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MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

UV interactive effects: cross-talk x cross-tolerance

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Tato akce se koná v rámci projektu:
Vybudování vědeckého týmu environmentální metabolomiky a ekofyziologie a jeho zapojení do mezinárodních sítí (ENVIMET; r.č. **CZ.1.07/2.3.00/20.0246**) realizovaného v rámci Operačního programu Vzdělávání pro konkurenceschopnost.

Cross-tolerance – what does it mean?

- Wikipedia – human physiology / pharmacology

- „Cross-tolerance is a phenomenon that occurs when someone who is tolerant to the effects of a certain drug also develops a tolerance to another drug. It often happens between two drugs with similar functions or effects – for example, acting on the same cell receptor or affecting the transmission of certain neurotransmitters."

Cross-talk x cross-tolerance in plants

- Multiple stressors, both abiotic and biotic, often are experienced simultaneously by organisms in nature. Responses to these stressors may share signaling pathways ("cross-talk") or protective mechanisms ("cross-tolerance").
- review papers
  - Knight H and Knight MR (2001) Trends Plant Sci 6: 262-267.
  - Sinclair BJ et al. (2013) Integrative and Comparative Biology 53: 545-556.
- **terminology is not consistent!**

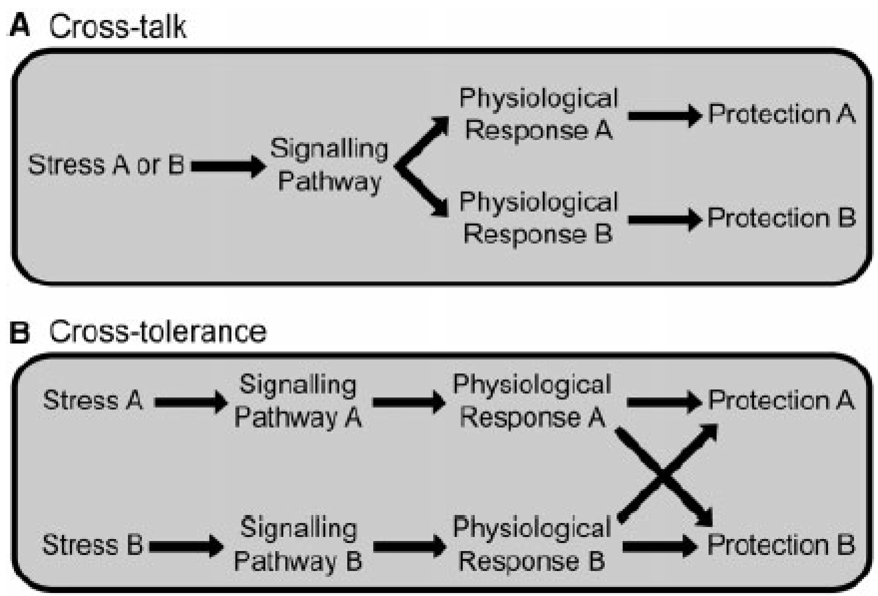


Fig. 1 Two different mechanisms underlying coordinated physiological responses to environmental stress. (**A**) Cross-talk, whereby a stress activates signaling pathways that lead to responses that protect against several different stressors using different mechanisms at the cellular level. (**B**) Cross-tolerance, whereby independent activation of pathways leads to physiological responses that offer overlapping protection at the cellular

BJ Sinclair et al. (2013)

- whether cross-talk or cross-tolerance underlie the response depends on the relationship among multiple stressors

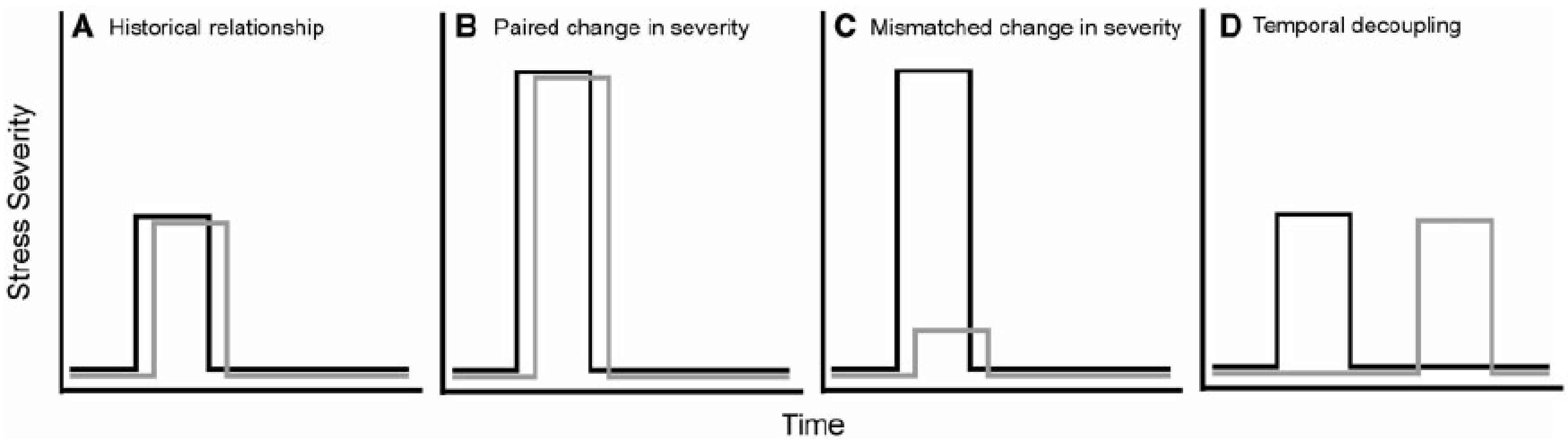


Fig. 3 Three exemplar scenarios of changes in interacting stressors. (**A**) The current timing and magnitude of the two stressors. (**B**) No change in timing, but an increase in the severity of both stressors (e.g., acidification and warming in marine systems). (**C**) No change in timing, but an increase in the severity of one stressor and a decrease in the other (e.g., reduced extreme cold stress is coupled with increased energetic demands in overwintering insects). (**D**) Severity of stresses remains the same, but there is a shift in the timing of one of the stressors (e.g., changing precipitation patterns could lead to increased cold stress in autumn, but increased energetic stress in spring for overwintering insects).

UV and cross-tolerance

- only 2 review-papers found
- Gang Wu et al. (2007) Insights into molecular mechanisms of mutual effect between plants and the environment. A review. *Agron. Sustain. Dev.* 27, 69-78.
- Hanna Bandurska et al. (2013) Separate and combined responses to water deficit and UV-B radiation. *Plant Science* 213, 98-105.

Bandurska et al. (2013) - #1

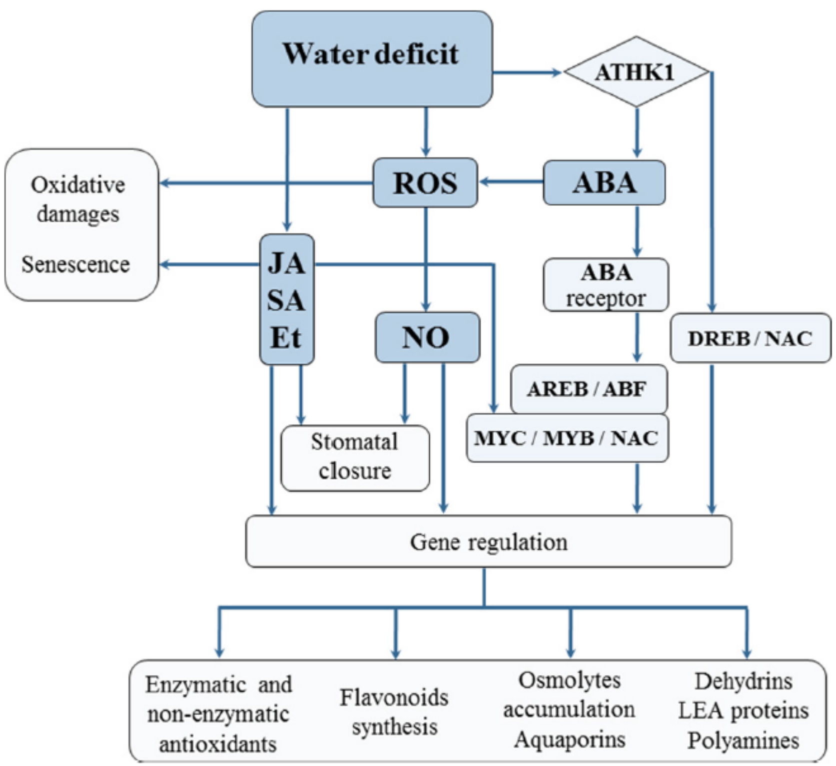
- water deficit x UV-B
- unique and joint responses to water deficit and UV-B radiation

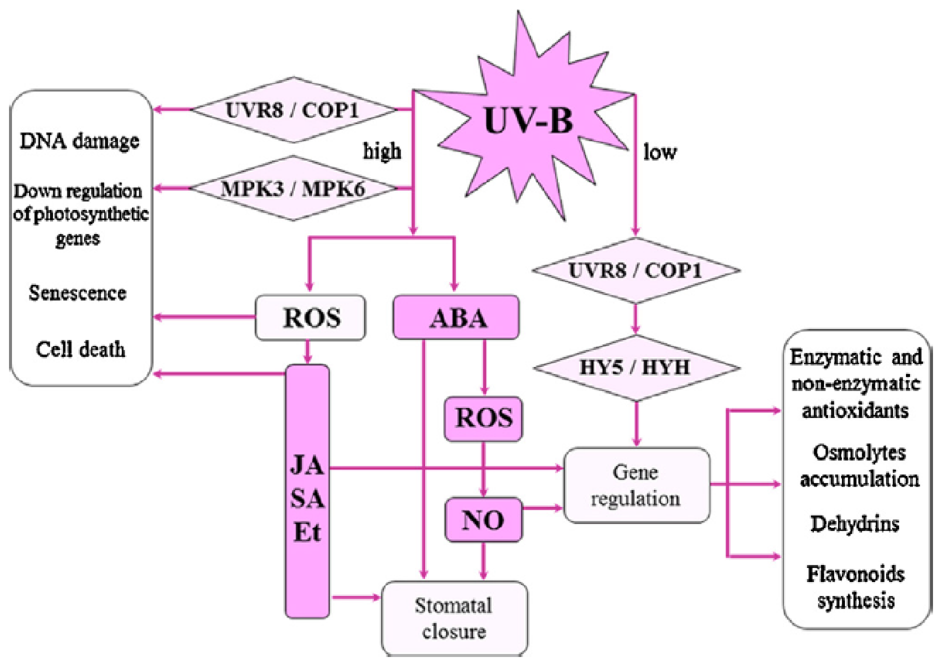
Table 1
Unique and joint responses to water deficit and UV-B radiation.

Stress	Responses	References
Unique to water deficit	Reduction of leaf water content, inhibition of photosynthetic activity, growth inhibition, reduced biomass accumulation	[4–10]
	Reduction of leaf water content, growth inhibition, ABA accumulation	[11–13][13]
Unique to UV-B	Increase in cuticle thickness, lower rate of transpiration	[6]
	Increased carotenoids levels, accumulation of UV-B absorbing compounds, growth inhibition	[10]
	Accumulation of UV-B absorbing compounds, increase of ascorbate oxidase activity	[7,13]
	Growth inhibition	[8,11–13]
	Slight decrease in photosynthetic activity and growth	[9]
Joint to both	UV-B alleviates adverse effect of drought on leaf hydration, photosynthetic rate and biomass accumulation	[4–6,10]
	Additive or synergistic effect on growth inhibition	[11–13]
	No significant effect on water relation, photosynthetic activity and biomass accumulation in relation to single stress	[7–9]
	UV-B does not aggravate the negative effect of effect drought and vice versa	

Bandurska et al. (2013) - #2

- simplified models of signaling pathways in plant response (separately)





Bandurska et al. (2013) - #3

- proposed model of cross-talk

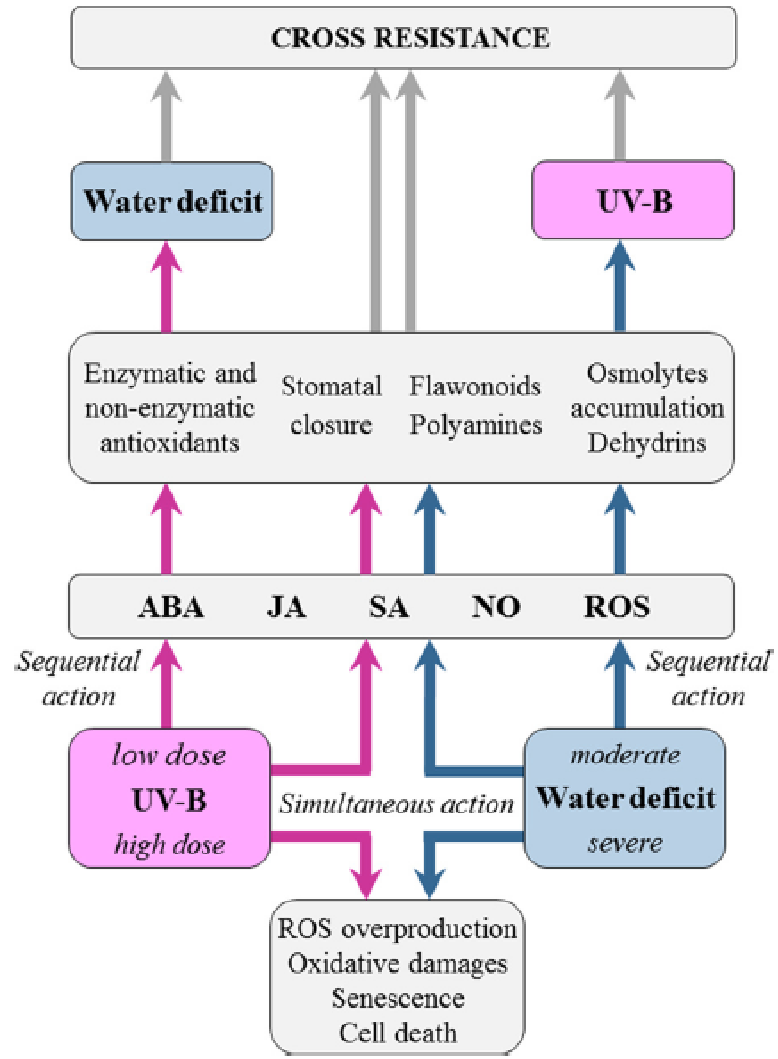


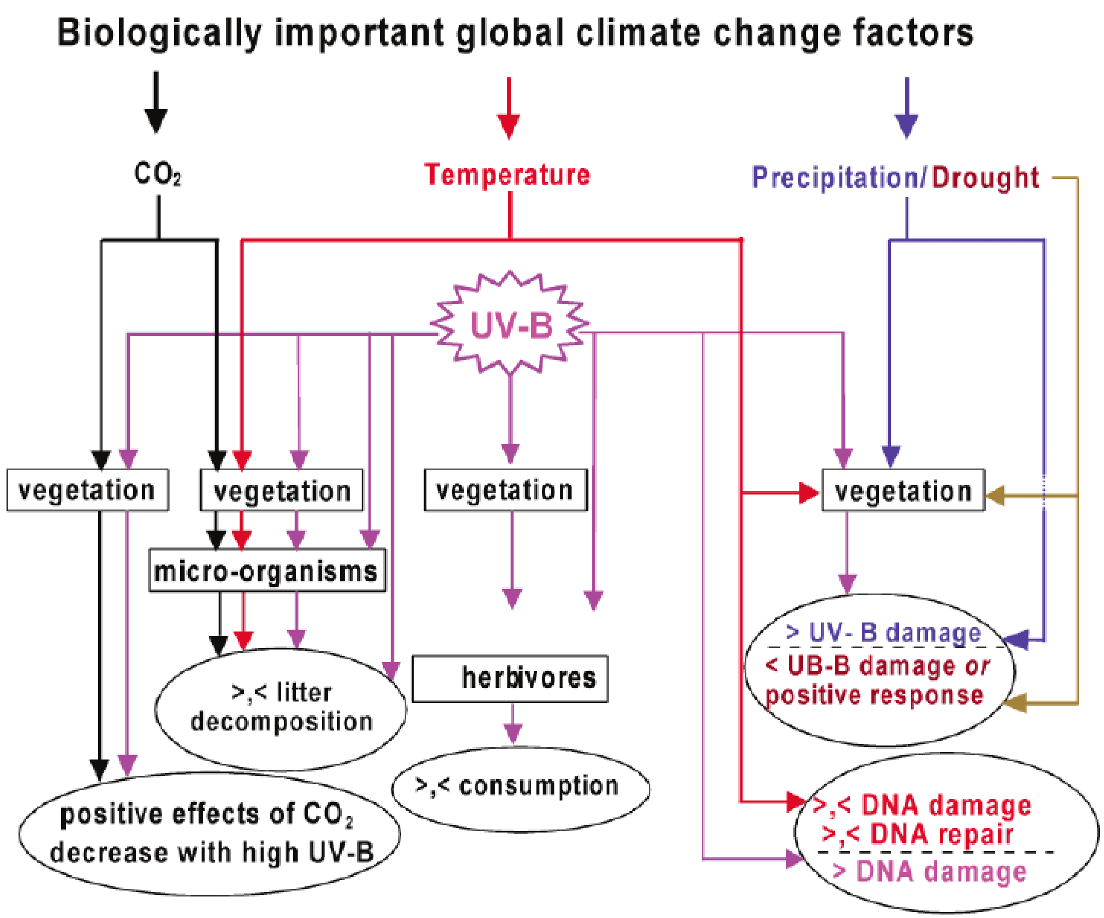
Fig. 3. A proposed model of cross-talk in plant responses to combined action of water deficit and UV-B radiation. Abbreviations: ABA, abscisic acid; Et, ethylene; JA, jasmonic acid; SA, salicylic acid, ROS, reactive oxygen species, NO, nitric oxide.

Review papers by Carlos Ballaré

- UV interactions with climate change factors
- 2 review papers
  - Martyn Caldwell et al. (2003) Photochemical and Photobiological Sciences 2, 29-38.
    - terrestrial ecosystems, increased solar ultraviolet radiation and interactions with other climate change factors
  - C. Ballaré et al. (2011) PPS 10, 226-241.
    - effects of solar ultraviolet radiation on terrestrial ecosystems. Patterns, mechanisms, and interactions with climate change

MM Caldwell et al. (2001) - #1

- major interactions of elevated UV-B with other climate change factors



  - *different trophic levels (in rectangles)*
  - *processes (in ovals)*

MM Caldwell et al. (2001) - #2

- UV-B effect on insect herbivory

Table 1 Effects of UV-B radiation on insect herbivory

Insect	Type of expt.[a]	Plant species	UV-B effect on herbivory/insects	Possible mechanism[e]	Study
Caliothrips phaseoli (thrips)	E	*Glycine max* (soybean)	Less herbivory[33]	Direct response of insects to solar UV-B	34
Diabrotica speciosa (leaf beetle), lepidopteran larvae, grasshoppers	E	*Glycine max* (soybean)	Less herbivory		35
Anticarsia gemmatilis (moth larva)	E[b]	*Glycine max* (soybean)	Slower growth, higher mortality	Indirect effect. (NC)[e] Increased phenolics but decreased lignin	
Schistocera gregaria (desert locust)	F[b]	*Lolium perenne, Festuca rubra, F. arundinaceae, F. pratensis*	No response in 3 species; in *Festuca pratensis*, preference for endophyte-infected plants changed	Indirect effect. (C)[e] Loline content changed, but this did not influence herbivory	36
Various chewing insects (not identified)	E	*Gunnera magellanica* (devil's strawberry)	Less herbivory	Not known	37
Spodoptera litura, Graphania mutans (moth larva)	C	*Trifolium repens* (white clover)	Tendency toward slight reduction in herbivory	Indirect effect. (NC) Slight N increase, larger carbohydrate decrease, population-specific changes in cyanogenesis	38
Epirrita antumnata (moth larva)	F	*Betula pubescens* (mountain birch)	More herbivory	Mechanism not known. (NC) Laboratory study indicated direct UV-B preference	39
Precis coenia, Trichoplusia ni (both lepidopteran larvae)	G	*Plantago lanceolata* (English plantain)	*Precis*—no effect *Trichoplusia*—more growth from eating treated material but direct UV-B growth inhibition	Direct inhibitory effect of UV-B on insect growth; indirect effects. (NC) Reduced crown and reproductive growth; some increase in leaf N and verbascosides	40
Various chewing insects (not identified)	F	*Quercus robur* (pedunculate oak)	No UV-B effect[c]		41
Caliothrips phaseoli (thrips)	E	*Glycine max* (soybean)	Less herbivory	Indirect effect (C) and direct UV-B avoidance	33,34
Lepidoptera: Noctuidae (moth larva)	E	*Gunnera magellanica* (devil's strawberry)	Less herbivory	Indirect effect. (C) Increase in leaf N	42
Strophingia ericae (psyllid)	F	*Calluna vulgaris* (heather)	Reduced insect populations	Not known. Reduced amino acid isoleucine	43
Operophtera brumata (moth larva)	G	*Betula pendula* (silver birch)	More herbivory	Indirect effect. (C) Leaf flavonoids increased, but flavonoids added to an artificial diet did not increase feeding.	44
Insects not identified	F	*Vaccinium myrtillus, V. uliginosum, V. vitis-idaea* (heathland shrubs)	More herbivory in *V. myrtillus*, less in *V. uliginosum*, no effect in *V. vitis-idaea*	Mechanism not known	45,46
Pieris rapae, (butterfly larva) *Trichoplusia ni* (moth larva)	C	*Arabidopsis thaliana*	*Pieris*: less herbivory and less insect weight gain	Indirect effect. (NC) Leaf flavonoids increased	47
Coleoptera (leaf beetles)	E	*Datura ferox* (summer annual)	Less herbivory	Indirect effect. (C) Mechanism not known	48
Acronicta, Nycteola, Orthosia, Ptiloden (moth larva)	F	*Quercus robur* (pedunculate oak)	No specific UV-B effect[c]		49
Autographa gamma (moth larva)	C	*Pisum sativum* (pea)	Less herbivory, but greater insect growth	Indirect effect. (NC) Higher phenolic and N contents	50
Ostrinia nubilalis (European corn borer)	E[d]	*Zea mays* (corn)	Less herbivory	Indirect effect. (NC) More cell-wall-bound truxillic and truxinic acids	51[b]
Trichoplusia ni (moth larva)	G	*Citrus jambhiri* (rough lemon)	Decrease in survivorship and growth	UV-B increased furanocoumarin levels	52

[a] C = controlled environment chamber, G = greenhouse, F = field UV-B supplement from lamps, E = field UV-B exclusion. [b] Field-treated material used in laboratory feeding trials. [c] More herbivory under UV-A and UV-B lamps compared to controls, but no specific UV-B effect. [d] UV-A and UV-B responses cannot be separated. [e] "Indirect effect" implies that an UV-B effect mediated by changes in the plant was demonstrated in a bioassay, even if the nature of the changes was not identified. (C), "choice" bioassay, (NC) "no choice" bioassay.

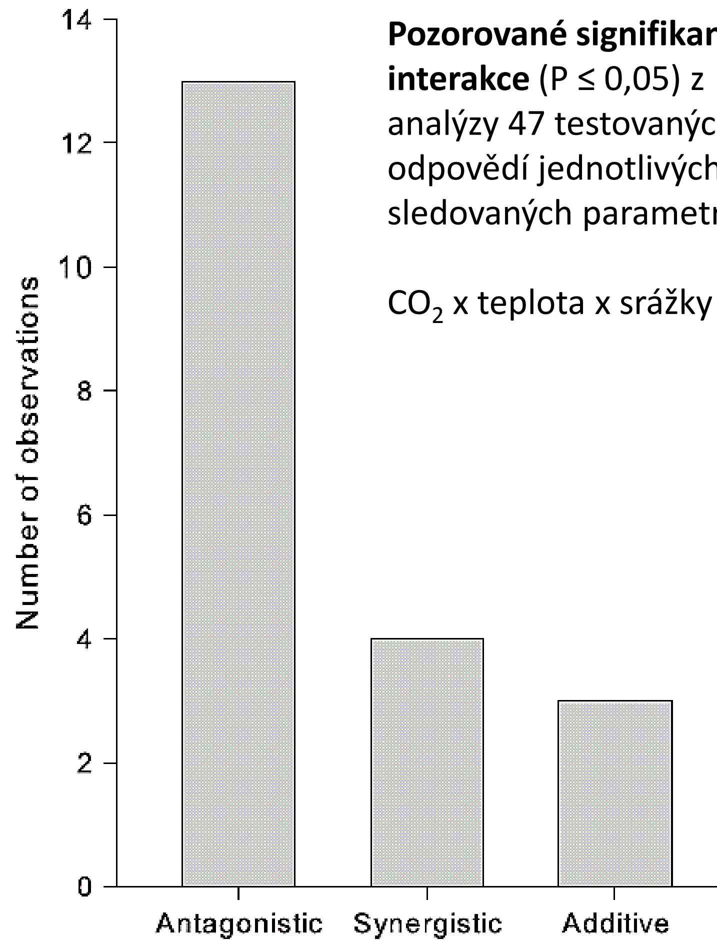
CL Ballaré et al. (2011)

- brief summary of interactions with other climate change factors
  - UV + precipitation
  - UV + CO_2 + temperature
  - UV + Nitrogen level

- there is little evidence of consistent interactive effects
- effects tended to be species-specific

Interaction of stressors

- **antagonistic effect**
  - mutual combination of stressors leads to the reduction of plant response
- **synergistic effect**
  - combination of stressors lead to the amplification of stress response or the response is observed only under the multiple-stress condition
- **additive effect**
  - two individual stressors with significant effect do not have significant interaction



Pozorované signifikantní interakce ($P \leq 0{,}05$) z analýzy 47 testovaných odpovědí jednotlivých sledovaných parametrů

CO_2 x teplota x srážky

Larsen et al. 2011 Global Change Biology

Graphical summarization

- how many case studies was already done
- what type of interaction prevails

- UV x CO2
- UV x drought
- UV x temperature
- UV x mineral (nitrogen) supply
- UV x photooxidative stress (high radiation stress)
- UV x biotic stress

Potential difficulties or Sources of variability in results

- hierarchical levels
  - is the interaction same at different hierarchical level (e.g. flavonoid accumulation x morphogenesis) ?

- different time scales
  - short- versus long-term effects

- species-specific effects
  - plant functional groups

WoS search

- (UV OR ultraviolet radiation) AND plant* AND (cross*talk OR cross*tolerance)

- about 45 findings
- 21 are relevant