Can we alleviate abiotic stress in berry production?

Jorge Duarte

CEO/Senior Agronomist

Hortitool Consulting Lda

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Index

- Importance of abiotic stress nowdays
- Is getting hotter!
- Key observations from the Mediterranean basin
- What is abiotic stress & types of stress
- Impact on berry crops
- Impact on plant physiology: Temperature
- Visual impact on plants
- What science already know
- What tools we have on the field?
- How we can impact with these tools?

Importance of impact of climate crops nowdays

- Since 2012, The Intergovernmental Panel on Climate Change declared

> “The scientific evidence is unequivocal: climate change is a threat to human wellbeing and the health of the planet. Any further delay in concerted global action will miss the brief, rapidly closing window to secure a liveable future.
>
> INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

Temperature rising, drought, floods, desertification and **deterioration of arable land and weather extremes** will severely affect agriculture, especially **in drought-prone regions of the developing world**

One of the major goals of **plant improvement is to develop crops** fit to **cope with environmental injuries but still capable to achieve substantial yield under abiotic stress.**

Resulting plants are being evaluated in controlled conditions (greenhouse and growth chambers) but also, importantly, **in the field to confirm the generation of improved cultivars.**

Regarding food security, this threatening scenario highlights the need for **a globally concerted research approach to address crop improvement to mitigate crop failure under marginal environments.**

Oomics in approach. Data from traditional breeding, plant molecular breeding based in the development of molecular markers, candidate gene identification or gene expression profiles and from the use of transgenic approaches are becoming more and more frequent

Despite the difficulty to establish **reliable methods to assess new breed or engineered plant phenotypes** as result of those approaches, some efforts are anticipated to fulfill the gap between plant molecular biology and plant physiology.

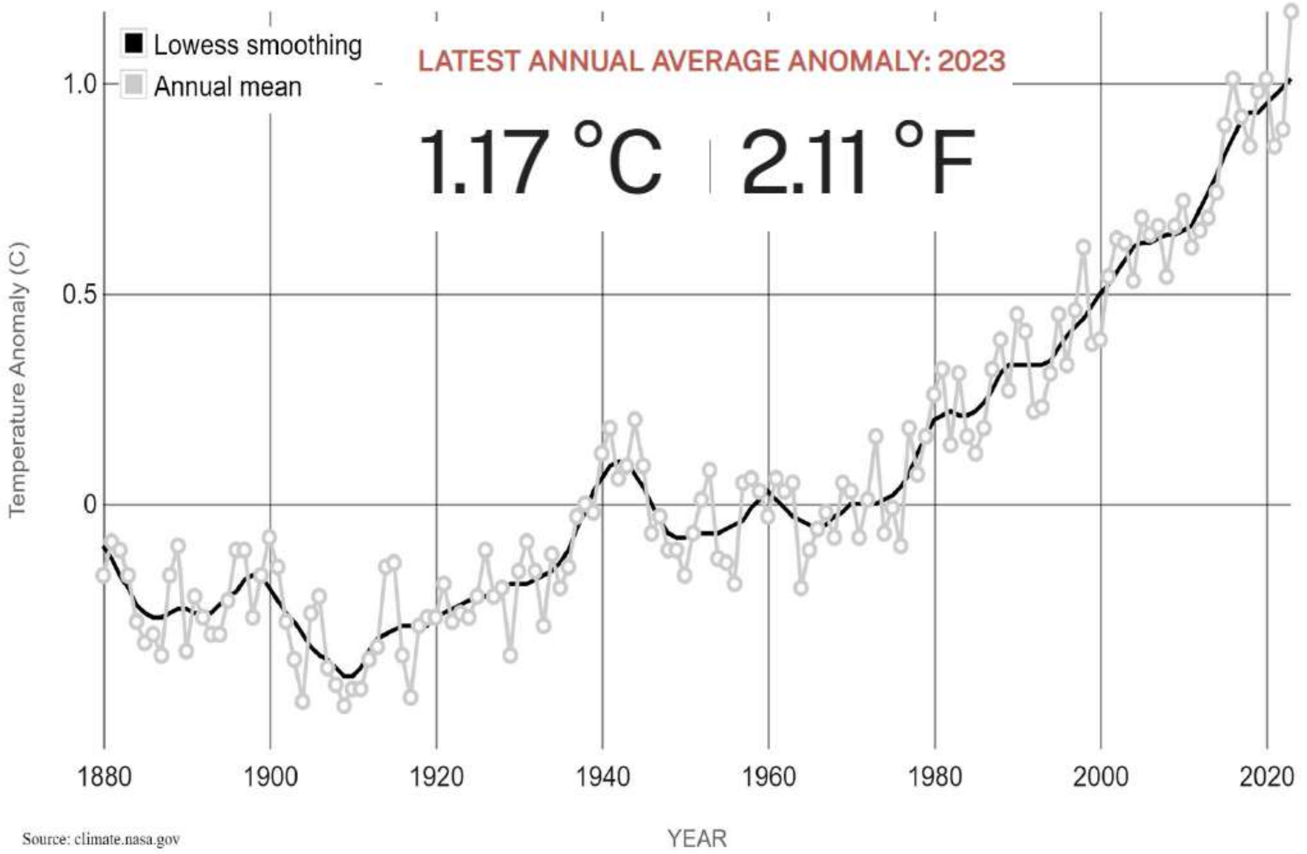
Abiotic Stress Responses in Plants: Unraveling the Complexity of Genes and Networks to Survive; http://dx.doi.org/10.5772/52779

https://science.nasa.gov/climate-change/effects/

Is getting hotter!!!

- Currently high-chill zones will transition to mid-chill in 10 years, and many mid-chill areas will become low-chill.

- Eventually, low-chill regions will turn into no-chill areas. These changes will significantly affect production cycles and the global blueberry market in the coming years.



Key Takeaway:
The 10 most recent years are the warmest years on record

https://climate.nasa.gov/vital-signs/global-temperature/?intent=121

Key observations of Mediterranean Basin

- **Annual precipitation** is likely to **decline by -9% to -11%,** February through June and October to January.
- **Minimum daily temperatures** will likely **increase slowly** with significant **increases not felt until 2050**.
- **Average daily temperatures** will likely **increase steadily**.
- **Maximum daily temperatures** will likely **increase more rapidly in all months**, on average **by 1.2C by 2030 and 2.4C by 2050**.
- **Chill hours** are likely to **decline by -9% to -15%.**
- **Growing Degree Days (7C)** are likely to **increase by 6% to 15%.**
- **Crop evapotranspiration (ETc)**: is likely to **increase by 7% to 10% on an annual basis**. The majority of this **increase** will likely occur in the **months of February through June. (More hot in the winter!)**

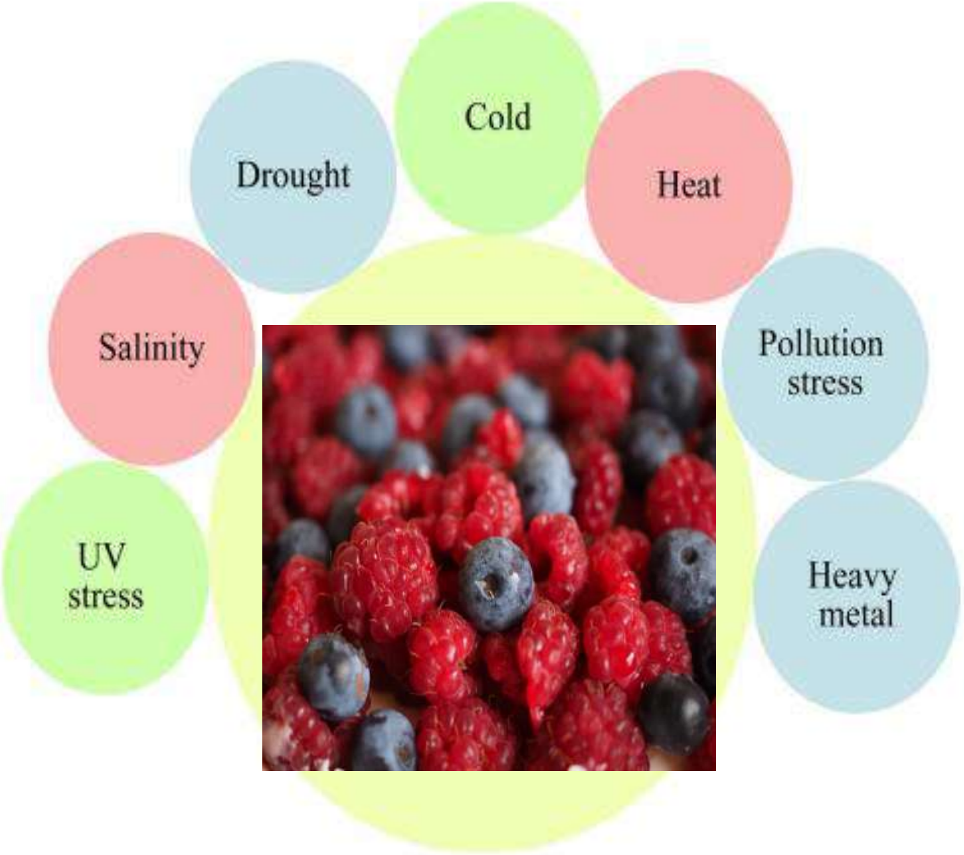
Source:MERRA-2 global climate model, NASA

Table 15: Estimated Changes from Baseline (2013-2019) to 2030 and 2050

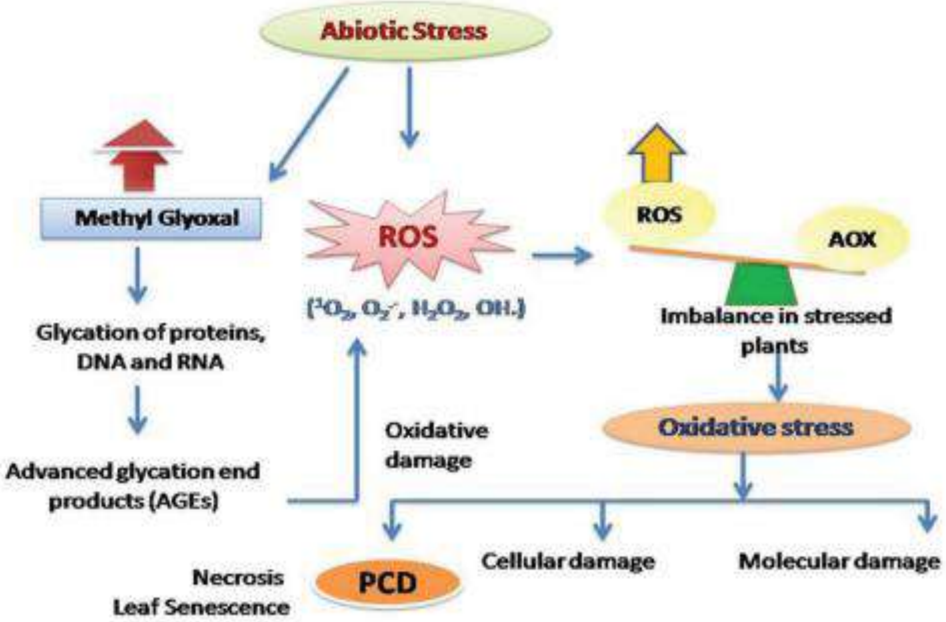
Parameter (short)	Units	Change (Baseline to 2030)	Change (Baseline to 2050)
Mean annual air temperature	°C	1.2	2.2
Mean diurnal air temperature range	°C	0.6	0.6
Isothermality	°C	2.3	0.7
Mean daily maximum air temperature of the warmest month	°C	1.1	2.5
Mean daily minimum air temperature of the coldest month	°C	0.8	1.0
Mean daily mean air temperatures of the wettest quarter	°C	1.8	2.8
Mean daily mean air temperatures of the driest quarter	°C	0.9	1.7
Mean daily mean air temperatures of the warmest quarter	°C	2.2	3.4
Mean daily mean air temperatures of the coldest quarter	°C	1.2	1.5
Annual precipitation amount	mm	-9%	-11%
Precipitation amount of the wettest month	mm	-1%	-4%
Precipitation amount of the driest month	mm	36%	18%
Mean monthly precipitation amount of the wettest quarter	mm	3%	-1%
Mean monthly precipitation amount of the driest quarter	mm	-34%	-41%
Mean monthly precipitation amount of the warmest quarter	mm	-77%	-79%
Mean monthly precipitation amount of the coldest quarter	mm	-17%	-8%
Precipitation Change Factor - January	%	-10%	-7%
Precipitation Change Factor - February	%	-31%	-19%
Precipitation Change Factor - March	%	-9%	-12%
Precipitation Change Factor - April	%	1%	-7%
Precipitation Change Factor - May	%	3%	-1%
Precipitation Change Factor - June	%	-27%	-31%
Precipitation Change Factor - July	%	35%	17%
Precipitation Change Factor - August	%	-32%	-39%
Precipitation Change Factor - September	%	-3%	-18%
Precipitation Change Factor - October	%	-22%	-24%
Precipitation Change Factor - November	%	-1%	-4%
Precipitation Change Factor - December	%	8%	4%
Chill hours bellow 45F	hours	-15%	-9%
Growing degree days heat sum above 7°C	°C	6%	15%
ET Change Factor - January	%	5%	4%
ET Change Factor - February	%	13%	11%
ET Change Factor - March	%	9%	10%
ET Change Factor - April	%	8%	12%
ET Change Factor - May	%	7%	12%
ET Change Factor - June	%	5%	7%
ET Change Factor - July	%	3%	5%
ET Change Factor - August	%	5%	8%
ET Change Factor - September	%	6%	11%
ET Change Factor - October	%	9%	13%
ET Change Factor - November	%	7%	10%
ET Change Factor - December	%	10%	13%

What it is and types of abiotic stress

Abiotic stress *"is defined as the negative impact of non living factors on the living organisms in a specific environment"*



https://www.researchgate.net/publication/330371495_Abiotic_Stress-Mediated_Oxidative_Damage_in_Plants_Profiling_and_CounterAction



Malekzadeh, M.R., Roosta, H.R. & Kalaji, H.M. Enhancing strawberry resilience to saline, alkaline, and combined stresses with light spectra: impacts on growth, enzymatic activity, nutrient uptake, and osmotic regulation. BMC Plant Biol 24, 1038 (2024). https://doi.org/10.1186/s12870-024-05755-5

Impact on Berry Crops

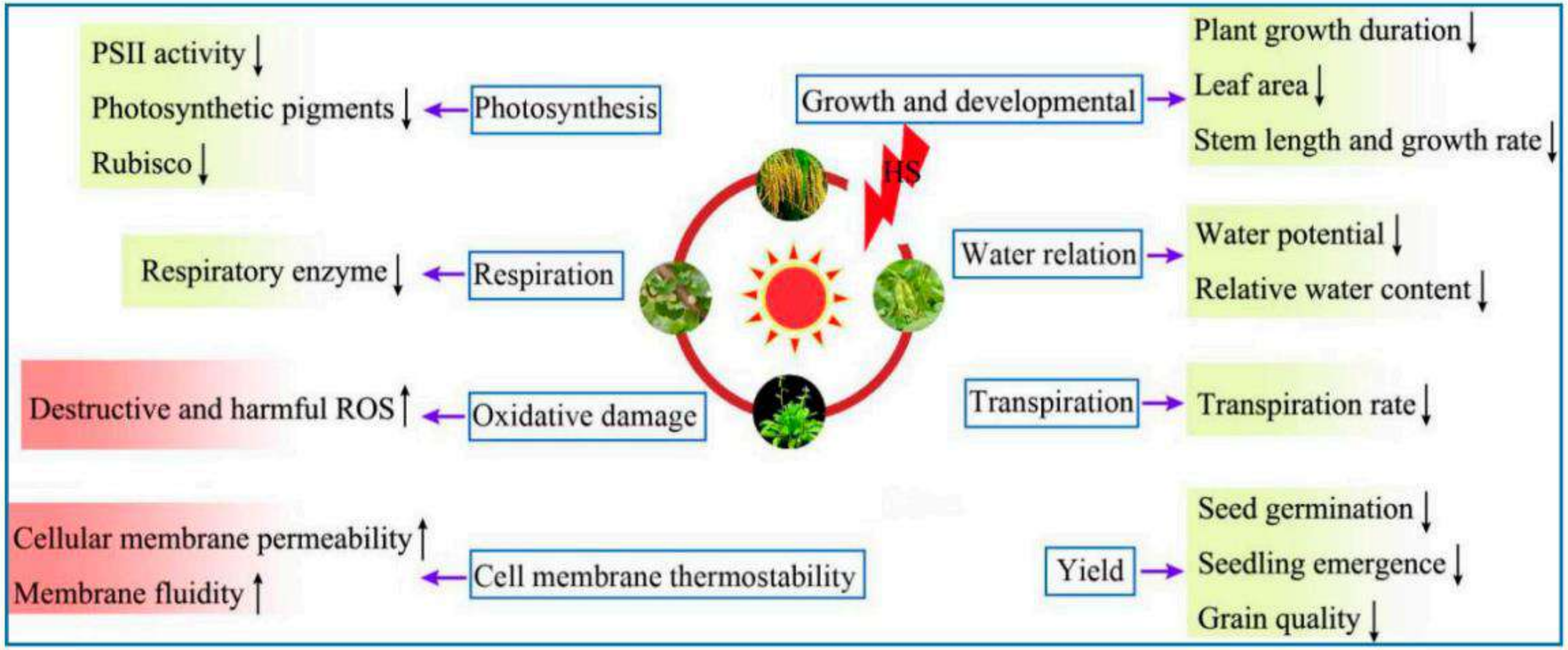
- Germplasm extinction
- Poor vernalization
- Unsatisfactory chilling hours
- Poor activity of pollinators
- Frost injuries (advanced bud break)
- Cracking
- Delay of flowering
- New pest of pests and diseases spectrum
- Changes in metabolites balance (amino acids, amines, sugars, etc.)
- Increase vegetative growth
- Traditional agricultural growing regions, are losing the seasons patterns, changing cultivation latitudes from lower areas to high altitudes.
- Impact on the quality and quantity on yields in berry production.

Impact on plant physiology

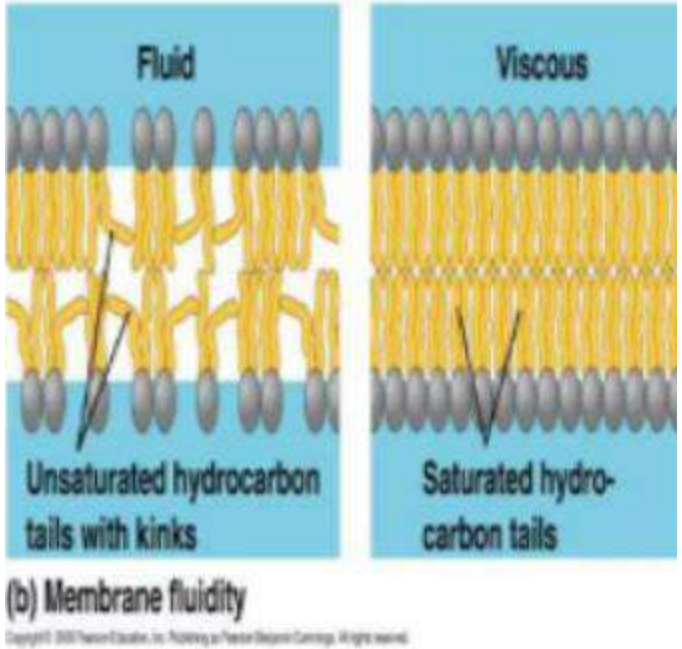
High temperature effect on plants

Downward-pointing arrow deactivated/downregulated physiological indices

Downward arrow indicate activated/upregulated physiological indices



Abbreviations: HS, heat stress; PSII, photosystem II; Rubisco, ribulose-1,5-bisphosphate carboxylase/oxygenase; ROS, reactive oxygen species

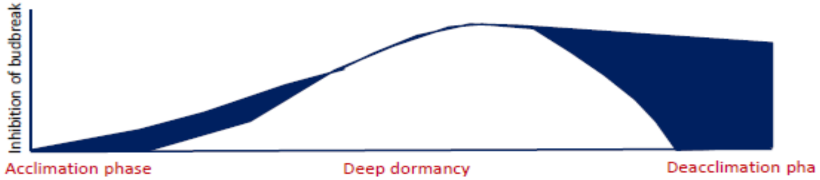


- Excessive membrane fluidity
- Disruption of protein function
- Metabolic imbalances
- Disruption of protein syntensis
- Disruption of mRNa percursor

Zhao, J.; Lu, Z.; Wang, L.; Jin, B. Plant Responses to Heat Stress: Physiology, Transcription, Noncoding RNAs, and Epigenetics. Int. J. Mol. Sci. 2021, 22, 117. https://doi.org/10.3390/ijms2201011

Impact in chill accumulation

Stages of dormancy (endodormancy)



Acclimation	Deep dormancy	Deacclimation
Triggered by shortening daylength and cooler temperatures (rate affected by weather)	Length of dormancy affected by weather	Plant becomes active (prior to visual budbreak). Rate affected by weather
Plants may start to grow again if weather favorable	Plants will not grow (no vegetative budbreak) until the chilling requirement is met	Rate of growth will increase with warmer temperatures

Dormancy development is promoted by short days and cool temperatures

At constant temperature of 0.5 ºC is the most effective to satisfy the cold needs of the HB group blueberries

The temperature between 1 ºC and 12 ºC (SHB) met the chill needs of HB blueberries, with the most effective temperature being 6 ºC.

The number of cold hours has an impact on quality and flowering period.

Insufficient cold hours lead to erratic budding patterns of both floral buds and vegetative buds. Floral buds have less cold requirements than vegetative buds.

Mainland, C. M., Buchanan, D. W. and Bartholic, J. F. 1977. The effects of five chilling regimes on bud break of highbush and rabbiteye blueberry hardwood cuttings. HortScience 12:43.

Norvell, D. J. & Moore, J. N. 1982. An evolution of chilling models for estimating rest requirements of Highbush blueberries (Vaccinium corymbosum L.). J. Amer. Soc. Hort. Sci. 107: 54-56.

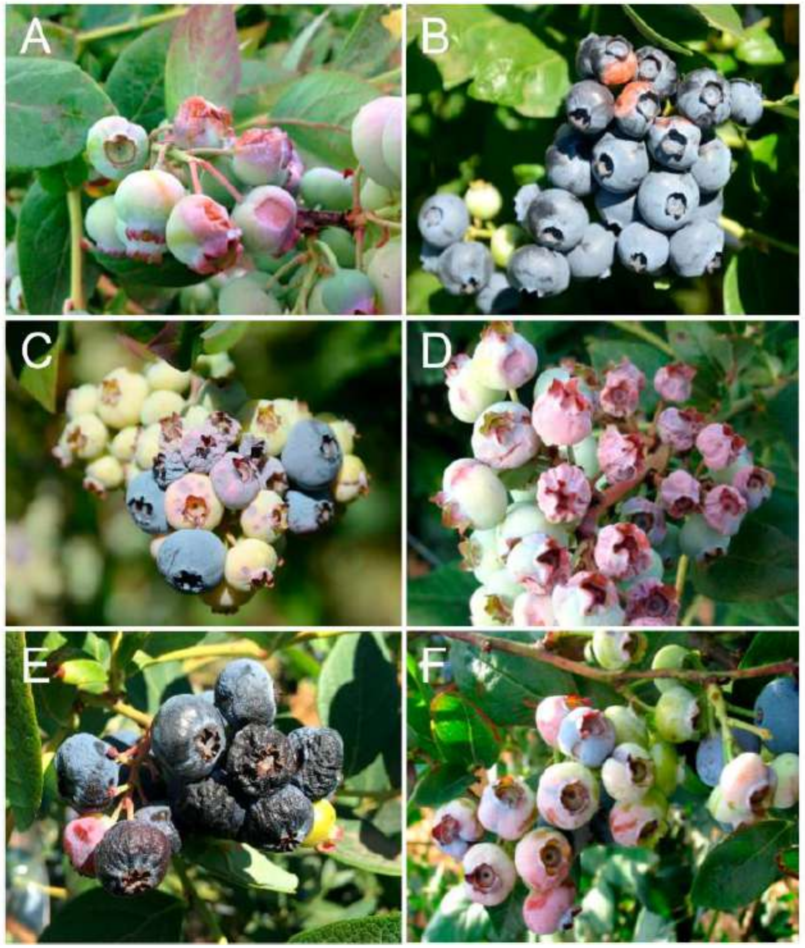
Visual Impact on plants: Blueberries

Shoot wilting from temporary water deficit during heat. (VPD > 2,5) Can be also related to estomatal density from a specific genotype.

Ripened cluster blueberry plant reveals sunburned fruit.

Undamaged blueberry tissue (left) compared to frost-damaged tissue (right)

https://www.growingproduce.com/fruits/historic-heat-wave-still-has-pnw-berry-growers-feeling-the-burn
https://extension.psu.edu/frost-and-freeze-damage-on-berry-crops



Symptoms of heat damage in northern highbush blueberry include
(A, B) necrosis, (C) spotting, (D, E) shriveling or wrinkling, and (F) poor coloration on the berries.

Drought stress leaves

Burned dead shoots

Burned shriveling shoots

- T: SHB > NHB ↑ T tolerance,
- SHB=NHB summer T ↓ CO_2 rates
- SHB=NHB ↓ fruit quality.

- T>32 C early green fruit
- T>35 C blue fruits

F.H. Yang; D. R. Bryla B. C. Strike; December 2019; Critical Temperatures and Heating Times for Fruit Damage in Northern Highbush Blueberry HortScience 54(12):2231-2239
DOI:10.21273/HORTSCI14427-19

Visual Impact on plants: Rasps and blacks

Heat stress can cause double fruit in many bramble berries

Sunscald on the side of a raspberry exposed to strong direct sunlight

Blackberry with inadequate drupelet development as a result of poor pollination.

High temperature and low humidity during pollination can lead to crumbly fruits

Frost damaged flowers in blackberry. Note the black, necrotic tissue

Frost-damaged raspberry blossoms with blackened centers

Salt injuries in raspberries and incorrect ph

https://extension.umn.edu/raspberry-farming/non-pest-problems
https://blogs.cornell.edu/berrytool/raspberries/raspberries-fruits-are-small-deformed-or-crumbly/#pollination

Visual Impact on plants: Strawberries

Frost-damaged strawberry blossom and developing fruit. Note darkened centers

Normal water supply and stressed plant

Classical tipburn cause by high VPD that leeds to calcium deficiency

Polito, Letizia et al. "Protein Synthesis Inhibition Activity by Strawberry Tissue Protein Extracts during Plant Life Cycle and under Biotic and Abiotic Stresses." International Journal of Molecular Sciences 14 (2013): 15532 - 15545.

Air movement is very limited inside of the high tunnel that results in poor pollination.

https://vegcropshotline.org/article/factors-may-cause-deformed-strawberry-fruit/

What science already know?

GLOBAL SCIENCE BOOKS

Plant Architecture of Strawberry in Relation to Abiotic Stress, Nutrient Application and Type of Propagation System

Article

Hardening Blueberry Plants to Face Drought and Cold Events by the Application of Fungal Endophytes

FOLIAR FEEDING TO INCREASE YIELD VALUE AND QUALITY IN STRAWBERRY (*Fragaria ananassa*) UNDER METEOROLOGICAL STRESSES

T.G. PRICHKO, M.G. GERMANOVA, L.A. KHILKO

Critical Temperatures and Heating Times for Fruit Damage in Northern Highbush Blueberry

Article in HortScience · December 2019

DOI: 10.21273/HORTSCI14427-19

tolerance from the perspective of cultivar improvement

Sushan Ru[1*], Alvaro Sanz-Saez[2], Courtney P. Leisner[3],

Comprehensive resistance evaluation of 15 blueberry cultivars under high soil pH stress based on growth phenotype and physiological traits

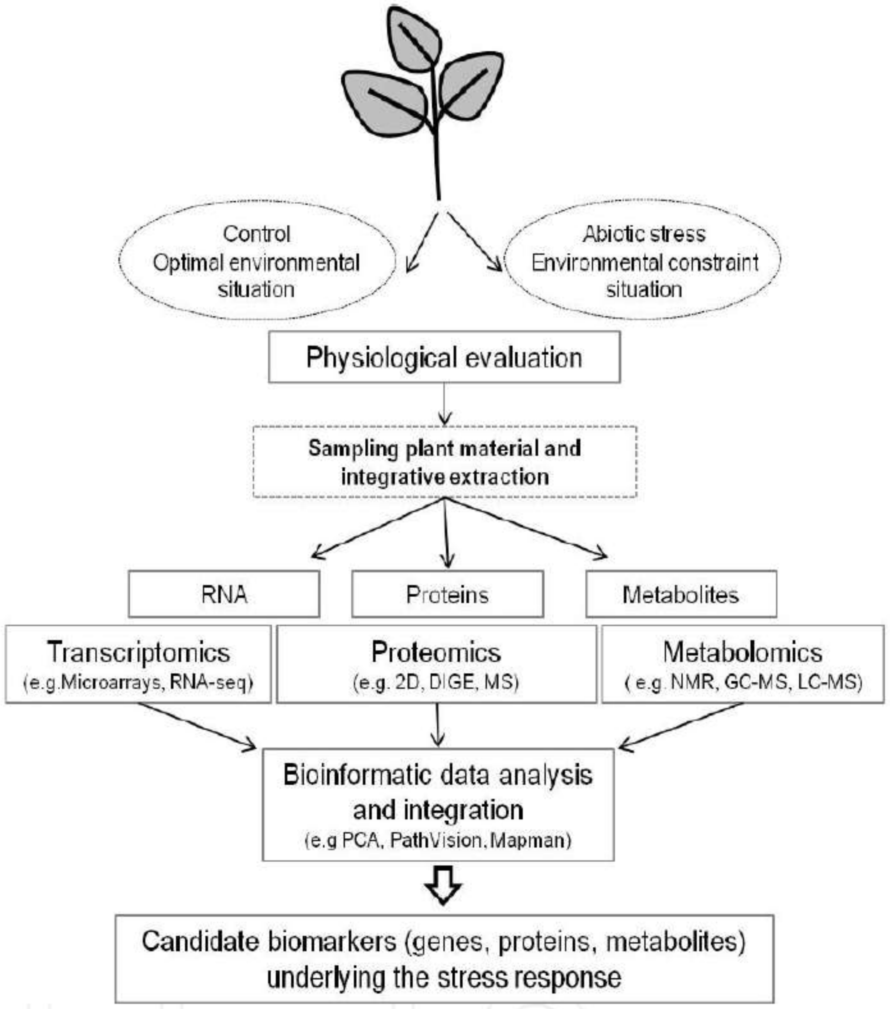
Hao Yang[1,2], Yaqiong Wu[2*], Chunhong Zhang[2], Wenlong Wu[2], Lianfei Lyu[2] and Weilin Li[1*]

[1]Co-Innovation Center for Sustainable Forestry in Southern China, Nanjing Forestry University

Effect of low temperature in the first development stage for five red raspberry genotypes

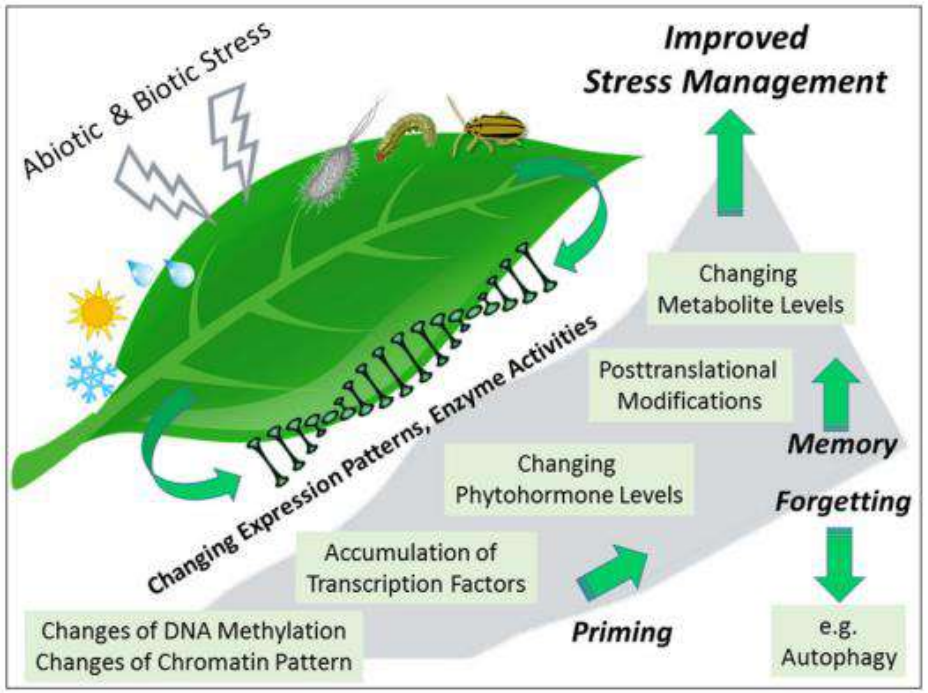
Elida Contreras [1], Javiera Grez[1], José A. Alcalde[1], Davide Neri[2], Marina Gambardella[1]*

Biology approach to study abiotic stress responses in plants



Abiotic Stress Responses in Plants: Unraveling the Complexity of Genes and Networks to Survive; http://dx.doi.org/10.5772/52779

Several types of responses "pave the way" to improved stress management

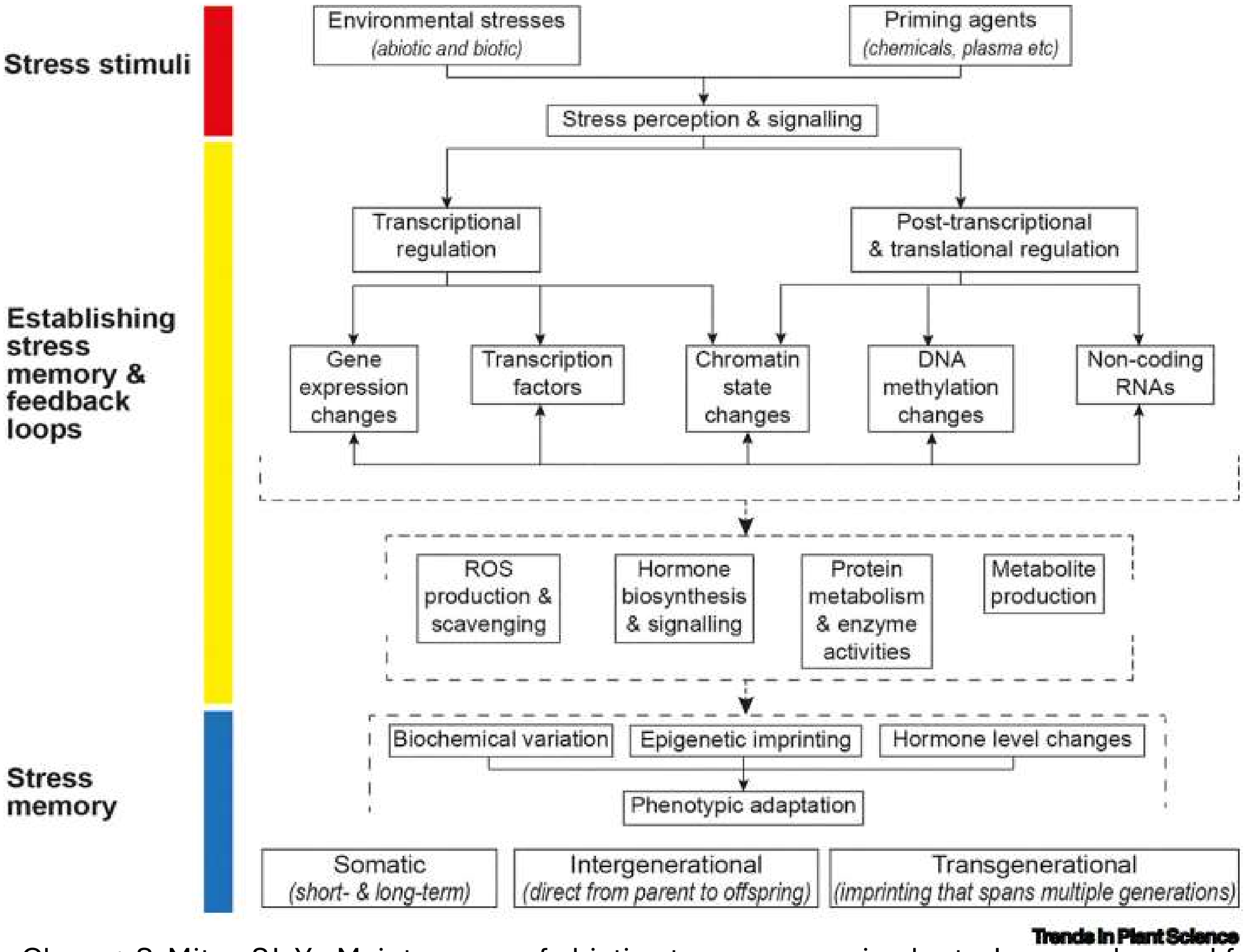


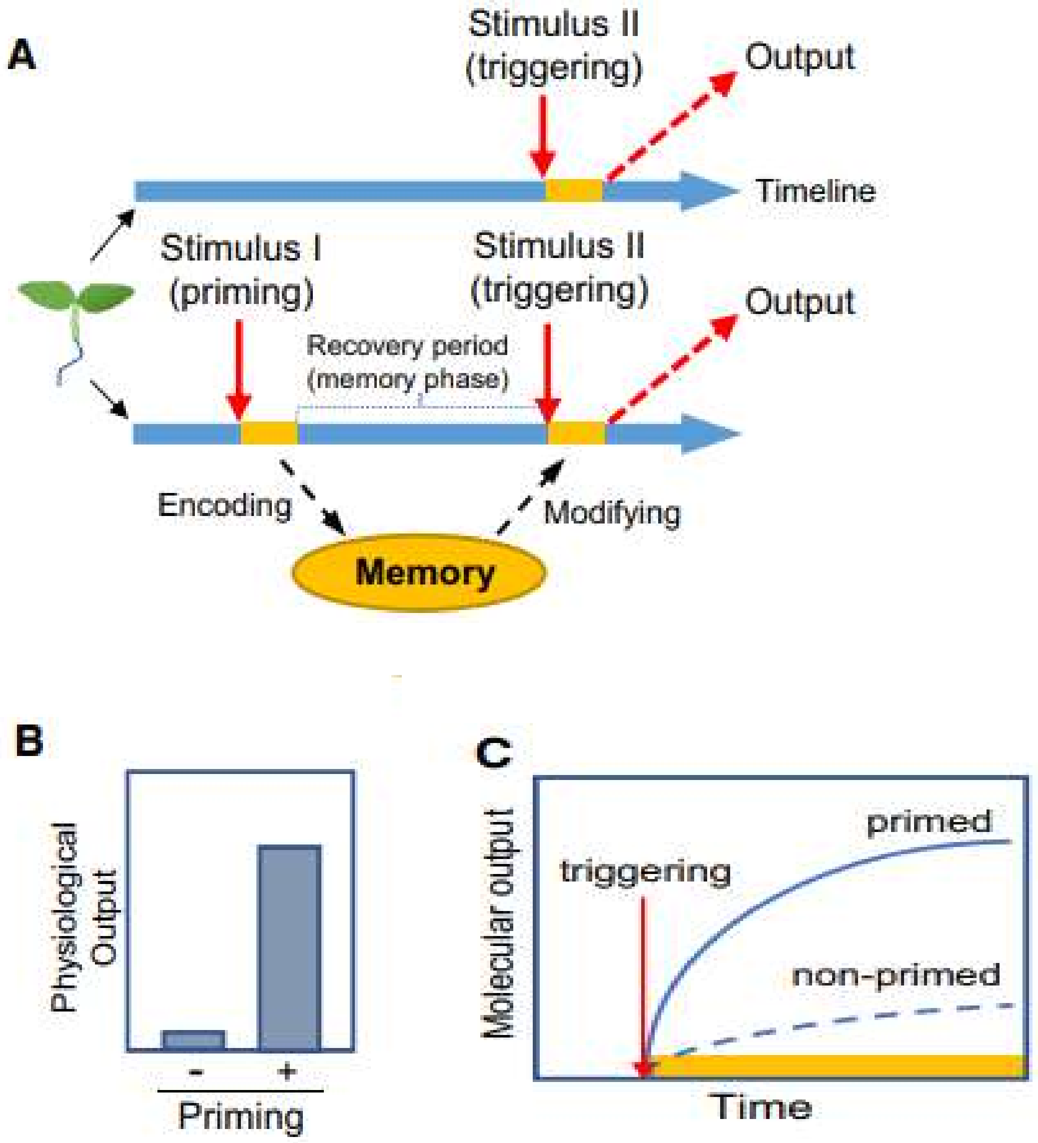
Priming (preparedness) and memory of a stress response. Autophagy is addressed just as one of several mechanisms, which result in "forgetting" of a response to a stress stimulus

Hilker M, Schmülling T. Stress priming, memory, and signalling in plants. *Plant Cell Environ*. 2019; 42: 753–761. https://doi.org/10.1111/pce.13526

Plant stress memory (PSM)

The molecular and physiological framework of stress memory, highlighting the stimuli (**red**), elements and feedback loops (**yellow**), and stress memory (**blue**) required to attenuate stress responses.





Yy. Charng; S. Mitra; SJ. Yu;Maintenance of abiotic stress memory in plants: Lessons learned from heat acclimation; THE PLANT CELL 2023: 35: 187–200; https://doi.org/10.1093/plcell/koac313

Studies related to PSM duration for acclimation to intermittent abiotic stress

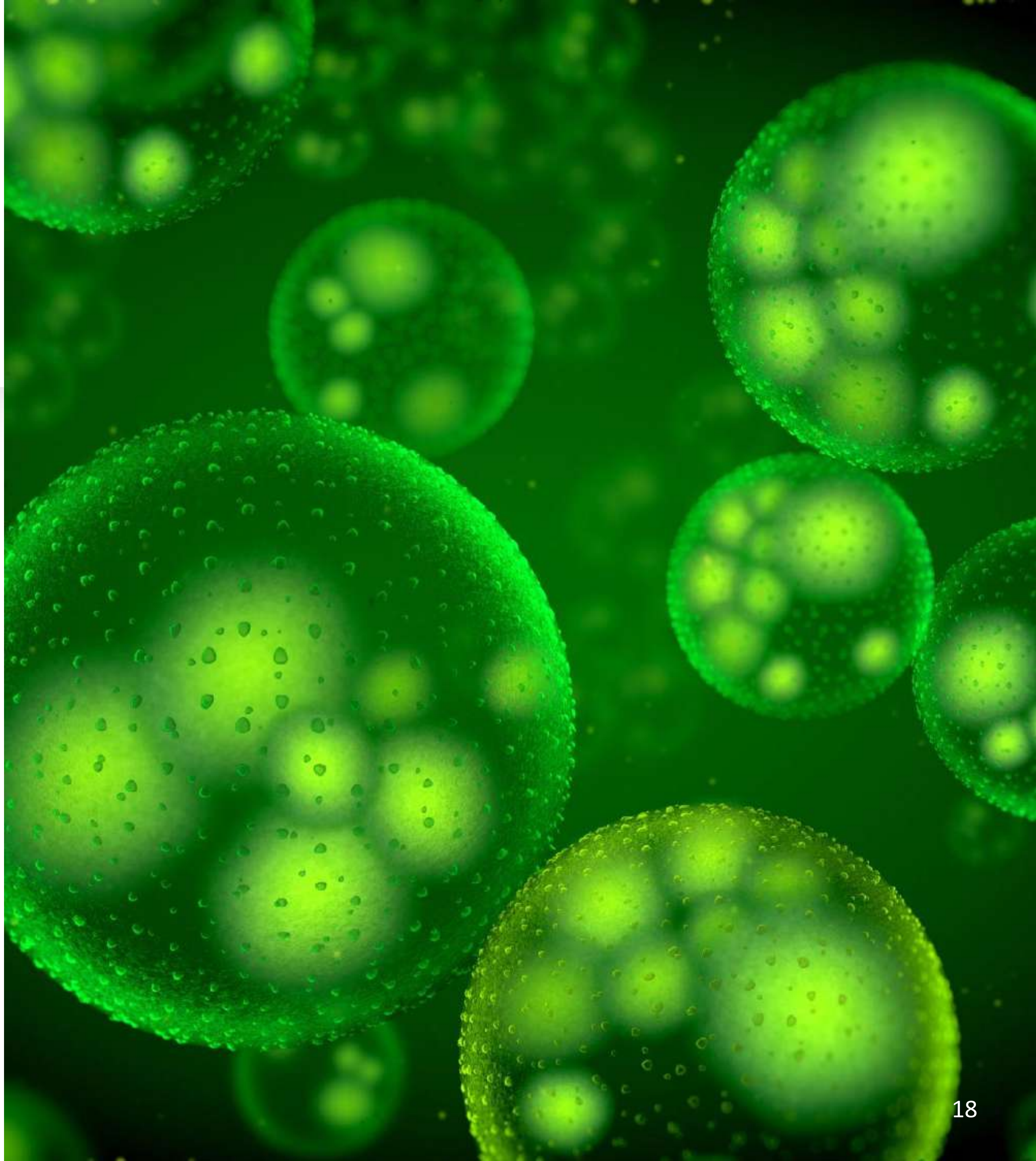
Stress species	Duration of primed state[a]	Output	Associated molecular components	References
Heat				
Arabidopsis thaliana	3 d	AT	HSA32, HSFA2, ROF1 (FKBP62), HSP101, *miR156s*, HSP21, FtsH6, BRU1, HLP1, JMJs	Charng et al. (2006, 2007); Meiri and Breiman (2009); Wu et al. (2013); Stief et al. (2014); Sedaghatmehr et al. (2016); Brzezinka et al. (2016); Sharma et al. (2019); Yamaguchi et al. (2021)
	3 d	*HSA32:Hsa32-LUCIFERASE* reporter activity and AT	FGT1, FGT2, and FGT3 (HSFA3)	Brzezinka et al. (2019); Urrea Castellanos et al. (2020); Friedrich et al. (2021)
	6 d	TM	HSFA2	Liu et al. (2018)
	5 min	Calcium concentration		Lenzoni and Knight (2019)
Oryza sativa	2 d	AT	HSA32 and HSP101	Lin et al. (2014)
Cold/freezing				
Arabidopsis thaliana			tAPX, AOS, and OPR3	Zarka et al. (2003)
	8–24 h	TM of *CBFs*		Zuther et al. (2019); Leuendorf et al. (2020); Bittner et al. (2021)
	3–7 d	AT		
Brachypodium distachyon	9 d	TM		Mayer and Charron (2021)
Cucumis sativus	2 d	AT	RBOH	Di et al. (2022)
Dehydration/drought				
Arabidopsis thaliana	5 d	TM	MYC2, SnRK2.2, SnRK2.3, SnRK2.6, DDE2/AOS, and COI1	Ding et al. (2012, 2014); Liu et al. (2014); Virlouvet et al. (2014); Virlouvet and Fromm (2015); Liu et al. (2016)
Alopecurus pratensis	3 weeks	AT	POX and SOD	Lukić et al. (2020)
Boea hygrometrica	13 weeks	AT and TM	DNA methylation	Sun et al. (2021)
Salt				
Arabidopsis thaliana	10 d	AT and TM	HKT1	Sani et al. (2013)
	5 d	Proline accumulation and TM		Feng et al. (2016)
	3 d	AT and TM	bZIP17 and HRD3A	Tian et al. (2019)
Lolium perenne	46 h	AT		Hu et al. (2016)
Populus alba × *P. glandulosa*	3 d	AT and TM		Liu et al. (2019a)
Oryza sativa	45 d	AT and TM		do Amaral et al. (2020a, 2020b)
Light/UV				
Arabidopsis thaliana	1 d	TM		Crisp et al. (2017)
	1 d	Acquired UV-C tolerance	PsbS	Gorecka et al. (2020)
	3 d	Acquired UV-B tolerance	UVR8	Xiong et al. (2021)
Mechanical loading				
Mimosa pudica	28 d	Leaf-folding habituation		Gagliano et al. (2014)
Populus tremula × *P. alba*	1 d	TM		Pomiès et al. (2017)

[a]The duration of the primed state was determined by measuring the length of the recovery period between priming and triggering, as indicated in Figure 1.
AT, acquired tolerance; TM, transcriptional memory.

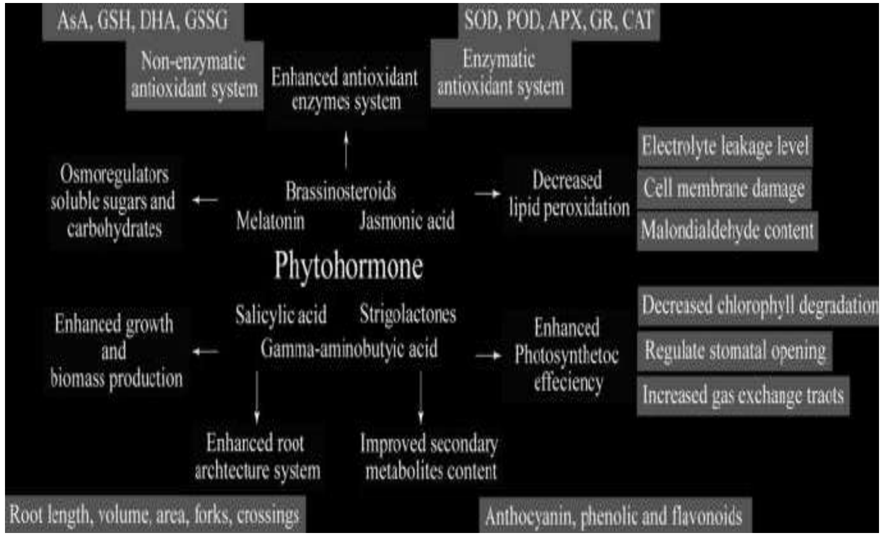
Yy. Charng; S. Mitra; SJ. Yu;Maintenance of abiotic stress memory in plants: Lessons learned from heat acclimation; THE PLANT CELL 2023: 35: 187–200; https://doi.org/10.1093/plcell/koac313;

What tools we have in the field?

- **Bio stimulants**: based seaweed & Microalgae, includes Phytohormones: Salicylic acid, Jasmonic acid, Brassinoesteroids, etc) & Aminoacid (Proline, Glycine betaine, Glutamic acid)
- **Biological Stress Mitigators** : Bacteria & Fungi Consortiums
- **Osmoprotectors** (Kaolin, SiO2 (silicon)
- **Protective films** (UV block) & **textiles** (shade nets): Nanoparticles UV and IF light blockers, radiation reduction
- **Evaporative cooling irrigation**: misters, micro sprinklers (evaporative cooling)



Phytohormones

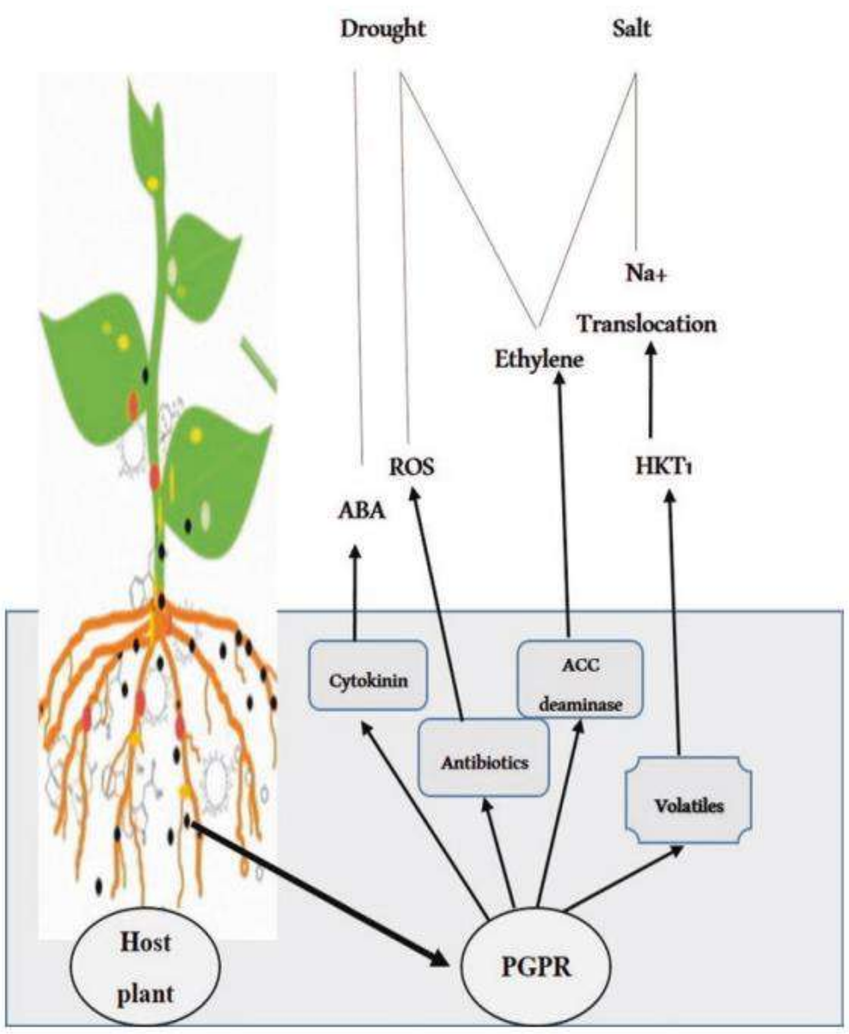


Brassinosteroids	Tomato	Salinity	I, II, III, IV, X	Ahanger et al., 2020
Salicylic acid	Colver	Aluminum	I, IV, V, VI,	Bortolin et al., 2020
Jasmonic acid	Citrus	Cold	IV, V, VI,	Habibi et al., 2019
Melatonin	Tomato	Acid rain	I, II, IV, V, VIII	Debnath et al., 2018
Strigolactones	Pea	Cold	I, III, VIII	Cooper et al., 2018
GABA	Melon	Saline-alkaline	I, IV, V	Xiang et al., 2016
Salicylic acid	Eggplant	Cold	IV, V, VIII,	Chen et al., 2011
Jasmonic acid	Pepper	Waterlogging	III, V, VI, VIII,	Ouli-Jun et al., 2017
Melatonin	Apple	Drought	I, II, VIII, XI	Liang et al., 2018
GABA	Peach	Cold	IV, V, V,	Yang et al., 2011
Brassinosteroids	Tomato	Nickel	I, II, V, VI, IX	Nazir et al., 2019
Salicylic acid	Peppermint	Cadmium	I, II, VIII, IX,	Ahmad et al., 2018
Strigolactones	Tomato	Drought	I, II, III,	Visentin et al., 2016
Jasmonic acid	Pea	Heat	I, IV, V,	Shahzad et al., 2015
Melatonin	Loquat	Drought	III, IV,	Wang et al., 2021
Salicylic acid	Okra	Cold	IV, V	Bahadoori et al., 2016
Strigolactones	Grapevine	drought	I, II, III, IV, V,	Min et al., 2019

Zheng Y, Wang X, Cui X, Wang K, Wang Y and He Y (2023) Phytohormones regulate the abiotic stress: An overview of physiological, biochemical, and molecular responses in horticultural crops. Front. Plant Sci. 13:1095363. doi: 10.3389/fpls.2022.1095363

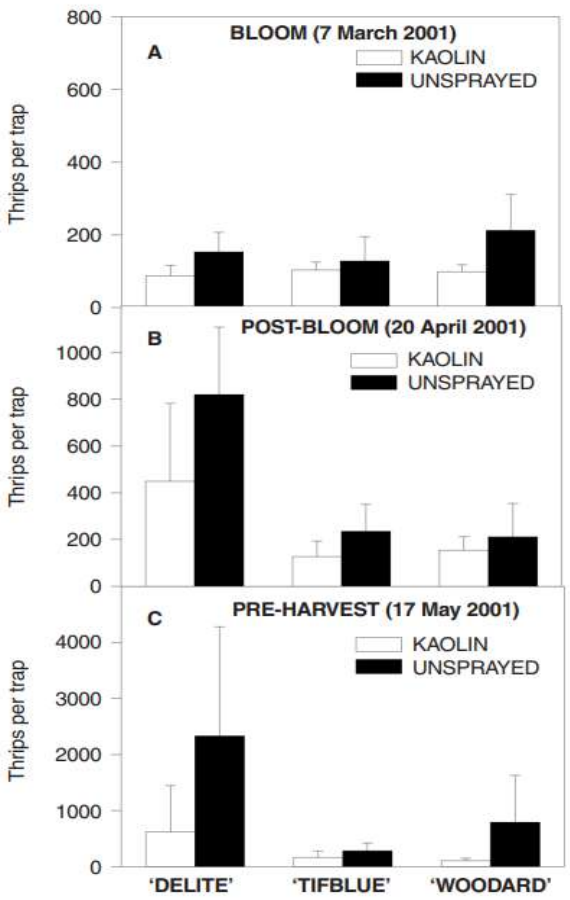
Biological Stress mitigadors

PGPRs	Crop plant	Effect	References
Achromobacter piechaudii	Tomato	Reduced levels of ethylene and improved plant growth	Mayak et al. (2004)
Azospirillum sp.	Maize	Restricted Na^+ uptake and increased K^+ and Ca^{2+} uptake along with increased nitrate reductase and nitrogenase activity	Hamdia et al. (2004)
Pseudomonas syringae, P. fluorescens, Enterobacter aerogenes	Maize	ACC deaminase activity	Nadeem et al. (2007)
P. mendocina	Lettuce	ACC deaminase activity and enhanced uptake of essential nutrients	Kohler et al. (2010)
P. pseudoalcaligenes, Bacillus pumilus	Rice	Increased concentration of glycine betaine (compatible solute)	Jha et al. (2013)
P. putida	Cotton	Increase the absorption of the Mg^{2+}, K^+ and Ca^{2+} and decrease the uptake of the Na^+ from the soil	Yao et al. (2010)
P. putida, E. cloacae, Serratia ficaria and *P. fluorescens*	Wheat	Enhanced germination percentage, germination rate, and index and improved the nutrient status of the wheat plants	Nadeem et al. (2013)
Acinetobacter spp. and *Pseudomonas* sp.	Barley and Oats	Production of ACC deaminase and IAA	Chang et al. (2014)
Rhizobium sp. and *Pseudomonas* sp.	Mung bean	IAA production and ACC deaminase activity	Ahmad et al. (2013)



Panhwar, Qurban & Naher, Umme & Depar, Nizamuddin & Memon, Muhammad & Ali, Amanat. (2019). Salt Stress, Microbes, and Plant Inter Vol.2 Chapter12.

Osmoprotectors



Treatment	Number of flowers/bud	Floral bud development[z] rating	Berries/bud[y]		Berries/bud[x]	
			Number	Size (mm)	Number	Size (mm)
Spray	5.72 a[w]	6.30 b	5.36 a	1.03 b	3.45 a	1.61 b
No Spray	4.86 b	6.45 a	4.44 b	1.07 a	1.90 b	1.70 a

[z] Floral bud development scales from Spiers, 1978, 10 days after kaolin treatment.
[y] Unharvested berries on bush, 17 April 2001.
[x] Harvested berries, 30 May 2001.
[w] Means separation within columns at $P \leq 0.05$ level.

- Application of **kaolin clay particle film at pre-fruit (50% bloom) can provide benefits** to blueberry plants.
- **Yield enhancement can be obtained without any significant residue on the berries** when applied before fruit set.
- **Kaolin clay can be used to increase fruit set without affecting fruit quality**.
- The application **of kaolin can promote growth of blueberry plants without affecting pollination**

- **Kaolin applications reduced the number of adult flower thrips** (secondary action)
- The efficacy of kaolin **increased as adult thrips became more numerous**.

Spiers, J. D., Matta, F. B., Marshall, D. A., & Sampson, B. J. (2004). Effects of Kaolin Clay Application on Flower Bud Development, Fruit Quality and Yield, and Flower Thrips [Frankliniella spp. (Thysanoptera: Thripidae)] Populations of Blueberry Plants. Small Fruits Review, 3(3–4), 361–373. https://doi.org/10.1300/J301v03n03_13

Protective films & Textiles


Morocco


Egypt


South Africa


India


Egypt

Evaporative cooling

- Through **evaporative cooling, plant transpiration brings down the temperature of leaves,** the largest plant organ.
- **Water balance in plants is also maintained** by transpiration.

How we can impact with these tools?

- Medium to long term impact: New strategies for improving crop resilience (**Stress memory, stress priming preparedness, pre-exposing crops to eliciting factors at early developmental stages, epigenetic variation across many generations, breeding priorities for thermotolerance). (See Primesoft project in Europe).**

- Short to Medium-term impact: **Start using real climate data and predictive models to evaluate risk on our investments and choose best technology to assist on the farm level** (Data analysis) to see where we are now and where we can be in the next 30 to 50 years with the berry farm development.

- Short to Medium-term impact: **Use sensors and sensoring monitoring/management systems** that allows to record and **learn in which condition we have a stress event in order to take an action/decision before it happens.**

- Medium to long term impact: We need to have **more applied research in Morocco** to learn more about the use of these tools mentions above. (See the case of Washington State and Oregon University project **"Beat the Heat")**

- Short to medium term impact: Small research is done in berries with the **impact of bio stimulation and their priming effect on stress alleviation**. Bio stress suppressors needs also to be analyzed as an alternative

- We need these supplying **companies of bio stimulants doing more hands-on approach (in situ R&D)** together with stakeholders and growers.

- Short to medium term impact: More **tests must be done with the new fabrics and plastics to see their impact on the berry crops**. These requires a better evaluation of choice of plastics and shading cloths.

- Medium to long term impact: **Improve exchange of information and effectiveness on these solutions among the industry** to create pathways of better decisions of management

Thank you for your attention!

Questions?