Sustainable Adaptation of Fruit Tree Production to Episodic Drought (FruitAdapt)

Antonios Petridis, Tenure Track
Dept. of Food Science

Kernefrugt Tematag
January 29, 2025

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Dept. of Food Science

Dept. of Agroecology (Assoc. Prof. Sabine Ravnskov)

Start date: 16 September 2024
End date: 31 August 2028

Ørskovs Frugtplantage

Varbjerggård Kim Nielsen

Planteskole Vester Skovgård

Project background

- Fruit trees require a **significant amount of water** to obtain high yields and to produce high-quality fruits
- Adequate water amount is important for both mature and young trees
- Yield losses due to drought can reach **up to 30%**

Project background

- Predictions (and recent experiences) indicate an increase in frequency, duration, and severity of drought episodes
- Irrigation is expensive and not sustainable in the long term
- A new approach is needed (cultivar and rootstock tolerance, biostimulants, mycorrhiza, compost)

Mitigate the adverse effects of drought on fruit tree production

O1. To select **resistant cultivars and rootstocks** that enable plants to maintain high yield and fruit quality following drought episodes

O2. To **develop management practices** that enhance drought tolerance and/or alleviate stress levels from fruit trees.

WP1. Apple cultivars and rootstocks with higher drought tolerance

- Drought tolerance depends on the **cultivar** and the **rootstock** on which they are grafted
- Only few cultivars and rootstocks have been tested so far

WP1. Apple cultivars and rootstocks with higher drought tolerance

Journal of Horticultural Science (1991) **66** (3) 367–379

Water relations and cropping of apple cultivars on a dwarfing rootstock in response to imposed drought

By K. H. HIGGS[1] and H. G. JONES[2]
[1]Horticulture Research International, East Malling, Maidstone, Kent ME19 6BJ, UK
[2]Horticulture Research International, Wellesbourne, Warwick CV35 9EF, UK

- Drought responses of **15 cultivars** for **3 years**
- Two treatments: **Irrigation** and **drought** (polythene covers)
- **Stem cross-sectional area** reduced by **37%** in drought treatment (average of 15 cultivars over 3 years)
- **Yield** decreased by **18%** in the 3 main cultivars and by **26%** in the 12 subsidiary cultivars (average over 3 years)

WP1. Apple cultivars and rootstocks with higher drought tolerance

plants

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Article

Comparative Study of Drought Stress Effects on Traditional and Modern Apple Cultivars

Ines Mihaljević *, Marija Viljevac Vuletić, Domagoj Šimić, Vesna Tomaš, Daniela Horvat, Marko Josipović, Zvonimir Zdunić, Krunoslav Dugalić and Dominik Vuković

Agricultural Institute Osijek, Južno predgrađe 17, HR-31000 Osijek, Croatia; marija.viljevac@poljinos.hr (M.V.V.); domagoj.simic@poljinos.hr (D.Š.); vesna.tomas@poljinos.hr (V.T.); daniela.horvat@poljinos.hr (D.H.); marko.josipovic@poljinos.hr (M.J.); zvonimir.zdunic@poljinos.hr (Z.Z.); krunoslav.dugalic@poljinos.hr (K.D.); dominik.vukovic@poljinos.hr (D.V.)
* Correspondence: ines.mihaljevic@poljinos.hr

Journal of Plant Physiology 162 (2005) 1308–1318

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JOURNAL OF PLANT PHYSIOLOGY

www.elsevier.de/jplph

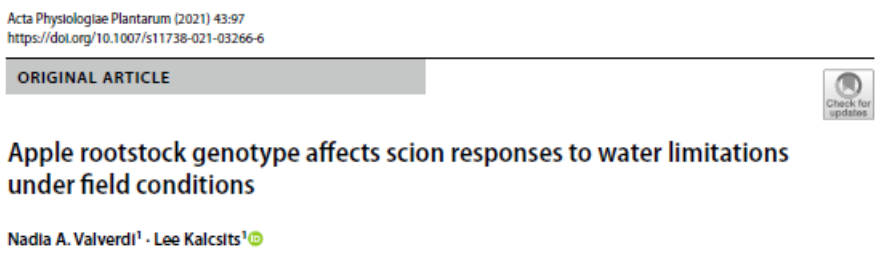
Biochemical responses in leaves of two apple tree cultivars subjected to progressing drought

Helena Šircelj[a,*], Michael Tausz[b,c], Dieter Grill[b], Franc Batič[a]

[a]Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, Ljubljana SI-1000, Slovenia
[b]Institute of Plant Physiology, Karl-Franzens University Graz, Schubertstraße 51, Graz A-8010, Austria
[c]Forest Science Centre, Department of Sustainability and Environment & University of Melbourne, Water Street, Creswick, Victoria 3363, Australia

- Drought responses of **2-year-old apple cultivars** grown in **pots** either in the greenhouse or outdoors
- Two treatments: **Irrigation** and **drought** (no water for up to 12 days)
- Physiological and biochemical parameters: photosynthetic responses, chlorophyll, antioxidants, osmoprotectants, etc.
- **All cultivars responded to drought stress**
- **Differences between cultivars in tolerating drought** (e.g., two traditional Croatian cultivars more tolerant than 'Golden Delicious Reinders')
- **Pot experiments, few cultivars, no information about productivity**

WP1. Apple cultivars and rootstocks with higher drought tolerance



Acta Physiologiae Plantarum (2021) 43:97
https://doi.org/10.1007/s11738-021-03266-6

ORIGINAL ARTICLE

Apple rootstock genotype affects scion responses to water limitations under field conditions

Nadia A. Valverdi[1] · Lee Kalcsits[1]

- Drought responses of **'Honeycrisp' grafted onto 'G41', 'G890', 'M9', and 'B9'** grown in **pots** either in the greenhouse (1-year-old) or outdoors (3-year-old)
- Two treatments: **Well-watered (100% Field Capacity)** and **drought (50% FC)**
- Physiological parameters: photosynthetic responses, leaf water potential, shoot growth
- No difference between rootstocks in improving 'Honeycrisp' tolerance in the glasshouse
- **But in the field: 'B9' was the most tolerant whereas 'G890' the least tolerant**

WP1. Apple cultivars and rootstocks with higher drought tolerance


Scientia Horticulturae 204 (2016) 70–78

Contents lists available at ScienceDirect

Scientia Horticulturae

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

Apple rootstock resistance to drought

Thomas Tworkoski[a,*], Gennaro Fazio[b], D. Michael Glenn[a]

[a] Appalachian Fruit Research Station, ARS, USDA, Kearneysville, WV, USA
[b] Plant Genetics Resources Unit, ARS, USDA, Cornell University, Geneva, NY, USA

- Drought responses of **'Gala' and 'Fuji' grafted onto 'M9' and 'MM111'** grown in **pots** in the greenhouse (2-year-old)
- Two treatments: **Well-watered** and **drought (water withheld for 1 (2014) or 3 weeks (2015))**
- Physiological parameters: photosynthetic responses, leaf water potential, dry weight distribution across organs
- The two rootstocks were equally good in controlling drought stress responses of both cultivars, but used different mechanisms ('M9'-ABA; 'MM111'-extensive root system)

WP1. Apple cultivars and rootstocks with higher drought tolerance

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Apple rootstock resistance to drought

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[a]Appalachian Fruit Research Station, ARS, USDA, Kearneysville, WV, USA
[b]Plant Genetics Resources Unit, ARS, USDA, Cornell University, Geneva, NY, USA

Conclusions from literature review

- Cultivars and rootstocks can differ in their ability to tolerate drought
- **Many research gaps**

- Limited number of cultivars and rootstocks tested (often not relevant for Denmark)
- Only few studies in the field with trees growing under soils conditions
- Most studies lasted for 1-2 years
- Most studies focused only on physiological responses, but not on yield (and fruit quality!)

WP1. Apple cultivars and rootstocks with higher drought tolerance

Aim: Select drought tolerant cultivars and rootstocks for Danish orchards

WP1. Apple cultivars and rootstocks with higher drought tolerance (2025-2027)

- **10 apple varieties** (Elstar, Ingrid Marie, Junami, Zari, Summer Crisp, Freya, Early Crunch, Braeburn Mariri Red, Crimson Crisp, Sweet Tango, Santana)
- **15 rootstocks** (M9, G11, G41, G16, G213, G214, B9, M26, Pi80, M7, MM106, G210, B118, G814, M9-RN29)
- Treatment: **Control** (irrigated) and **drought-treated** (3 weeks; polythene cover)
- Parameters measured: Growth, physiology (leaf water potential, photosynthetic responses), yield, fruit quality

WP2. Application of protective biostimulants to enhance drought tolerance

- Biostimulants: natural substances extracted from plants or microorganisms, which when applied to crops, enhance their growth, resource use efficiency, and resilience
- Studies on annual crops show that BS can improve drought stress tolerance
- BS are not always efficient in the field
- Limited knowledge on the use of biostimulants on temperate fruit trees in relation to drought stress

WP2. Application of protective biostimulants to enhance drought tolerance

Journal of Experimental Botany, Vol. 66, No. 3 pp. 669–680, 2015
doi:10.1093/jxb/eru476 Advance Access publication 5 December, 2014

Journal of Experimental Botany
www.jxb.oxfordjournals.org

RESEARCH PAPER

Melatonin mediates the regulation of ABA metabolism, free-radical scavenging, and stomatal behaviour in two *Malus* species under drought stress

Chao Li[1], Dun-Xian Tan[2], Dong Liang[1], Cong Chang[1], Dongfeng Jia[1] and Fengwang Ma[1,*]

[1] State Key Laboratory of Crop Stress Biology for Arid Areas, College of Horticulture, Northwest A and F University, Yangling, Shaanxi 712100, China
[2] Department of Cellular and Structural Biology, The University of Texas, Health Science Center at San Antonio, 7703 Floyd Curl, San Antonio, TX 78229, USA

- Melatonin application in two *Malus* species (*M. prunifolia* and *M. hupehensis – 2 years old*)
- Plants grown in the greenhouse in pots
- Plants were pretreated with melatonin (100 μM in nutrient solution) for 10 days, and then water was withheld for 6 days
- Measured physiological parameters (photosynthetic responses, stomata opening, chlorophyll content, electrolyte leakage, ABA)
- Melatonin treatment improved most of the physiological parameters

WP2. Application of protective biostimulants to enhance drought tolerance

Plant Growth Regul (2009) 58:131–136
DOI 10.1007/s10725-009-9361-4

BRIEF COMMUNICATION

Chitosan enhances leaf membrane stability and antioxidant enzyme activities in apple seedlings under drought stress

Feng Yang · Jingjiang Hu · Jianlong Li · Xiaoling Wu · Yurong Qian

- Chitosan (marine polysaccharide) application in 1-year-old 'Fuji' apple plants growing under well-watered and drought (21 days without water) conditions
- Plant grown in the greenhouse in pots
- Decreased electrolyte leakage and enhanced the activities of antioxidant enzymes

WP1. Apple cultivars and rootstocks with higher drought tolerance

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BRIEF COMMUNICATION

Chitosan enhances leaf membrane stability and antioxidant enzyme activities in apple seedlings under drought stress

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Conclusions from literature review

- Biostimulants can have a positive impact in protecting against drought
- **Many research gaps**
  - No long-term studies on apple trees in the field
  - Only a few compounds tested
  - Most studies focused only on physiological responses, but not on yield

WP2. Application of protective biostimulants to enhance drought tolerance

Aim: Evaluate the effect of BS on apple drought tolerance

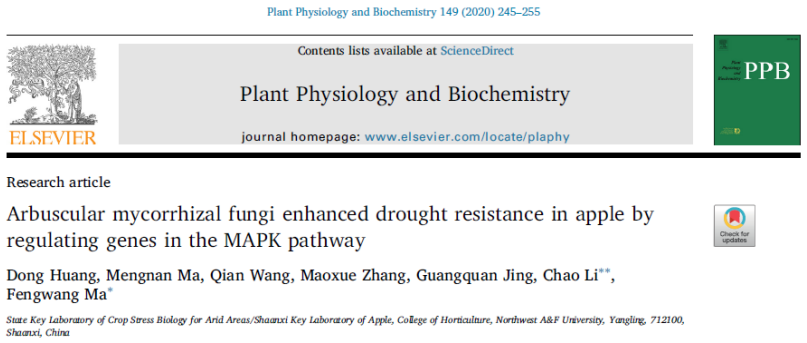
WP2. Application of protective biostimulants to enhance drought tolerance

- Compounds: **amino acids** (proline, glutamate, γ-aminobutyric acid, arginine, combination), **trehalose**, **melatonin**, **chitosan**, **kaolin**
- Trial 1 (2025): Trial in potted plants under tunnel ('Elstar', select the most efficient)
- Trial 2 (2026, 2027): Trial in the field in two developmental stages ('Elstar', 'Junami')
- Trial 3 (2027-2028): Growers' site
- Parameters measured: Physiology (photosynthetic responses, chlorophyll, leaf water potential), yield

WP3. Use of arbuscular mycorrhiza to improve apple performance to drought episodes

- Arbuscular mycorrhizal fungi form symbiotic associations with 80% of land plant species
- They **provide water and nutrients** to plants from areas that are inaccessible to them
- They can improve osmotic adjustment, protect against oxidative damage, enhance photosynthetic response, and modify root morphology and soil
- Limited knowledge on their potential to improve drought tolerance in apples

WP3. Use of arbuscular mycorrhiza to improve apple performance to drought episodes



Plant Physiology and Biochemistry 149 (2020) 245–255

Contents lists available at ScienceDirect

Plant Physiology and Biochemistry

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

Research article

Arbuscular mycorrhizal fungi enhanced drought resistance in apple by regulating genes in the MAPK pathway

Dong Huang, Mengnan Ma, Qian Wang, Maoxue Zhang, Guangquan Jing, Chao Li**, Fengwang Ma*

State Key Laboratory of Crop Stress Biology for Arid Areas/Shaanxi Key Laboratory of Apple, College of Horticulture, Northwest A&F University, Yangling, 712100, Shaanxi, China

- Chinese crab apple (*M. hupehensis*) seedlings growing in pots in the glasshouse
- Four treatments in total: **2 water treatments** (well-watered and drought (no water for 8 days) and **2 inoculation treatments** (with or without inoculation)
- Physiological, biochemical, and molecular parameters
- Enhanced growth, photosynthetic responses, chlorophyll content, osmoprotection, activity of antioxidant enzymes, and reduced electrolyte leakage

WP3. Use of arbuscular mycorrhiza to improve apple performance to drought episodes

Aim: Determine the extent to which AM improve drought stress tolerance and productivity in apples

WP3. Use of arbuscular mycorrhiza to improve apple performance to drought episodes

- Trial 1 (2025): Optimizing inoculation of apple trees at the nursery level
- Trial 2 (2026, 2027): Trial in the field at AU-Auning
- Trial 3 (2027-2028): Growers' site
- Parameters measured: Physiology (chlorophyll, chlorophyll fluorescence; AU-Auning), rootstock association with mycorrhiza, yield

WP4. Compost for a healthy soil

- Limited information on the effect of compost application on apple drought tolerance

- In one study, composted animal manure increased soil organic carbon, porosity, soil bulk density, soil water storage, soil water content, leaf water potential, and yield (up to 13%) (Li et al. 2017, Arid Land Res. Manag.)

WP4. Compost for a healthy soil

Aim: Reduce drought stress in apples via compost application

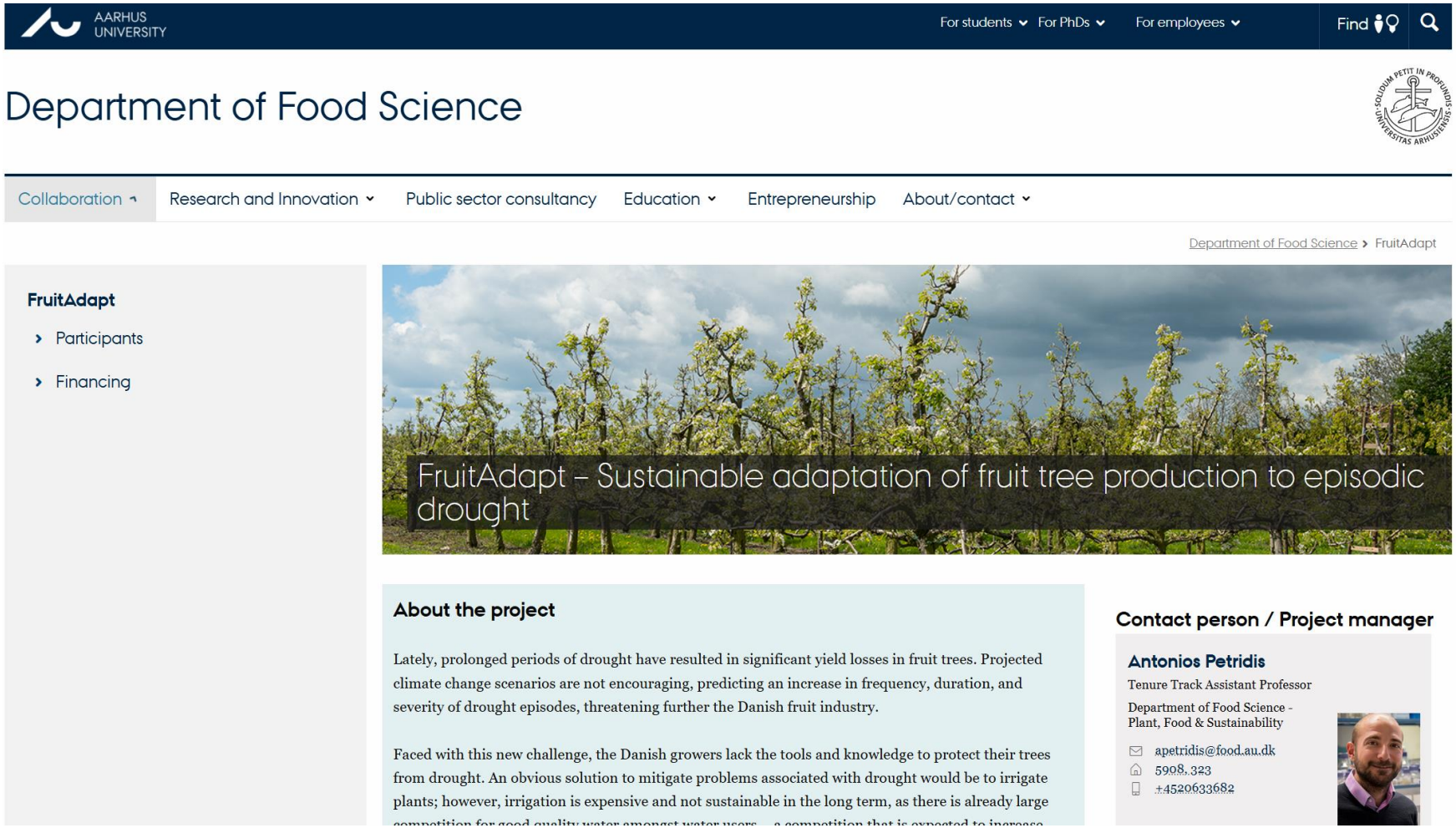
WP4. Compost for a healthy soil

- Two types of compost (1 more nutrients, 1 as soil amendment) applied at a rate of 30 tons/ha
- Measurements on the 3rd and 4th year of the project
- Parameters measured: soil properties, plant nutritional status, yield, fruit quality

General information about the project

Project's website

Link to project's website: **https://food.au.dk/fruitadapt**



Acknowledgments

AU-Auning staff

Kim Flemming Nielsen

Emil Bitsch Kobberup Lynggaard

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