The priming molecule β-aminobutyric acid (BABA) is produced by plants and accumulates during senescence: a link with the age-related resistance to pathogens?

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(IPSP, Firenze)
β-aminobutyric acid (BABA)

- Non-protein **amino acid**, considered so far a **xenobiotic**
- Known to **induce resistance** in plants for more than **50 years**
- Mainly active by **priming** plant defenses
- Transgenerational capacity: priming still visible in the **descendants** of treated plants
- The **R enantiomer** is biologically active in plants:

![Chemical structures of R-BABA and S-BABA](image)
Primming and memory of stress responses in organisms lacking a nervous system

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Defense priming and induced resistance in plants

- Systemic-acquired resistance (SAR)
- Induced-systemic resistance (ISR)
- Herbivore-induced resistance (HIR)
- Mycorrhiza-induced resistance (MIR)
- Etc...

Local and systemic induction of defenses

State of alert (Defense priming)

β-aminobutyric acid (BABA)

...development of a selective and sensitive protocol for the simultaneous analysis of aminobutyric acid isomers \textit{in planta}

Method based on stable isotope quantification by ultra-high pressure liquid chromatography tandem mass spectrometry (UHPLC-MS/MS)

In \textit{Arabidopsis thaliana} Col-0 leaves \textbf{NOT treated} with BABA:

<table>
<thead>
<tr>
<th>Analytes</th>
<th>Amount(^\text{**}) (ng/g FW)</th>
<th>Precision(^\text{***})</th>
<th>Accuracy</th>
<th>Recovery</th>
<th>Matrix effect(^\text{****})</th>
<th>Process efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>RSD(_1)(%) RSD(_2)(%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AABA</td>
<td>388 ± 21</td>
<td>5.3 6.7</td>
<td>103.3%</td>
<td>94%</td>
<td>0%</td>
<td>94%</td>
</tr>
<tr>
<td>BABA</td>
<td>6.4 ± 0.5</td>
<td>7.7 10.2</td>
<td>92.2%</td>
<td>93%</td>
<td>-11%</td>
<td>83%</td>
</tr>
<tr>
<td>GABA(^*)</td>
<td>7790 ± 930</td>
<td>14.2 15.2</td>
<td>103.1%</td>
<td>84%</td>
<td>+5%</td>
<td>88%</td>
</tr>
</tbody>
</table>

Thevenet et al 2017 – \textit{New Phytol}
BABA is not a xenobiotic: BABA is produced by plants!!

(a) Control leaves
- Arabidopsis thaliana Ws
- Arabidopsis thaliana Ler
- Brassica rapa
- Zea mays
- Zea mays spp. mexicana
- Triticum aestivum
- Physcomitrella patens

(b) Control roots
- Arabidopsis thaliana Ws
- Arabidopsis thaliana Ler
- Brassica rapa
- Zea mays
- Zea mays spp. mexicana
- Triticum aestivum

Thevenet et al 2017 – *New Phytol*
BABA levels increase during biotic and abiotic stress
(Arabidopsis Col-0)

Thevenet et al. 2017 – New Phytol
1) What is the **role** of endogenous BABA in plants?
   
   May BABA be a novel **priming hormone**?

2) How do plants produce BABA (**biosynthetic pathway**)?
The plant's immune system

PAMPs/MAMPs (Pathogen/Microbe-associated molecular patterns)

PTI
PAMP-Triggered Immunity

ETS
Effector-Triggered Immunity

ETI
Threshold for effective resistance

Threshold for HR

Amplitude of defence

High
Low

Pathogen effectors

Avr-R

Jones and Dangl 2006 - Nature (readapted)
BABA is accumulated during PAMP-triggered immunity

10 µM Flagellin-22

Arabidopsis Col-0

10 µM Flagellin-22

Arabidopsis Ws-0 (expresses a nonfunctional FLS2 receptor)

Baccelli et al 2017 – Planta
BABA is accumulated during effector-triggered immunity (ETI)

Inoculum: 10^6 CFU/ml

Inoculum: 10^5 CFU/ml

Baccelli et al 2017 – *Planta*
BABA levels increase locally after pathogen infection

A

- Mock-treated leaves
- Systemic leaves (mock plants)
- Infected leaves
- Systemic leaves (infected plants)

$Pst$ DC3000
$avrRpt2$

B

- $P. cucumerina$

Balmer et al. 2019 – *Plant Biol.*
The role of endogenous BABA in plant defense: two models

**Model 1: Exogenous BABA as a "mimic" of a local defense response in the whole plant**

- Infection
- Local BABA accumulation
- Systemic transport and BABA content increase
- Priming
- "Mimicking" a widespread defense
- Whole plant priming
- BABA contributes to local defense

**Model 2: BABA as a "local trigger" for a systemic defense**

- Infection
- Local BABA accumulation
- Local defense response (??)
- Priming
- Systemic transport and BABA content increase
- Exogenous application of BABA boosts the generation of the priming signal

Exogenous BABA as a "mimic" of a local defense response in the whole plant
BABA levels increase during growth in Arabidopsis leaves

Senescence symptoms visible

Floral transition

Balmer et al. 2019 – *Plant Biol.*
BABA levels increase during dark-induced senescence
To sum up

1) BABA is naturally **produced by plants**

2) BABA levels are controlled by the **plant immune system** (PTI and ETI)

3) Local BABA raise participates to **local** or **systemic immunity** (priming?)

4) BABA levels naturally increase during **senescence**

... What is the link between BABA, role in pathogen defense, and senescence?
Age-related resistance (ARR) in Arabidopsis

- Mature plants are more resistant than young plants to virulent Pst DC3000
- SA accumulation required
- ARR-competent Arabidopsis plants may alleviate coronatine-mediated suppression of SA accumulation by virulent Pst DC3000 (Carella et al. 2015)

High endogenous BABA levels in old plants may contribute to ARR by impeding suppression of SA accumulation by Pst
ABA (100 µM-soil drench)

Stefanelli et al – Unpublished
Thanks for the attention