatino [a]

[a] Departamento de Botânica, Instituto de Biociências, Universidade de São Paulo, CP 11461, 05422-970 São Paulo, SP, Brazil
[b] Seção de Ecologia, Instituto de Botânica, SMA, CP 4005, 01061-970 São Paulo, Brazil
[c] Fundación Centro de Estudios Ambientales del Mediterráneo, Parque Tecnológico, E-46980 Paterna, Valencia, Spain

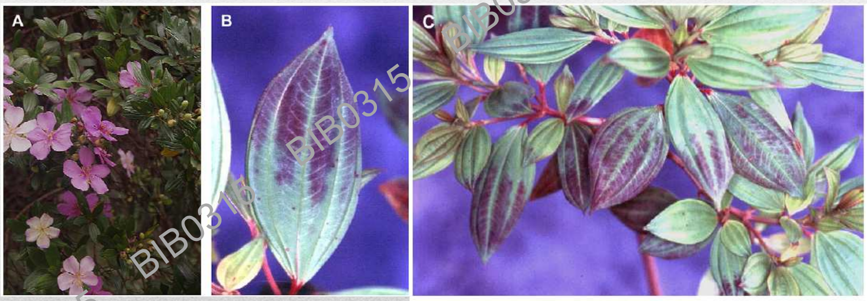

Fig. 2. Ozone visible injury in leaves of *Tibouchina pulchra*. (A) An adult tree used as ornamental at São Paulo, (B) detail of upper surface stippling at the onset, and (C) a general view of one affected sapling at the end of the exposure period.

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Ozone sensing and early signaling in plants: An outline from the cloud

Marie-Noëlle Vaultier [a,b,*], Yves Jolivet [a,b]

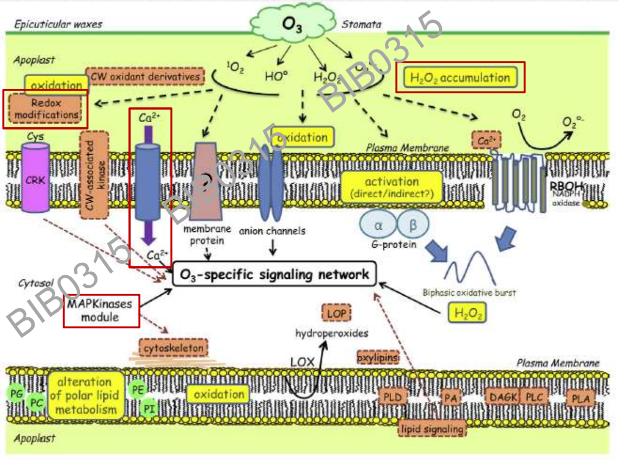
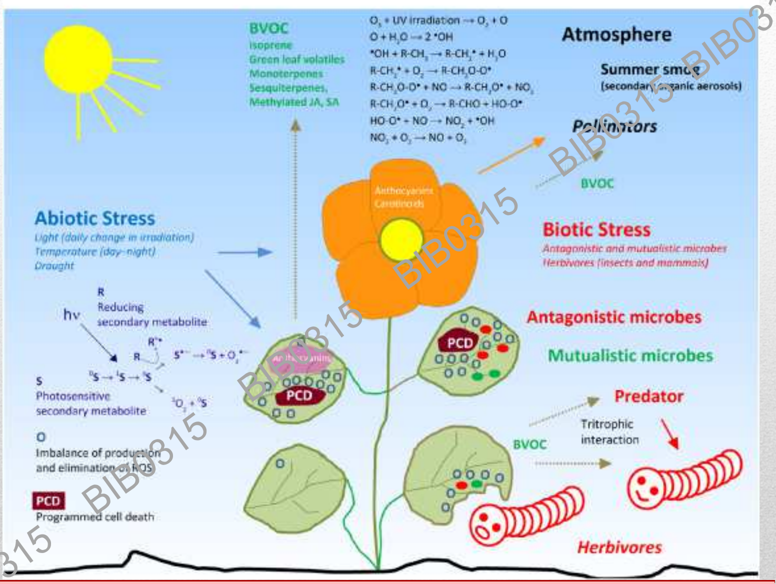
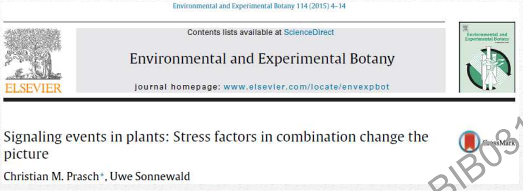

Epicuticular waxes
O_3
Stomata
Apoplast
$^1O_2$
HO°
H_2O_2
H_2O_2 accumulation
CW oxidant derivatives
oxidation
Redox modifications
Ca^{2+}
Cys
CRK
CW-associated kinase
oxidation
Plasma Membrane
Ca^{2+}
O_2
$O_2^{°-}$
activation (direct/indirect?)
RBOH
NADPH oxidase
membrane protein
anion channels
α
β
G-protein
Ca^{2+}
O_3-specific signaling network
Cytosol
MAPKinases module
Biphasic oxidative burst
H_2O_2
LOP
hydroperoxides
cytoskeleton
LOX
oxylipins
Plasma Membrane
PG
PC
alteration of polar lipid metabolism
PE
PI
oxidation
PLD
PA
DAGK
PLC
PLA
lipid signaling
Apoplast

Figure 34 from David B Graves 2012 J. Phys. D: Appl. Phys. 45 263001


BVOC
Isoprene
Green leaf volatiles
Monoterpenes
Sesquiterpenes,
Methylated JA, SA
O3 + UV irradiation → O2 + O
O + H2O → 2 •OH
•OH + R-CH3 → R-CH2• + H2O
R-CH2• + O2 → R-CH2O-O•
R-CH2O-O• + NO → R-CH2O• + NO2
R-CH2O• + O2 → R-CHO + HO-O•
HO-O• + NO → NO2 + •OH
NO2 + O2 → NO + O3
Atmosphere
Summer smog
(secondary organic aerosols)
Pollinators
BVOC
Anthocyanins
Carotinoids
Abiotic Stress
Light (daily change in irradiation)
Temperature (day-night)
Drought
Biotic Stress
Antagonistic and mutualistic microbes
Herbivores (insects and mammals)
R
Reducing
secondary metabolite
hν
R'•
R
S•− → 0S + O2•−
0S → 1S → 3S
1O2 + 0S
S
Photosensitive
secondary metabolite
O
Imbalance of production
and elimination of ROS
PCD
Programmed cell death
Anthocyanins
PCD
PCD
Antagonistic microbes
Mutualistic microbes
Predator
Tritrophic
interaction
BVOC
Herbivores

Sabendo-se como as plantas respondem aos diversos fatores estressantes isoladamente, há como prever suas respostas no campo?


Environmental and Experimental Botany 114 (2015) 4–14

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Signaling events in plants: Stress factors in combination change the picture

Christian M. Prasch*, Uwe Sonnewald

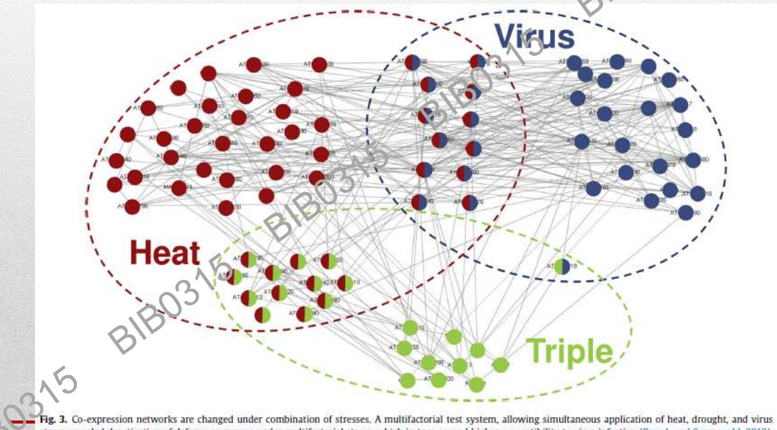
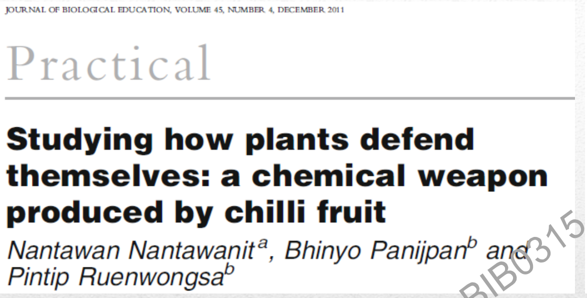

Virus
Heat
Triple

Fig. 3. Co-expression networks are changed under combination of stresses. A multifactorial test system, allowing simultaneous application of heat, drought, and virus stress revealed deactivation of defense responses under multifactorial stress, which in turn caused higher susceptibility to virus infection (Prasch and Sonnewald, 2013). As further transcriptome analysis showed clear changes in signaling genes, co-expression analysis of signaling genes under single and combined stress conditions have been conducted. The picture illustrates significantly regulated signaling genes within the heat, virus and triple stress network visualized by the ARANET Web tool (www.functionalnet.org/aranet/). These observations suggested that abiotic stress factors in combination with virus stress repress virus-specific networks. Gene identities are given in the supplemental Table S5 provided by Prasch and Sonnewald (2013).



JOURNAL OF BIOLOGICAL EDUCATION, VOLUME 45, NUMBER 4, DECEMBER 2011

Practical

Studying how plants defend themselves: a chemical weapon produced by chilli fruit

Nantawan Nantawanit[a]*, Bhinyo Panijpan*[b] *and Pintip Ruenwongsa*[b]

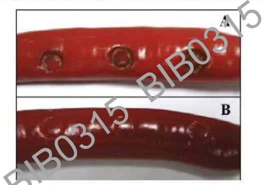


Figure 2. Effect of the yeast ***Saccharomyces cerevisiae*** on the physical changes on the surface of wounded areas in chilli fruits. The treated fruit was inoculated with yeast cells (A), whereas the control fruit was treated with sterile-distilled water (B)

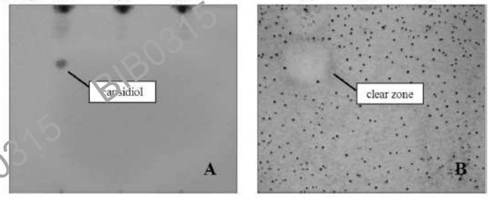


Figure 3. Effect of the yeast ***Saccharomyces cerevisiae*** on the accumulation of capsidiol phytoalexin in chilli fruit tissue. One thin-layer chromatography (TLC) plate (A) was developed by using vanillin reagent determination, and the other TLC plate (B) was developed to test capsidiol fungitoxicity. Samples 1 and 2 were extracted from wound and non-wound sites of the yeast-treated chilli fruits, respectively. Sample 3 was extracted from wound sites of sterile-distilled water-treated chilli fruits and used as the control sample

- ✓ plantas organismos ativos e capazes de se defender

BIB 315 – Metabólitos vegetais: origem, diversidade e aplicações

Caracterização de algumas classes de metabólitos secundários envolvidas nas interações planta-ambiente

Déborah Santos
dyacsan@ib.usp.br

BIB0315

GLICOSÍDEOS CIANOGÊNICOS

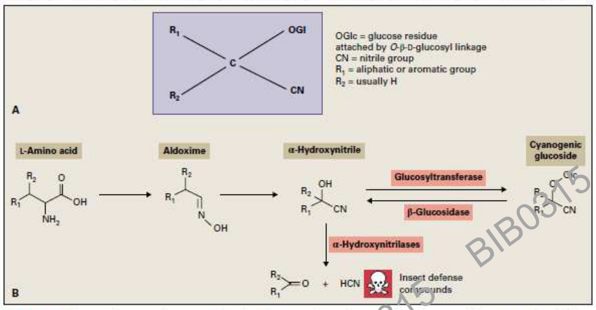

A
R1
OGl
C
R2
CN
OGlc = glucose residue attached by O-β-D-glucosyl linkage
CN = nitrile group
R1 = aliphatic or aromatic group
R2 = usually H
B
L-Amino acid
Aldoxime
α-Hydroxynitrile
Cyanogenic glucoside
Glucosyltransferase
β-Glucosidase
α-Hydroxynitrilases
HCN
Insect defense compounds

FIGURE 24.17 *(A) General structure of cyanogenic glycosides. The sugar residue is always D-glucose that is joined by an O-β-D-glucosyl linkage (referred to more specifically, then, as cyanogenic glucosides), but additional sugars present may be different. (B) Cyanogenesis. Cyanogenic glycosides are formed from a limited number of L-amino acids and converted to cyanogenic glycosides with E-oximes and α-hydroxynitriles as key intermediates. Upon hydrolysis of the cyanogenic glycoside by the action of β-glycosidases and α-hydroxynitrilases, toxic hydrogen cyanide (HCN) and ketones or aldehydes are produced.*

✓CN^-: Combina-se com o íon Fe^{++} da hemoglobina e dos citocromos.

✓Causa intoxicação por asfixia.

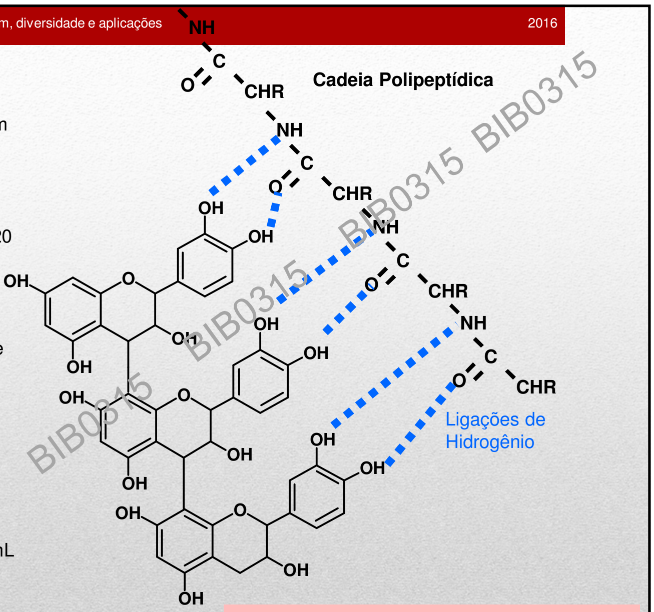
✓Pode levar pacientes a óbito.

- ✓ Picar o material fresco a ser testado (folhas ou qualquer órgão vegetal) e transferir para um tubo de ensaio;
- ✓ Adicionar 5 mL de água e 2 gotas de diclorometano;
- ✓ Tampar o tubo com uma rolha que contenha o papel de picrato suspenso (cuidado para não deixar o papel em contato com a parede do tubo);
- ✓ Aquecer em banho-maria por cerca de 2 h. Observar a coloração do papel.

- ✓ *Psidium guajava* (Myrtaceae) – goiabeira
- ✓ *Thunbergia erecta* (Acanthaceae)
- ✓ *Malus domestica* (Rosaceae) – maçã
- ✓ *Passiflora* sp (Passifloraceae) – maracujá
- ✓ *Manihot esculenta* (Euphorbiaceae) – mandioca
- ✓ *Rhododendron* sp (Ericaceae) - azaleia
- ✓ *Malvaviscus* sp (Malvaceae)

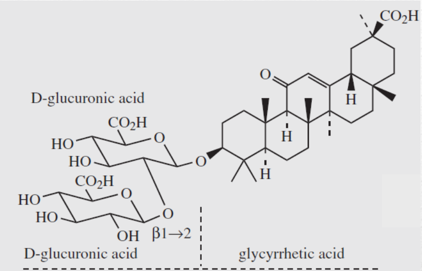
TANINOS

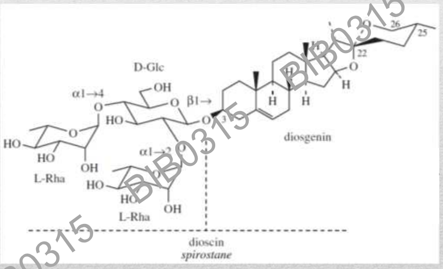
- ✓ Pesar cerca de 1 g de cada um dos materiais secos e pulverizados;
- ✓ Extrair os taninos, a quente, com 8 mL de etanol 50% por 20 min;
- ✓ Filtrar o extrato;
- ✓ Transferir para outros tubos de ensaio 2 mL de cada um dos extratos e adicionar em um deles igual volume de solução de gelatina 2% e no outro solução de clara de ovo;
- ✓ Fazer outros dois tubos com 2 mL de etanol 50% + 2 mL solução de gelatina 2% ou 2 mL solução de clara de ovo;
- ✓ Verificar a precipitação nos quatro tubos.


NH
C
O
CHR
Cadeia Polipeptídica
OH
O
Ligações de Hidrogênio

- ✓ *Nicotiana tabacum* (Solanaceae) - fumo
- ✓ *Psidium guajava* (Myrtaceae) – goiabeira
- ✓ *Piptadenia gonoacantha* (Fabaceae) – pau-jacaré
- ✓ *Thunbergia erecta* (Acanthaceae)

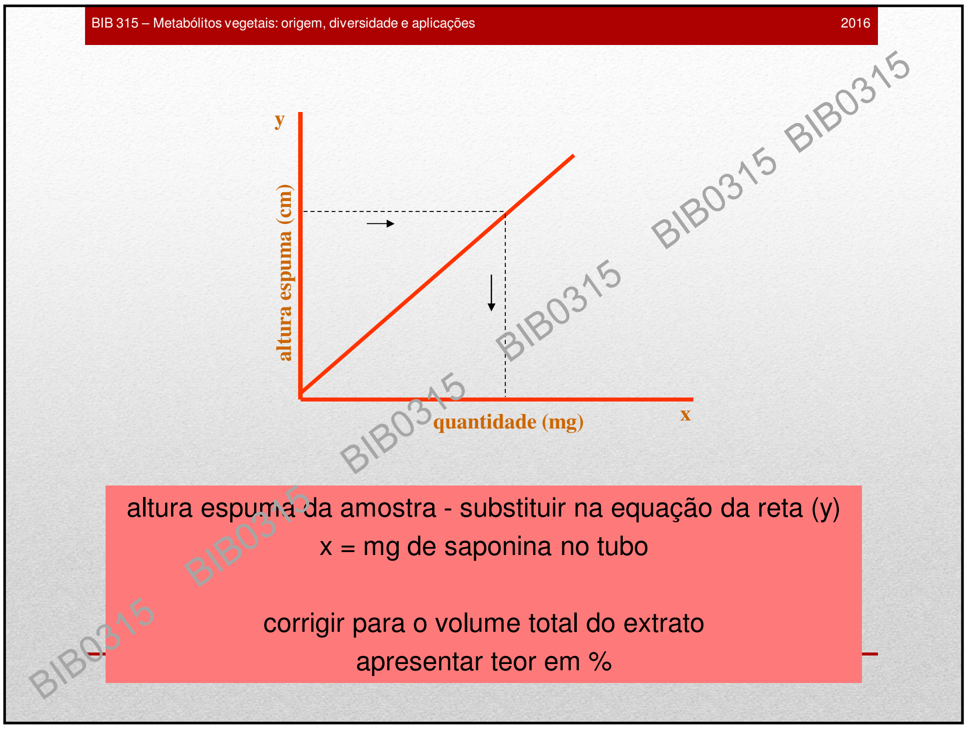
SAPONINAS


D-glucuronic acid
CO2H
HO
O
OH
β1→2
D-glucuronic acid
glycyrrhetic acid
glycyrrhizic acid
H


D-Glc
α1→4
β1→
α1→2
L-Rha
L-Rha
diosgenin
dioscin
spirostane

- ✓ Pesar 1g do material seco e previamente triturado (anotar o valor exato da massa utilizada);
- ✓ Extrair sob refluxo com 45 mL de água por 30 min;
- ✓ Filtrar para balão volumétrico de 50 mL;
- ✓ Completar o volume com água para 50 mL em balão volumétrico;
- ✓ Transferir 10 mL do extrato para tubos de banho-seco;
- ✓ Agitar vigorosamente, de modo idêntico aos tubos para construção da curva padrão;
- ✓ Após 2 min, medir as alturas das camadas de espuma;
- ✓ Calcular, aproximadamente, a quantidade de saponina nas plantas utilizando o gráfico construído com a curva padrão

- ✓ *Sapindus saponaria* (Sapindaceae)
- ✓ Agave sp (Agavaceae)
- ✓ *Illex paraguariensis* (Aquifoliaceae) – erva-mate



BIB 315 – Metabólitos vegetais: origem, diversidade e aplicações

2016

altura espuma da amostra - substituir na equação da reta (y)
x = mg de saponina no tubo

corrigir para o volume total do extrato
apresentar teor em %