Molecular perspectives into seed priming
The seed repair response as a key player in the pre-germinative metabolism

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isss international society for seed science

ISTA Seed Quality Assurance

Outline…

- Brief overview on Seed Priming research
- Seed pre-germinative metabolism
- DNA Damage Response (DDR) as a seed repair response

- Systems developed to investigate seed priming at the molecular level
  - The chemical stress system
  - The priming/overpriming system
  - The intra- and inter-specific variation system

plants

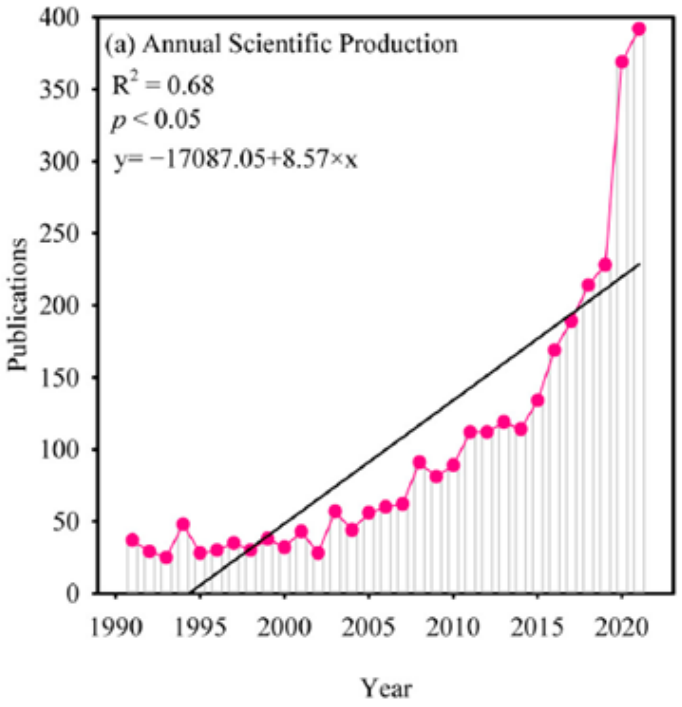
MDPI

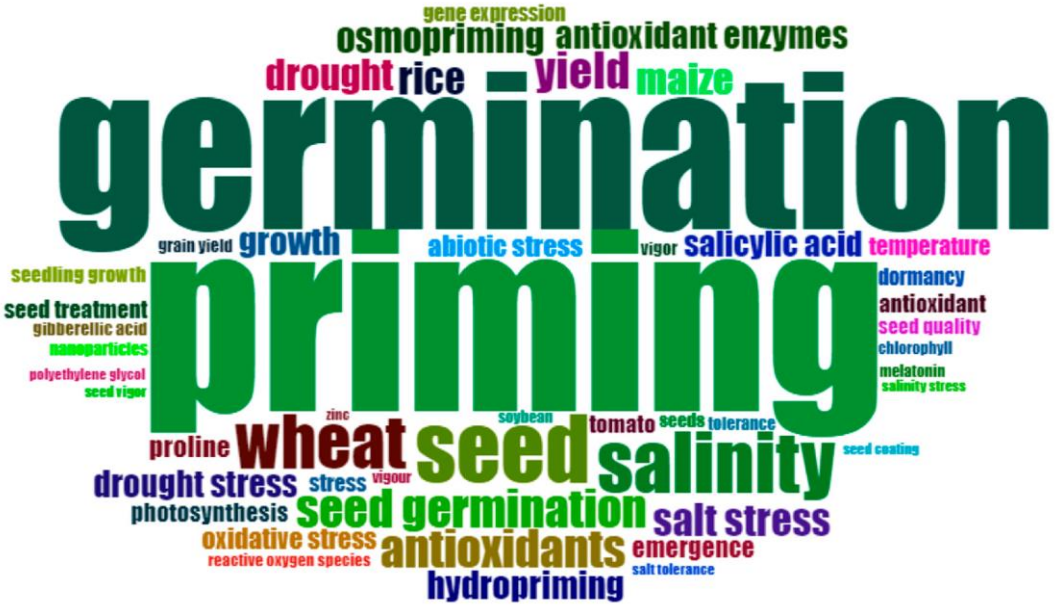
Review

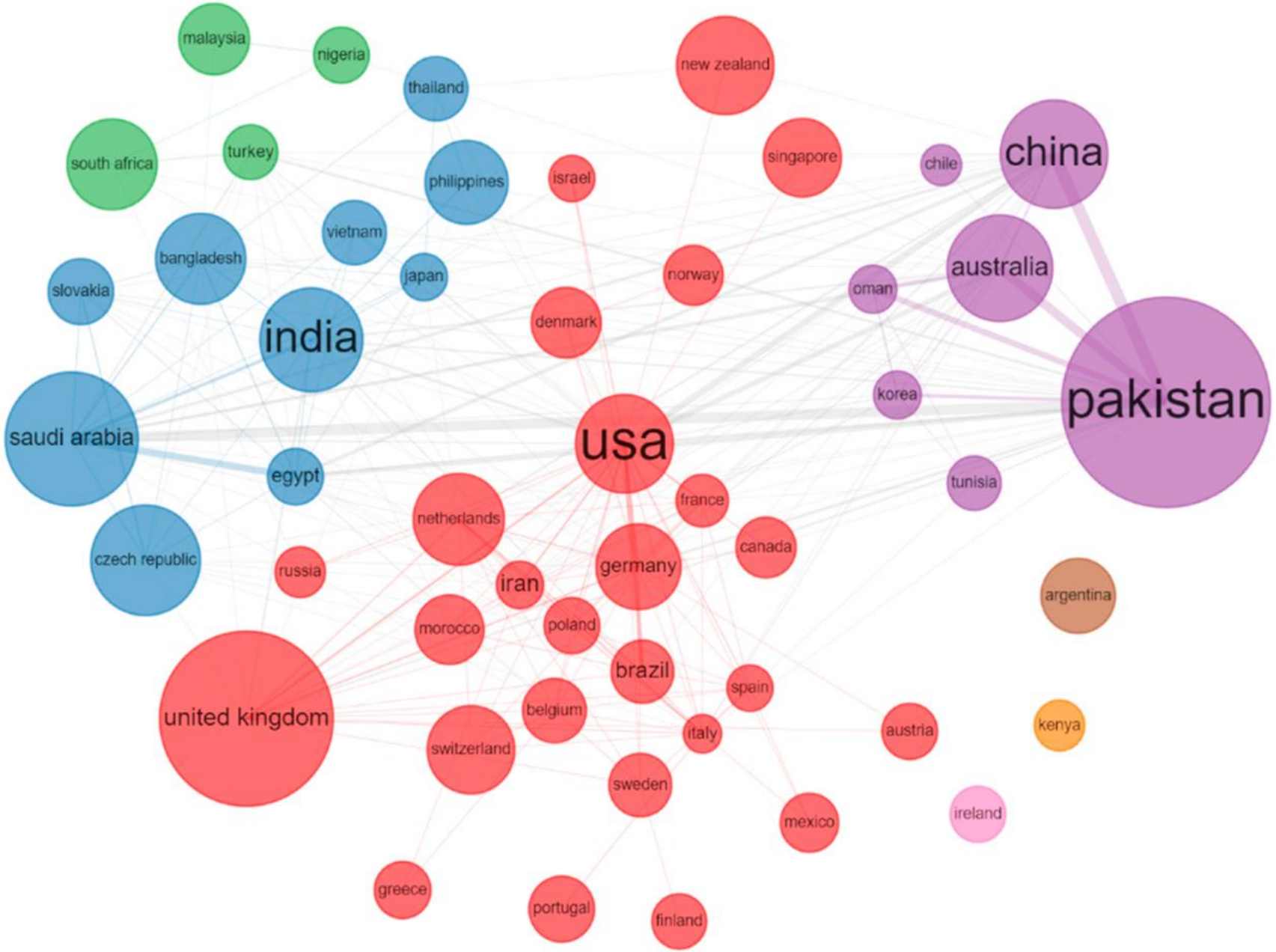
Trends in Seed Priming Research in the Past 30 Years Based on Bibliometric Analysis

Yu Tian [1], Nalin Suranjith Gama-Arachchige [2] and Ming Zhao [3,*]

Web of Science (WOS) core collection database https://www.webofscience.com/WOS accessed on 14 November 2022



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denmark
saudi arabia
usa
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pakistan
egypt
tunisia
netherlands
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czech republic
russia
iran
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argentina
morocco
poland
brazil
spain
united kingdom
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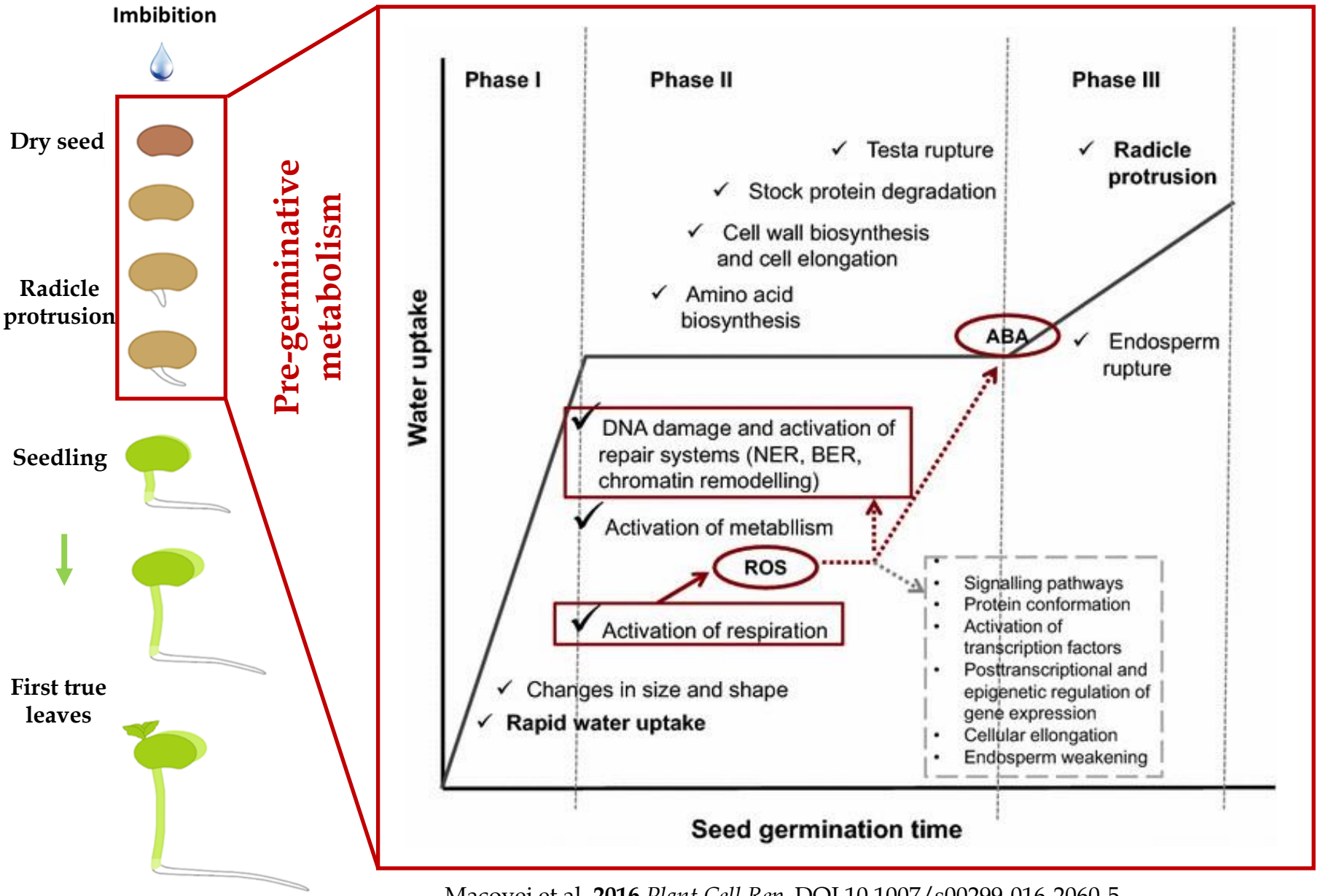
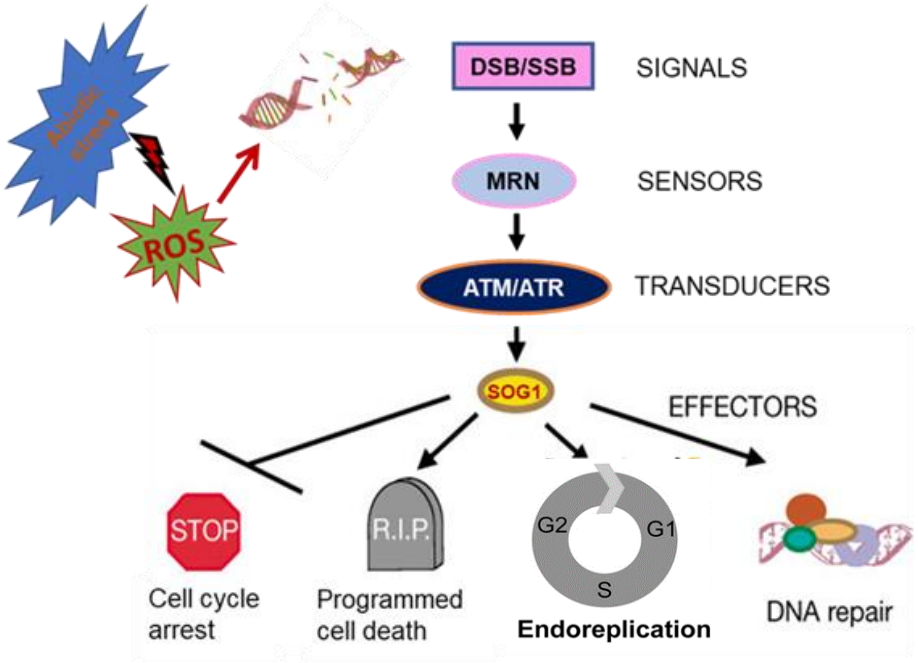
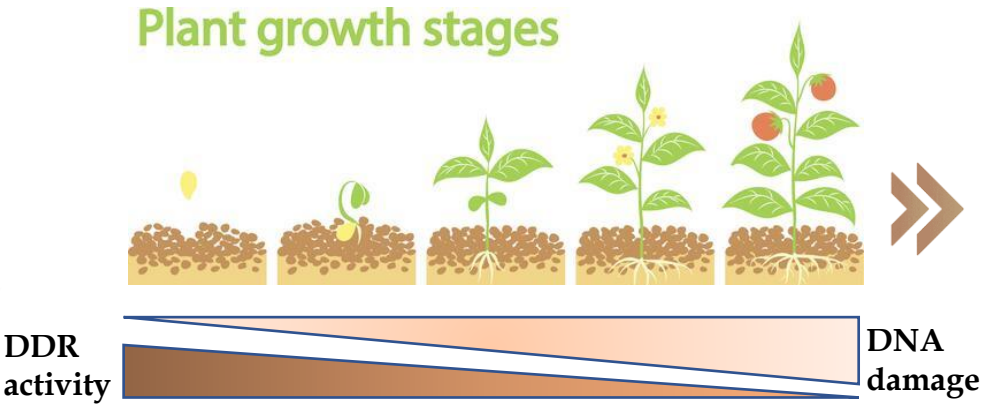
Seed pre-germinative metabolism



Macovei et al. **2016** *Plant Cell Rep.* DOI 10.1007/s00299-016-2060-5

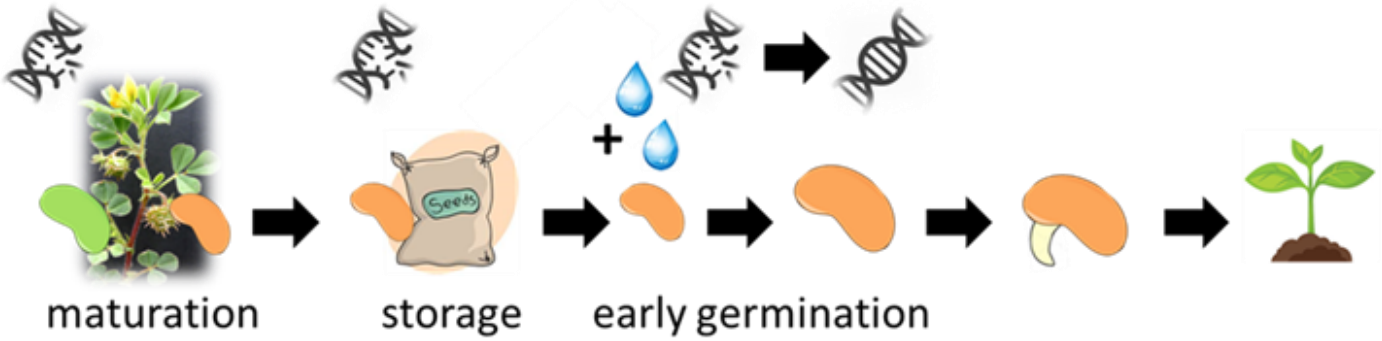
DNA Damage Response (DDR)





What happens to DDR during plant life…?

When do seeds accumulate or repair DNA damage?



DDR and the seed repair response

frontiers in Plant Science

REVIEW
published: 31 May 2019
doi: 10.3389/fpls.2019.00706

Seeds and the Art of Genome Maintenance

Wanda M. Waterworth[1], Clifford M. Bray[2] and Christopher E. West[1]*

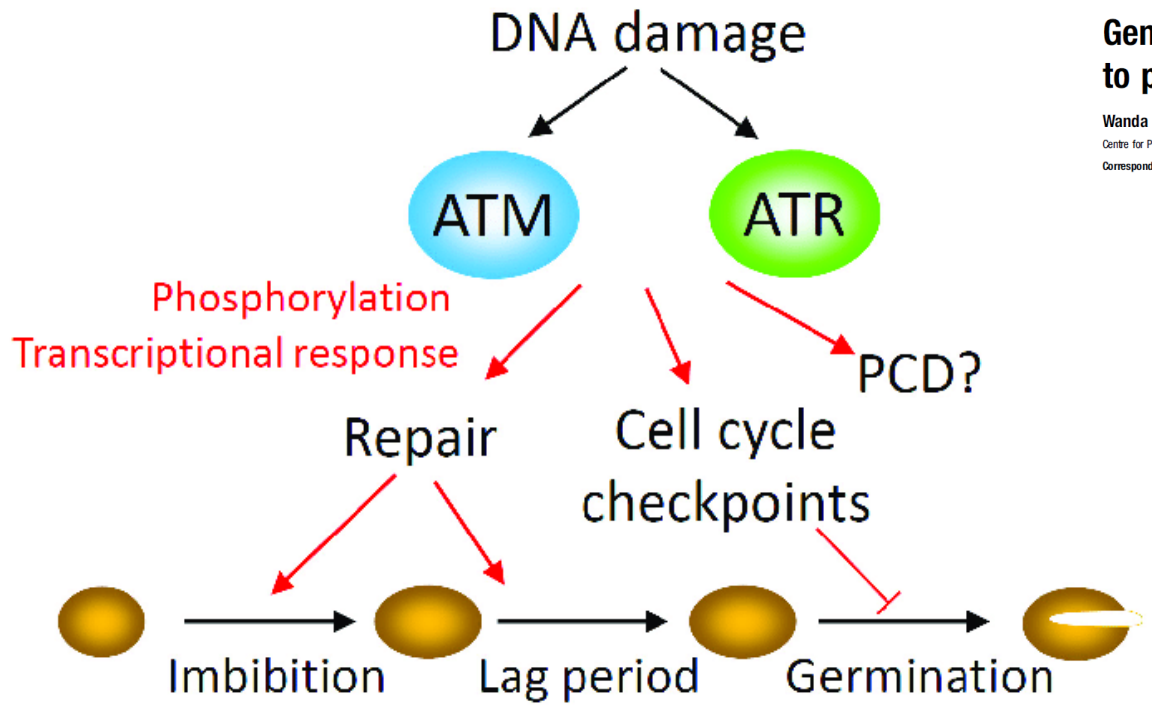
[1] University of Leeds, Leeds, United Kingdom, [2] The University of Manchester, Manchester, United Kingdom

PNAS RESEARCH ARTICLE | PLANT BIOLOGY OPEN ACCESS

Seed DNA damage responses promote germination and growth in *Arabidopsis thaliana*

Wanda M. Waterworth[a], Rosalind Latham[a], Dapeng Wang[b,c,d], Mona Alsharif[a], and Christopher E. West[a,1]

Edited by Maarten Koornneef, Max-Planck-Institut fur Pflanzenzuchtungsforschung, Cologne, Germany; received February 14, 2022; accepted June 6, 2022



Biochemical Journal (2023) **480** 461–470
https://doi.org/10.1042/BCJ20230006

PORTLAND PRESS

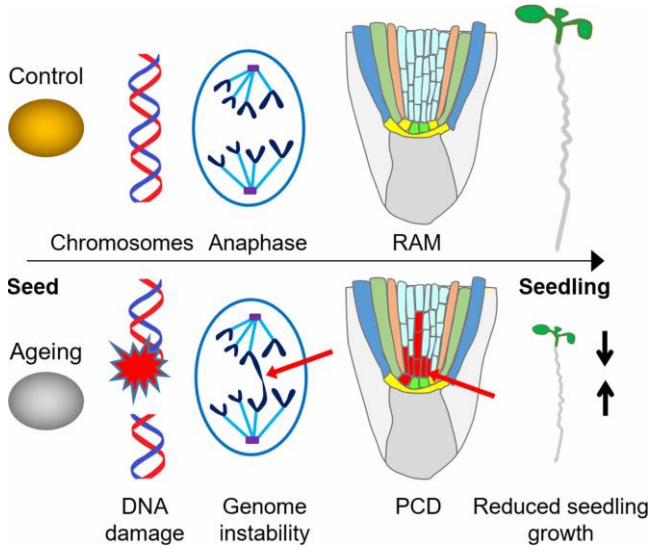
Research Article

Genome damage accumulated in seed ageing leads to plant genome instability and growth inhibition

Wanda M. Waterworth and Christopher E. West

Centre for Plant Sciences, University of Leeds, Woodhouse Lane, Leeds LS2 9JT, U.K.

Correspondence: Christopher E. West (c.e.west@leeds.ac.uk)

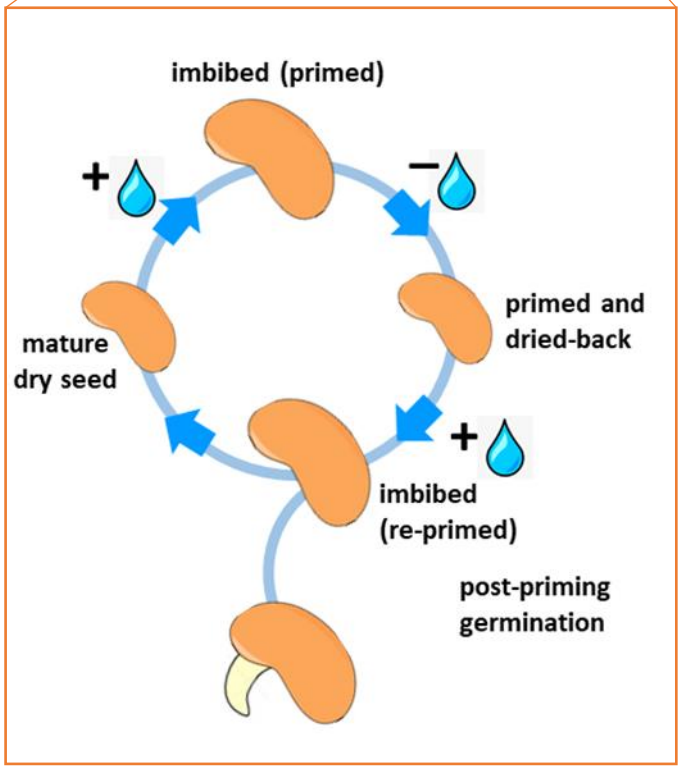


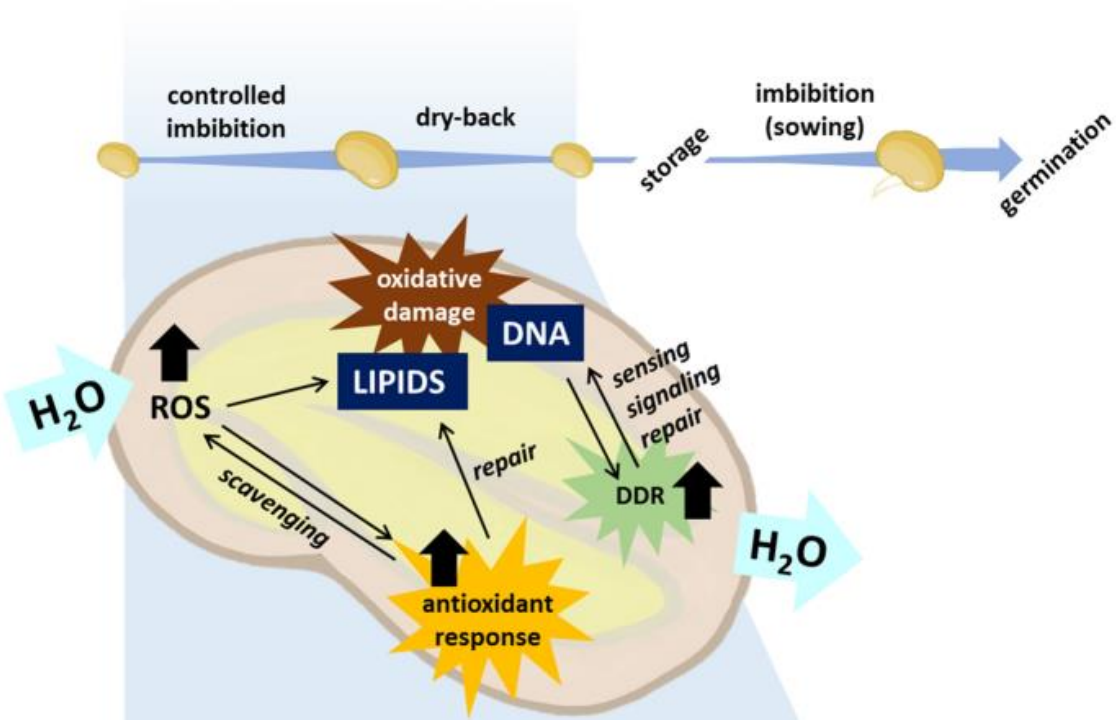
…how is DDR related to seed priming?

PRIMING - adaptive strategy where exposure to one stimulus can influence the response to subsequent stimuli – physiological state than enable plants to respond more rapidly to stress

Seed Priming

Chemical methods | Physical methods | Biological methods





Pagano et al. **2023** *Plant Cell Rep.* https://doi.org/10.1007/s00299-023-02988-w

Systems developed to investigate seed priming at the molecular level

1 **TIMEPOINTS**

- dry seed
- imbibition (2h, 8h)
- radicle protrusion
- seedlings (4,7,14-days)

2 **TREATMENTS**

- gamma irradiation
- polyethylene glycol (PEG)
- sodium chloride (NaCl)
- trichostatin A (TSA)
- sodium butyrate (NaB)
- kinetin
- desiccation-rehydration
- hydropriming

3 **ANALYSES**

toolkit

- phenotyping
- ROS detection
- DNA damage/repair
- gene expression
- metabolomics
- lipidomics
- biochemical HPLC
- ultrastructural TEM

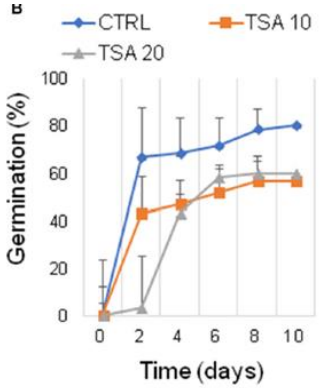
The «chemical stress» system

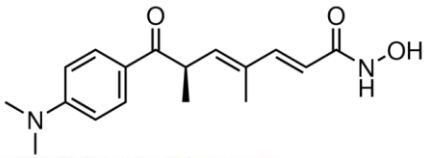
frontiers in Plant Science

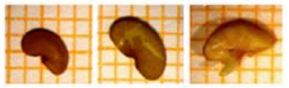
ORIGINAL RESEARCH
published: 14 November 2017
doi: 10.3389/fpls.2017.01972

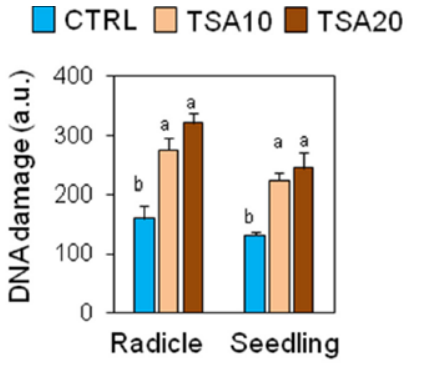
The Seed Repair Response during Germination: Disclosing Correlations between DNA Repair, Antioxidant Response, and Chromatin Remodeling in *Medicago truncatula*

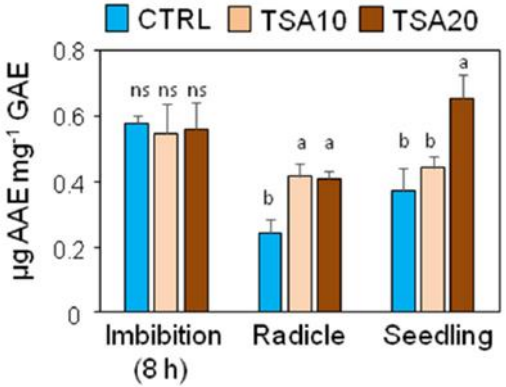
*Andrea Pagano[1], Susana de Sousa Araújo[2], Anca Macovei[1], Paola Leonetti[3] and Alma Balestrazzi[1]**

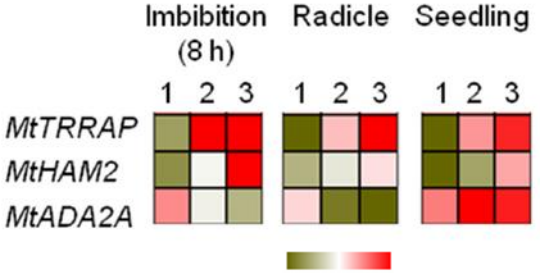


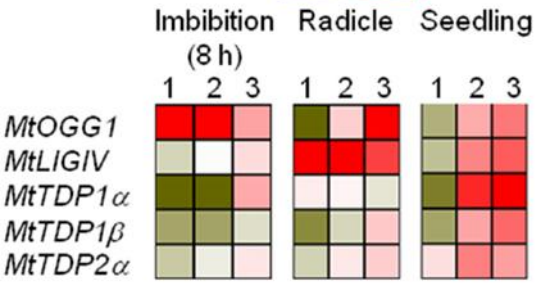


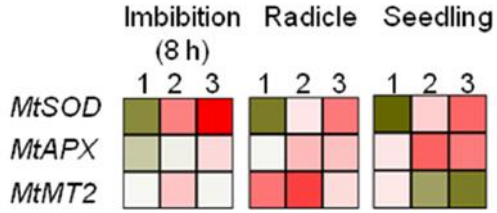


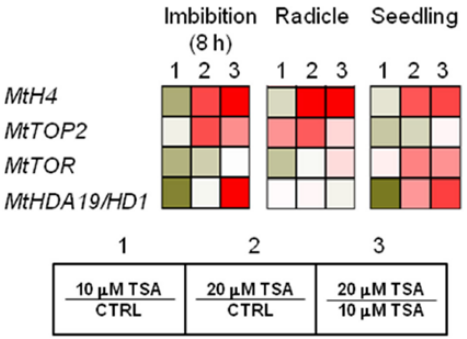






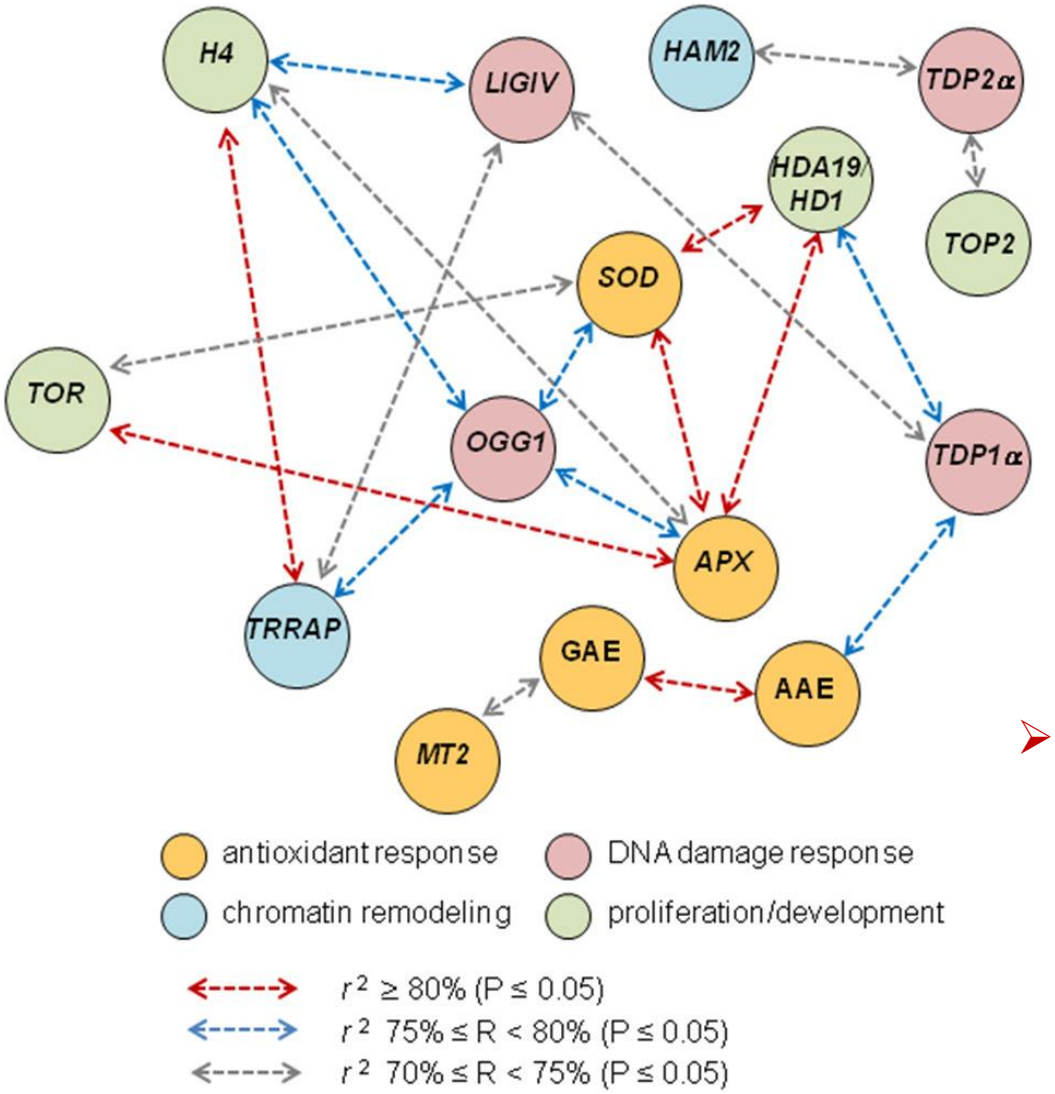






The «chemical stress» system

Schematic representation of the most relevant cases of correlation of biochemical and gene expression variables based on the Pearson correlation coefficients *r*



- Correlation analysis discloses novel putative links between DNA repair, chromatin remodeling, antioxidant response and proliferation markers.

  - ***TRRAP - OGG1*** - bridge DNA repair and chromatin remodeling in the context of seed germination
  - ***OGG1 – APX, SOD*** - link between DNA repair and antioxidant response a crucial aspect of seed vigor

- TSA blocks cell cycle, induces ROS accumulation and DNA damage, and all these events touch directly or indirectly molecular processes that contribute to the seed stress response

The «chemical stress» system

Plant, Cell & Environment

Received: 28 November 2017 | Revised: 3 May 2018 | Accepted: 5 May 2018

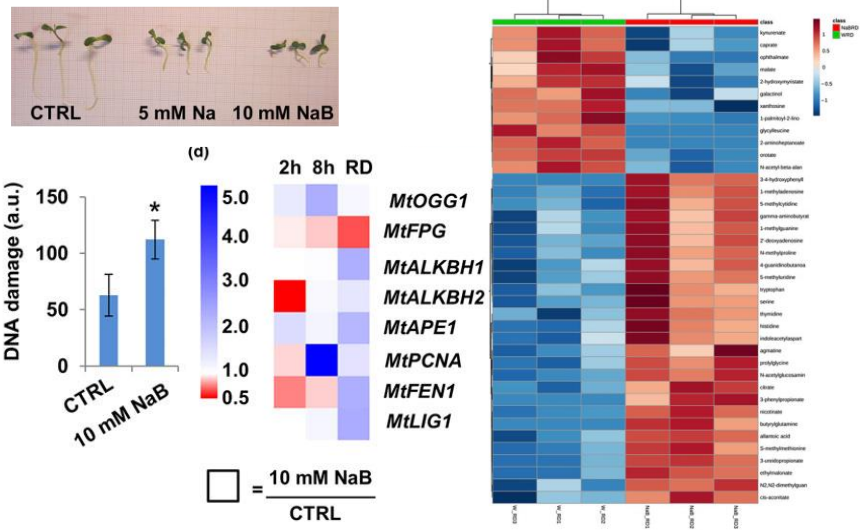
DOI: 10.1111/pce.13342

ORIGINAL ARTICLE

WILEY

Metabolic and gene expression hallmarks of seed germination uncovered by sodium butyrate in *Medicago truncatula*

Andrea Pagano[1] | Susana de Sousa Araújo[2] | Anca Macovei[1] | Daniele Dondi[3] | Simone Lazzaroni[3] | Alma Balestrazzi[1]



- Polyamine biosynthesis
- Uracil degradation pathway
- Purine and pyrimidine metabolism

➢ METABOLIC HALLMARKS OF SEED RESPONSE TO GENOTOXIC STRESS

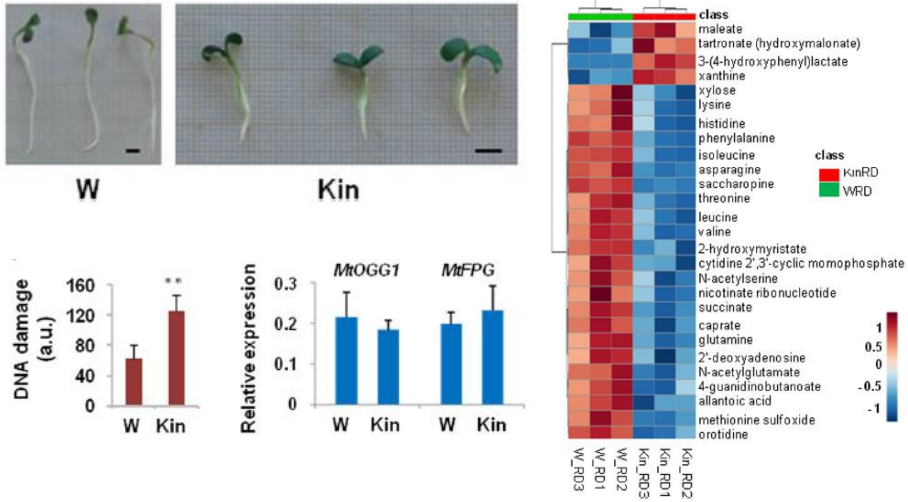
SCIENTIFIC REPORTS

OPEN

Metabolic signatures of germination triggered by kinetin in *Medicago truncatula*

Received: 11 March 2019
Accepted: 1 July 2019
Published online: 18 July 2019

Susana Araújo[1], Andrea Pagano[2], Daniele Dondi[3], Simone Lazzaroni[3], Eduardo Pinela[1], Anca Macovei[2] & Alma Balestrazzi[2]

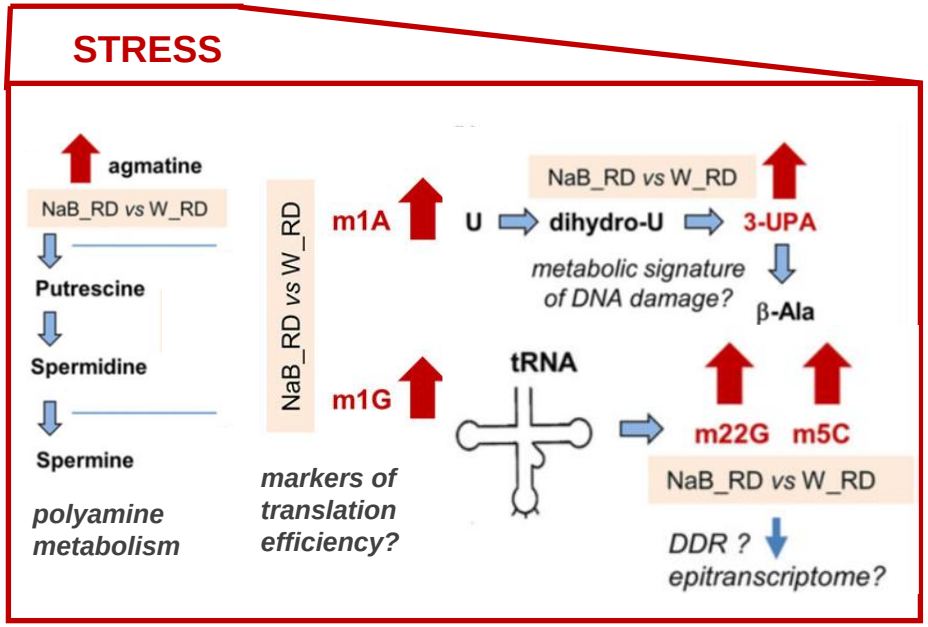


- 27 metabolites showed significant changes triggered by kinetin
- inositol, pentakisphosphate, agmatine, digalactosylglycerol, inositol hexakisphosphate, oleoylcholine
- changes linked to fast metabolic depletion associated with a fast germination

The «chemical stress» system

- **Identification of "quality"/stress hallmarks during the early phases of seed germination**

DDR (e.g. OGG1, TDP1)
Antioxidants (e.g. APX, SOD)



The «priming/overpriming» system

Overpriminig = loss of desiccation tolerance

agronomy

MDPI

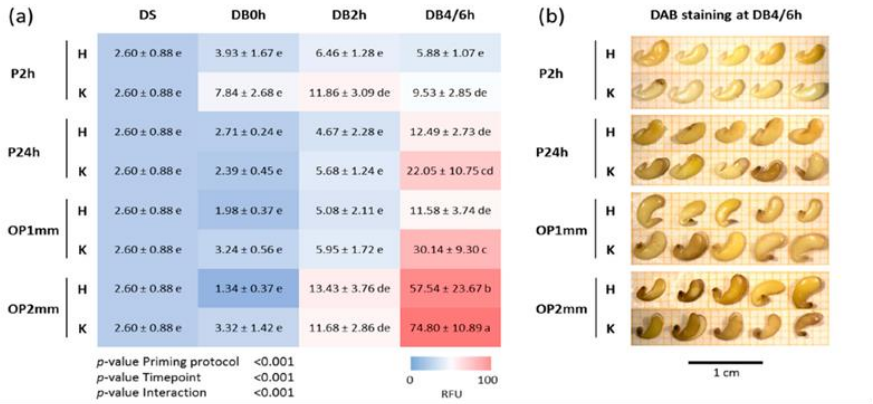
Article

ROS Accumulation as a Hallmark of Dehydration Stress in Primed and Overprimed *Medicago truncatula* Seeds

Andrea Pagano *, Giulia Folini, Paola Pagano, Federico Sincinelli, Andrea Rossetto, Anca Macovei and Alma Balestrazzi

Hydropriming/ Hormopriming 2 h

Overpriming 24 h



		DS	DB0h	DB2h	DB4/6h
P2h	H	2.60 ± 0.88 e	3.93 ± 1.67 e	6.46 ± 1.28 e	5.88 ± 1.07 e
	K	2.60 ± 0.88 e	7.84 ± 2.68 e	11.86 ± 3.09 de	9.53 ± 2.85 de
P24h	H	2.60 ± 0.88 e	2.71 ± 0.24 e	4.67 ± 2.28 e	12.49 ± 2.73 de
	K	2.60 ± 0.88 e	2.39 ± 0.45 e	5.68 ± 1.24 e	22.05 ± 10.75 cd
OP1mm	H	2.60 ± 0.88 e	1.98 ± 0.37 e	5.08 ± 2.11 e	11.58 ± 3.74 de
	K	2.60 ± 0.88 e	3.24 ± 0.56 e	5.95 ± 1.72 e	30.14 ± 9.30 c
OP2mm	H	2.60 ± 0.88 e	1.34 ± 0.37 e	13.43 ± 3.76 de	57.54 ± 23.67 b
	K	2.60 ± 0.88 e	3.32 ± 1.42 e	11.68 ± 2.86 de	74.80 ± 10.89 a

p-value Priming protocol <0.001
p-value Timepoint <0.001
p-value Interaction <0.001

(a) 0 100 RFU

(b) DAB staining at DB4/6h

P2h H K
P24h H K
OP1mm H K
OP2mm H K

1 cm

antioxidants

MDPI

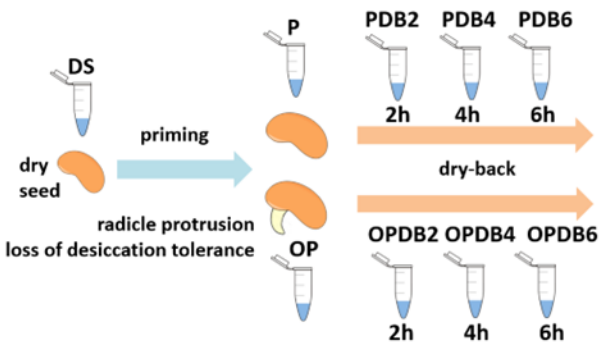
Article

Noninvasive Methods to Detect Reactive Oxygen Species as a Proxy of Seed Quality

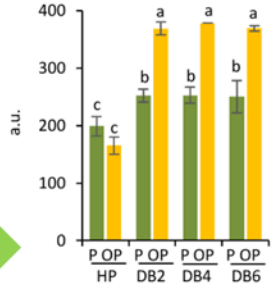
Adriano Griffo [1,†], Nicola Bosco [1,†], Andrea Pagano [1], Alma Balestrazzi [1,2] and Anca Macovei [1,2,*]

The «priming/overpriming» system

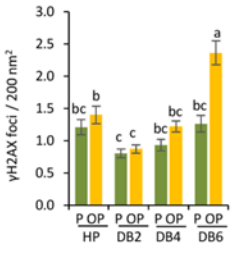
HALLMARKS



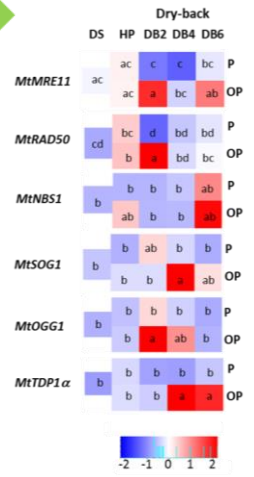
primed *vs.* overprimed

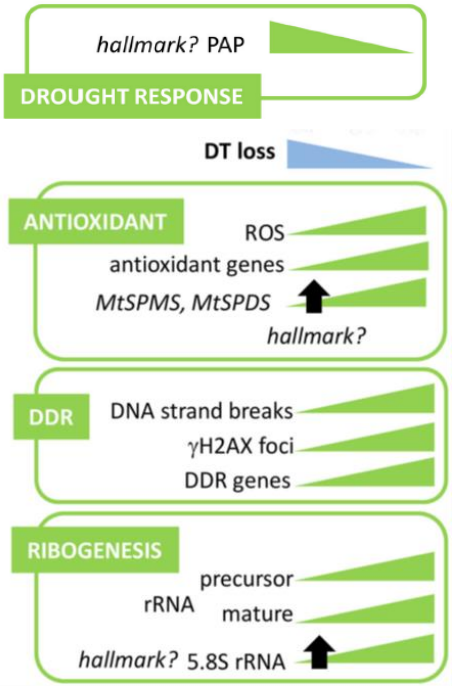


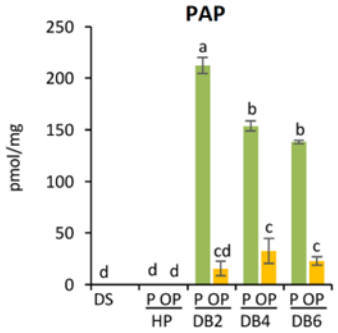
genotoxic stress



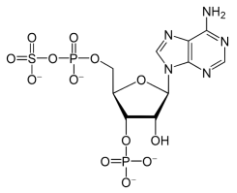
DDR

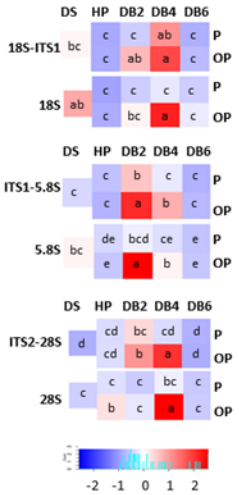




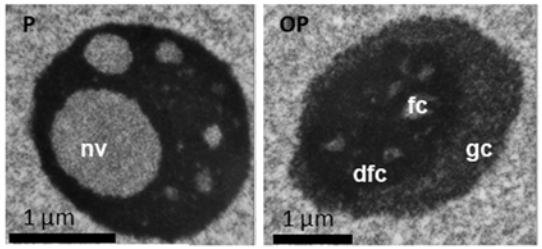


3'-phosphoadenosine 5'-phosphate





altered ribogenesis



nucleolus as stress sensor

Received: 27 December 2021 | Revised: 4 February 2022 | Accepted: 5 February 2022
DOI: 10.1111/pce.14295

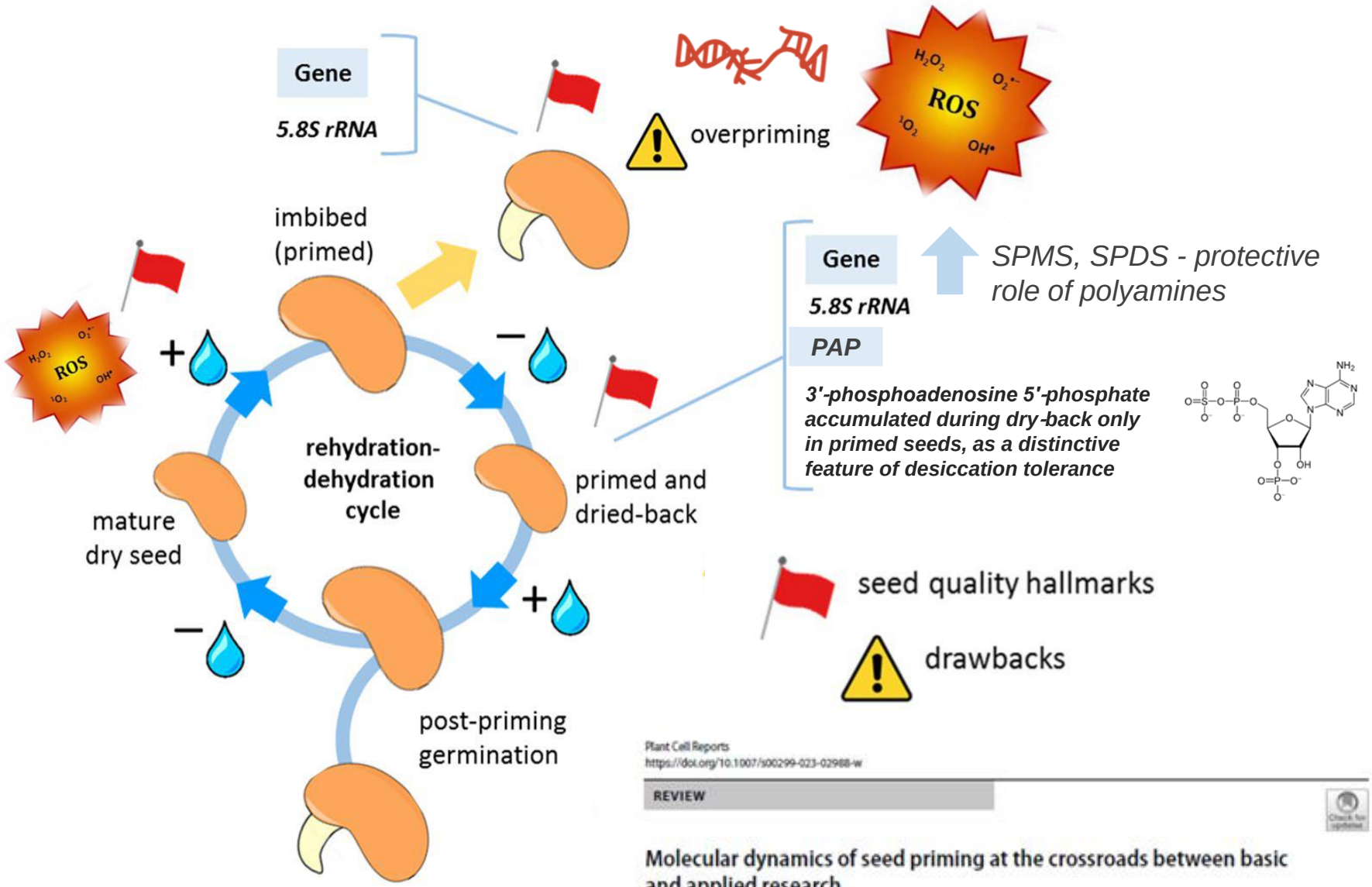
ORIGINAL ARTICLE

Plant, Cell & Environment WILEY

Changes in genotoxic stress response, ribogenesis and PAP (3′-phosphoadenosine 5′-phosphate) levels are associated with loss of desiccation tolerance in overprimed *Medicago truncatula* seeds

Andrea Pagano[1] | Lorena Zannino[1] | Paola Pagano[1] | Enrico Doria[1] | Daniele Dondi[2] | Anca Macovei[1] | Marco Biggiogera[1] | Susana de Sousa Araújo[3] | Alma Balestrazzi[1]

The «priming/overpriming» system



Plant Cell Reports
https://doi.org/10.1007/s00299-023-02988-w

REVIEW

Molecular dynamics of seed priming at the crossroads between basic and applied research

Andrea Pagano[1] · Anca Macovei[1,2] · Alma Balestrazzi[1,2]

The «intra- and inter-specific variation» system

- ✓ **Priming protocols – species/genotype/seed lot-dependent**
- ❑ **Gene expression as indicators of seed quality and priming efficiency**

Contents lists available at ScienceDirect

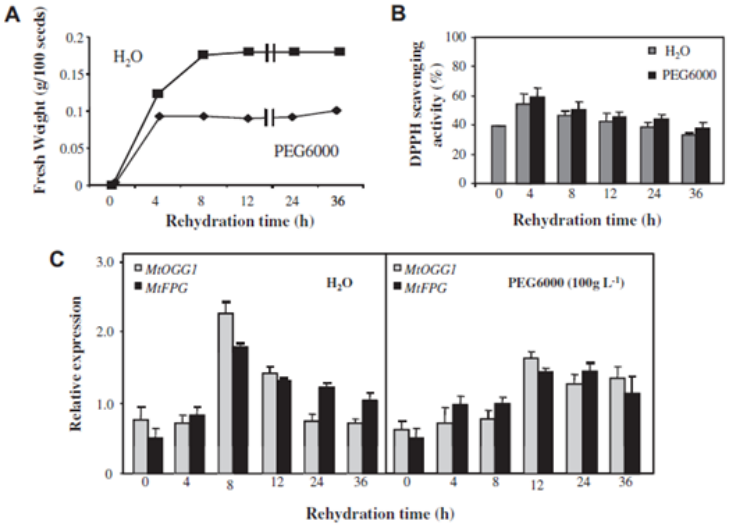
Plant Physiology and Biochemistry

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

Research article

New insights on the barrel medic *MtOGG1* and *MtFPG* functions in relation to oxidative stress response in planta and during seed imbibition

Anca Macovei [a], Alma Balestrazzi [a], Massimo Confalonieri [b], Matteo Faé [a], Daniela Carbonera [a,*]



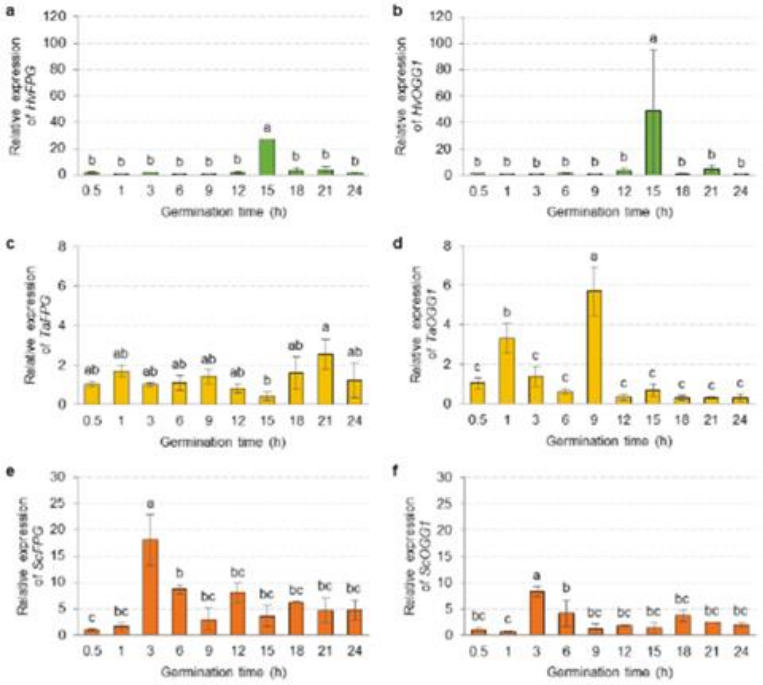
International Journal of *Molecular Sciences*

MDPI

Communication

Profiling of Barley, Wheat, and Rye *FPG* and *OGG1* Genes during Grain Germination

Sylwia Kowalik and Jolanta Groszyk *



The «intra- and inter-specific variation» system

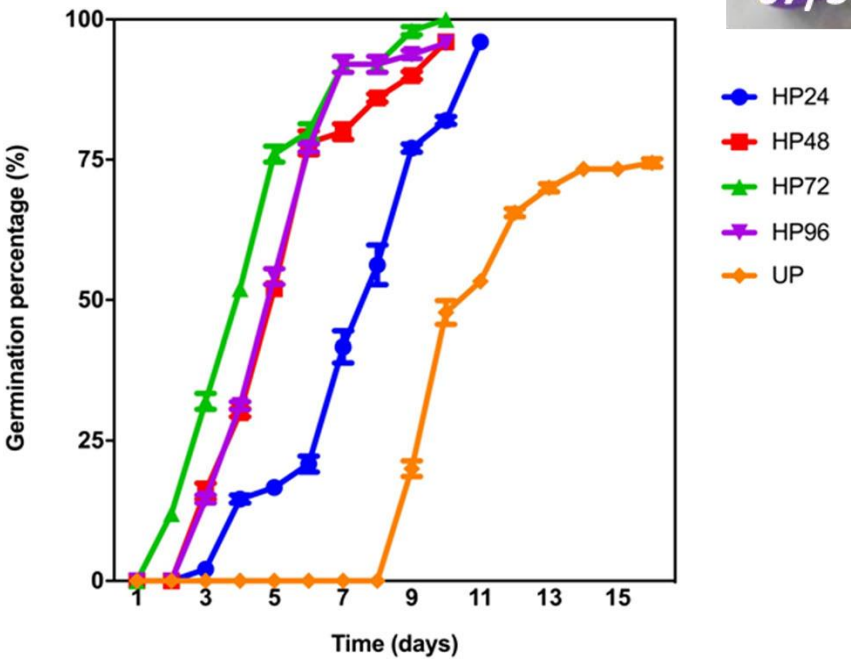
Forti et al. *Horticulture Research* (2020)7:87
https://doi.org/10.1038/s41438-020-0310-8

Horticulture Research
www.nature.com/hortres

ARTICLE Open Access

Molecular dynamics of pre-germinative metabolism in primed eggplant (*Solanum melongena* L.) seeds

Chiara Forti[1], Valentino Ottobrino[1], Laura Bassolino[2,3], Laura Toppino[2], Giuseppe Leonardo Rotino[2], Andrea Pagano[1,4], Anca Macovei[1] and Alma Balestrazzi[1]



frontiers in Plant Science

ORIGINAL RESEARCH
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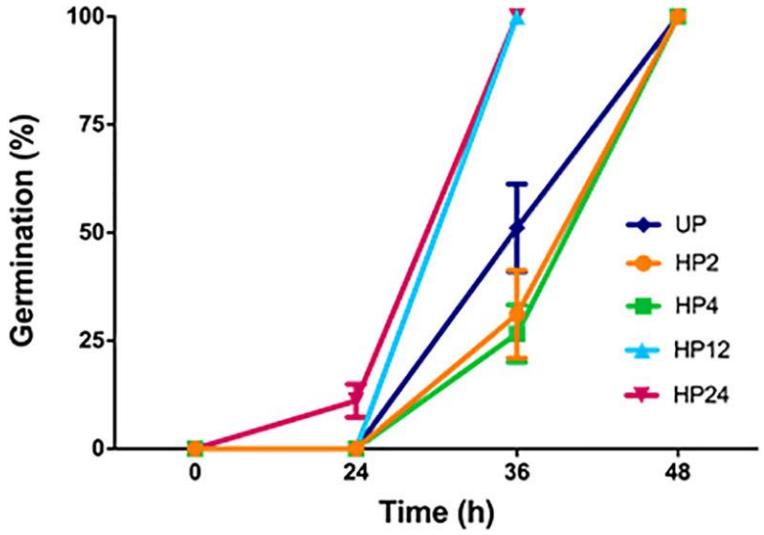
Hydropriming Applied on Fast Germinating *Solanum villosum* Miller Seeds: Impact on Pre-germinative Metabolism

*Chiara Forti†, Valentino Ottobrino, Enrico Doria, Laura Bassolino, Laura Toppino, Giuseppe Leonardo Rotino, Andrea Pagano, Anca Macovei and Alma Balestrazzi**

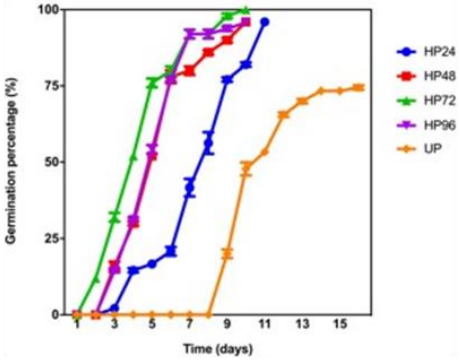


The «intra- and inter-specific variation» system

- ✓ 34 *S. melongena* accessions + 9 CWRs from the CREA-GB Germplasm Collection
- ✓ grouped based on germination phenotypes (EARLY, NORMAL, LATE)
- ✓ seed lots collected at different years

HALLMARKS

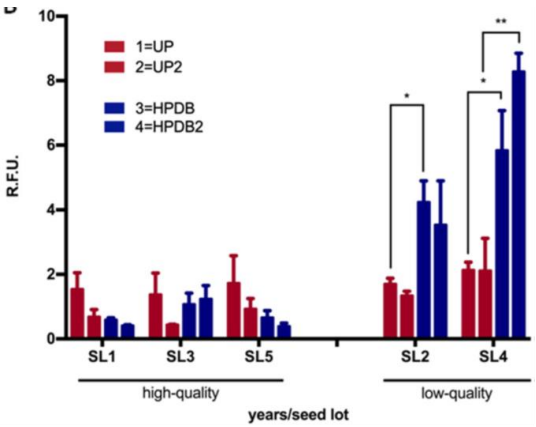
germination delay



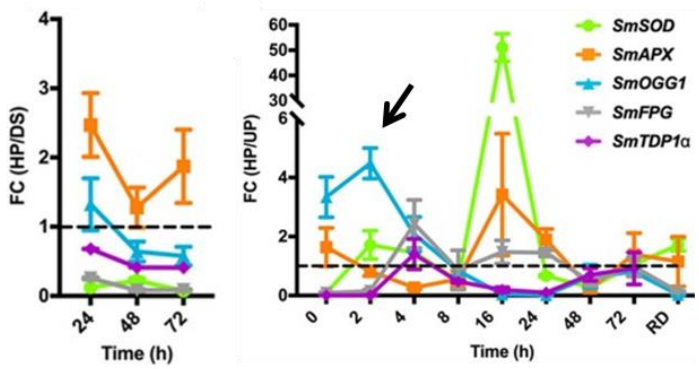
hydropriming accelerates germination of '67/3' seeds

selected treatment

impact on pre-germinative metabolism



ROS levels



expression of antioxidant/DNA repair genes

variability and heterogeneity observed when comparing different genotypes and seed lots

…

search for hallmarks is delayed

The «intra- and inter-specific variation» system

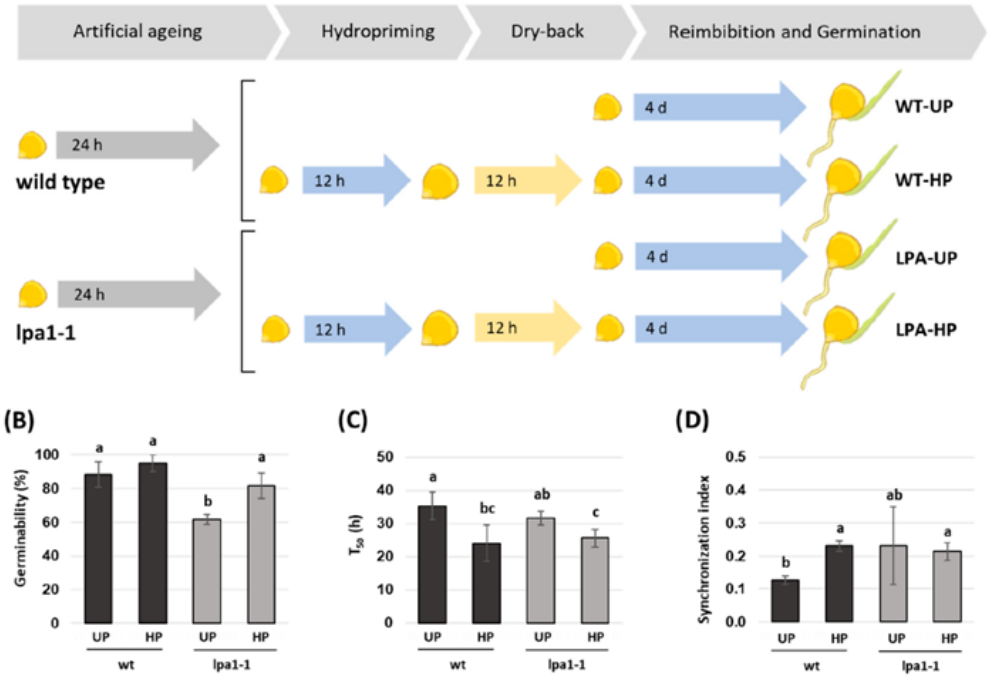
International Journal of *Molecular Sciences*

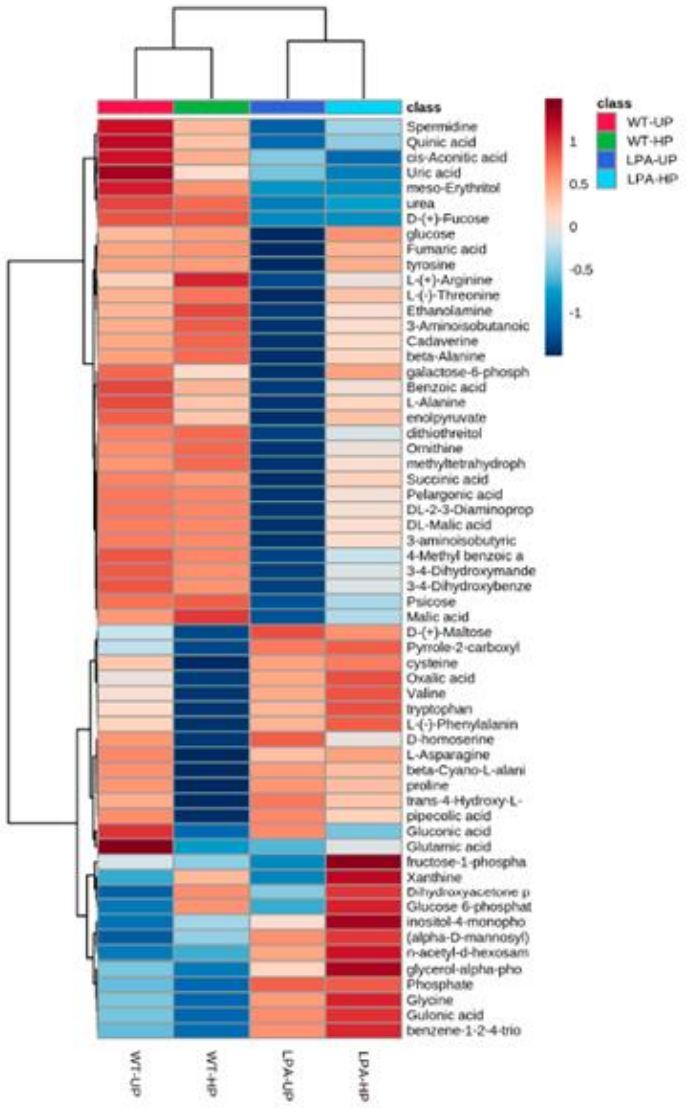
MDPI

Article

Study of Seed Ageing in *lpa1-1* Maize Mutant and Two Possible Approaches to Restore Seed Germination

Federico Colombo [1,†], Andrea Pagano [2,†], Stefano Sangiorgio [1], Anca Macovei [2], Alma Balestrazzi [2], Fabrizio Araniti [1] and Roberto Pilu [1,*]





- metabolomic differences among genotypes and priming treatments

CLOSING REMARKS

Basic	Translational	Applied
Models of the pre-germinative metabolism responding to seed priming and stress conditions	**Proofs-of-concept in different model, crop and wild species**	**Scale-up validation and biomarker-assisted breeding in various agricultural contexts**
Identification of quality-related traits	Assays for seed quality evaluation	Climate-ready crops
Identification of key molecular players	Tailored seed priming protocols	Food security

Boosting technologies of **orphan legumes** towards resilient farming systems in the Greater Mediterranean Region: from bench to open field

https://www.benefit-med.eu/

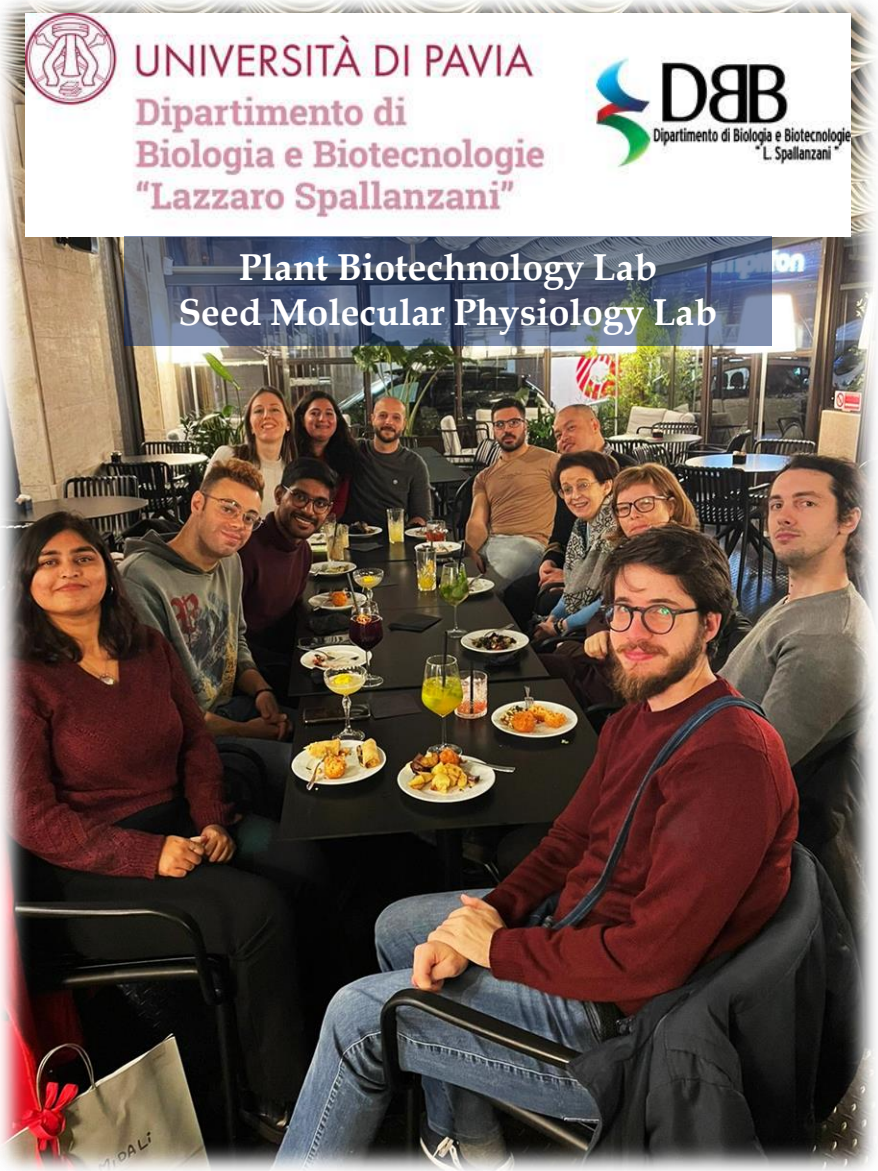
Strengthening capacities and promoting innovation in **plant omics** at University of Sfax

https://www.inplantomics.org/

Plant-based biostimulants for seeds in the context of circular economy and sustainability

PIANO NAZIONALE DI RIPRESA E RESILIENZA

ACKNOWLEGEMENTS



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