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Does plant flammability vary according to terpene content throughout the year?

Anne Ganteaume, B. Romero

► **To cite this version:**

Anne Ganteaume, B. Romero. Does plant flammability vary according to terpene content throughout the year?. *Cultivating Pyrodiversity: 8th International Fire Ecology and Management Congress*, Nov 2019, Tucson, United States. pp.31. hal-02609865

HAL Id: hal-02609865

<https://hal.inrae.fr/hal-02609865v1>

Submitted on 16 May 2020

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Does plant flammability vary according to terpene content throughout the year?

Anne GANTEAUME, Bastien ROMERO

Irstea Aix en Provence; UR EMAX
Contact: anne.ganteaume@irstea.fr



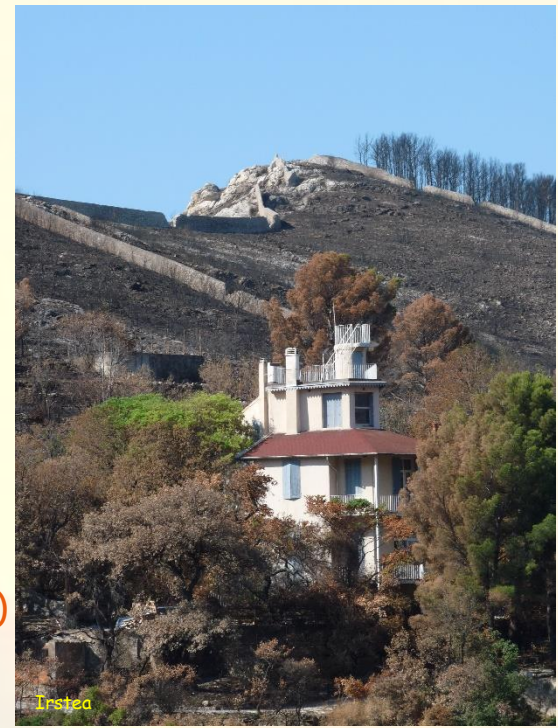
INTRODUCTION

Context

- ~60% of fires occurred in the French Mediterranean region
- Increasing WUI in SE France => Increasing fire occurrence



Fire propagation through WUI vegetation (native and exotic species)



Possible significant damage to structures



INTRODUCTION

Context

- Better understanding drivers of fuel flammability

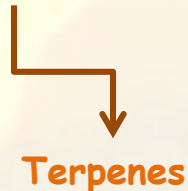
Leaf physical characteristics

- Surface area
- SVR
- SLA
- Density
- Thickness
- Mass



Leaf chemical characteristics

- FMC
- Lignin content
- Mineral content
- VOC content ?



Positive effect on flammability

Negative effect on flammability



INTRODUCTION

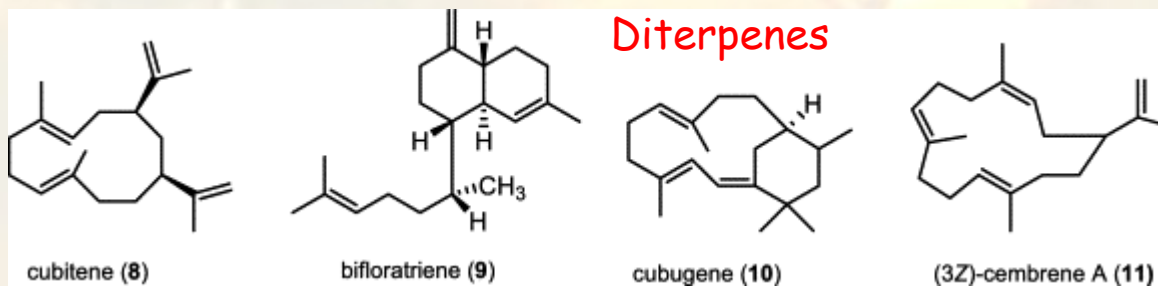
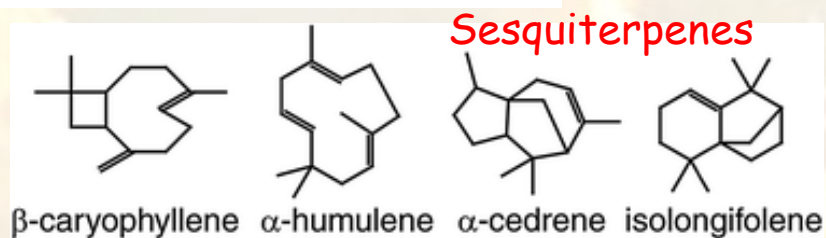
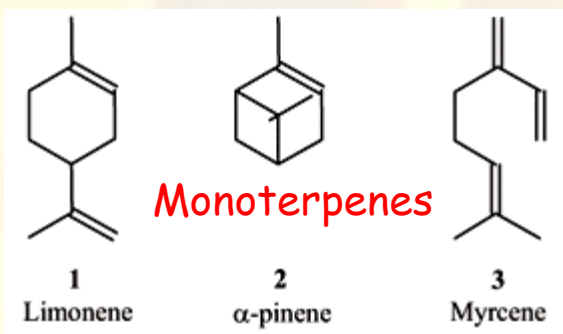
Context

➤ What do we know of terpenes ?

Produced by a large range of plants

=> Different subgroups

=> Emitted and/or stored in leaf

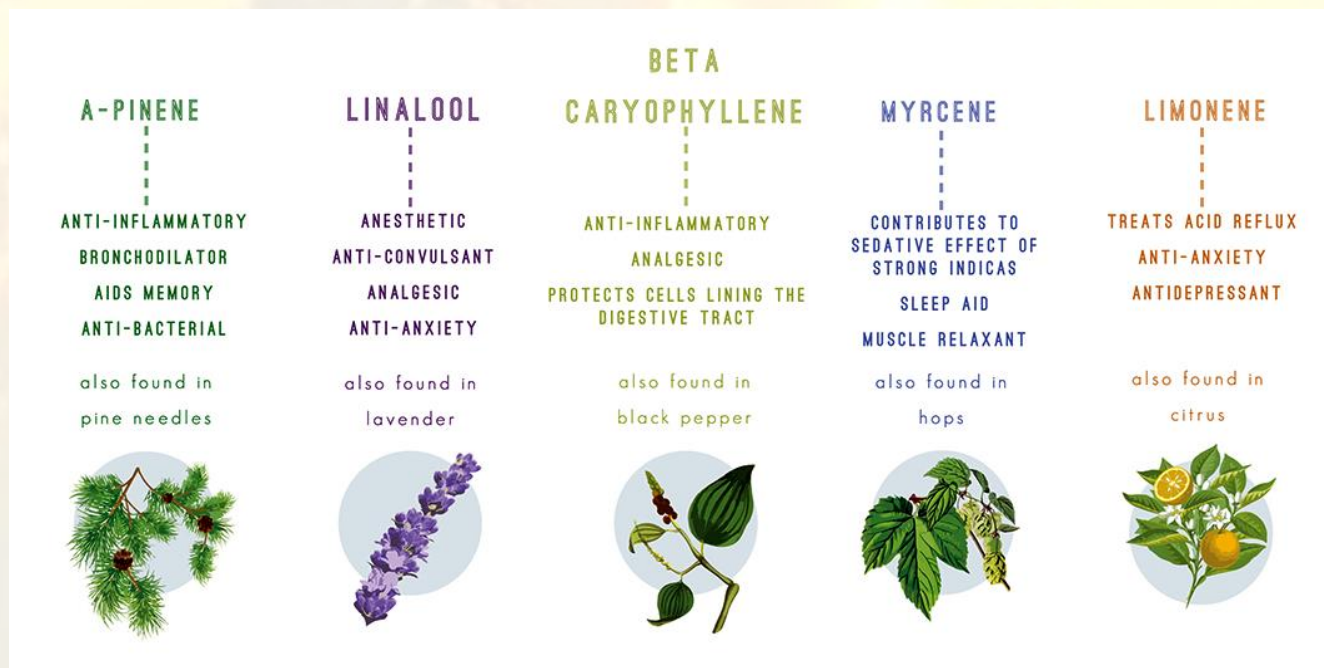


INTRODUCTION

Context

➤ What do we know of terpenes ?

Produced by a large range of plants
=> Used for human health

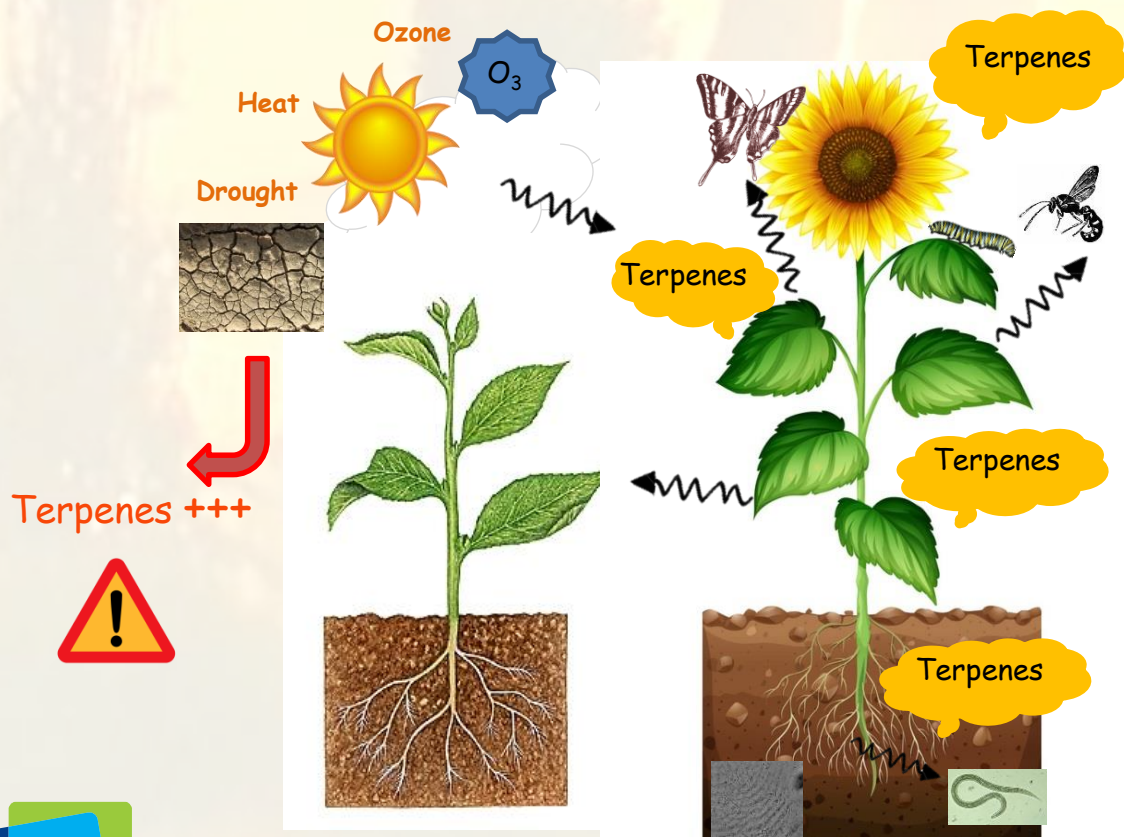


INTRODUCTION

Context

➤ What do we know of terpenes ?

Produced by a large range of plants => To react against biotic or abiotic stresses



Adapted from Fantaye et al. (2014)

- Role in **communication** between plants
- Role in **defense** against herbivores
- Role in **attracting** pollinators
- Role in **enhancing tolerance** against abiotic stresses

INTRODUCTION

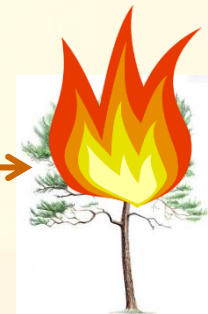
Context

➤ What do we know of terpenes ?

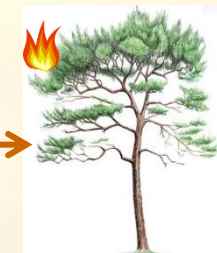
=> **Role on flammability** (Romero et al. , IJWF, 2019)

- ✓ **Positive/negative** depending on the terpene subgroup
sometimes overridden by **FMC or leaf thickness**
- ✓ **Leaf terpene content = litter terpene content**

Sesquiterpenes



Diterpenes



Objectives

- Seasonal variation of terpene content and composition? => Seasonal variation of flammability?
- Change of the main flammability driver (FMC vs terpenes) according to season?

MATERIAL AND METHODS

4 species studied among the most common in WUI

➤ 1 native to the area (Pinaceae)



Pinus halepensis

➤ 3 exotic species (Cupressaceae)



Cupressus arizonica



Cupressus sempervirens



Cupressocyparis leylandii



SDIS13

MATERIAL AND METHODS

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MATERIAL AND METHODS

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Cupressus arizonica



Cupressus sempervirens



Cupressocyparis leylandii

5 plants per species sampled
3 replicates per plants



15 Leaf samples / species

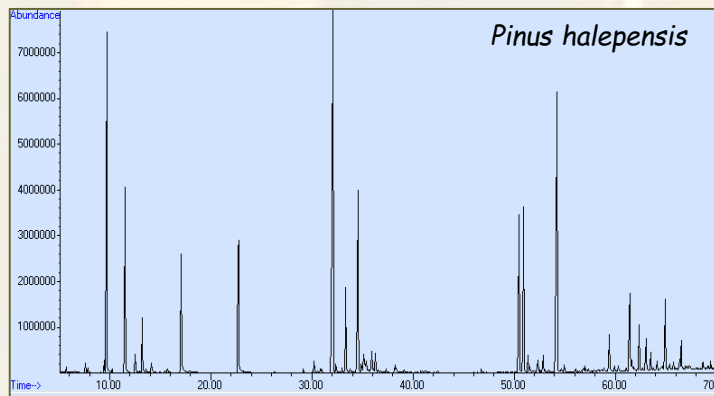
Sampling carried out in winter, spring, and summer

MATERIAL AND METHODS

Laboratory analyses and experiments

➤ Exhaustive terpene screening

⇒ Composition in Monoterpenes, Sesquiterpenes, Diterpenes



- ⇒ Total terpene content
- ⇒ Subgroup content
- ⇒ Compound content



➤ Live leaf burning experiments



N=30; Ignition frequency (IF, %), time-to-ignition (TTI, s), and flaming duration (FD, s)

➤ Leaf moisture content measurements (FMC)

RESULTS

➤ Variation in Terpene Diversity according to Species

34
compounds



Cupressocyparis leylandii

22
compounds



Cupressus arizonica

21
compounds



Cupressus sempervirens

18
compounds



Pinus halepensis

➤ Seasonal Variation in Terpene Diversity

IN SUMMER

34 terpenes

11 mono-, 11 sesqui-, 12 di-

22 terpenes

6 mono-, 9 sesqui-, 7 di-

20 terpenes

6 mono-, 6 sesqui-, 8 di-

17 terpenes

7 mono-, 6 sesqui-, 4 di-

IN SPRING

32 terpenes

11 mono-, 11 sesqui-, 10 di-

21 terpenes

6 mono-, 8 sesqui-, 7 di-

17 terpenes

5 mono-, 6 sesqui-, 6 di-

18 terpenes

7 mono-, 6 sesqui-, 5 di-

IN WINTER

32 terpenes

11 mono-, 11 sesqui-, 10 di-

21 terpenes

6 mono-, 8 sesqui-, 7 di-

21 terpenes

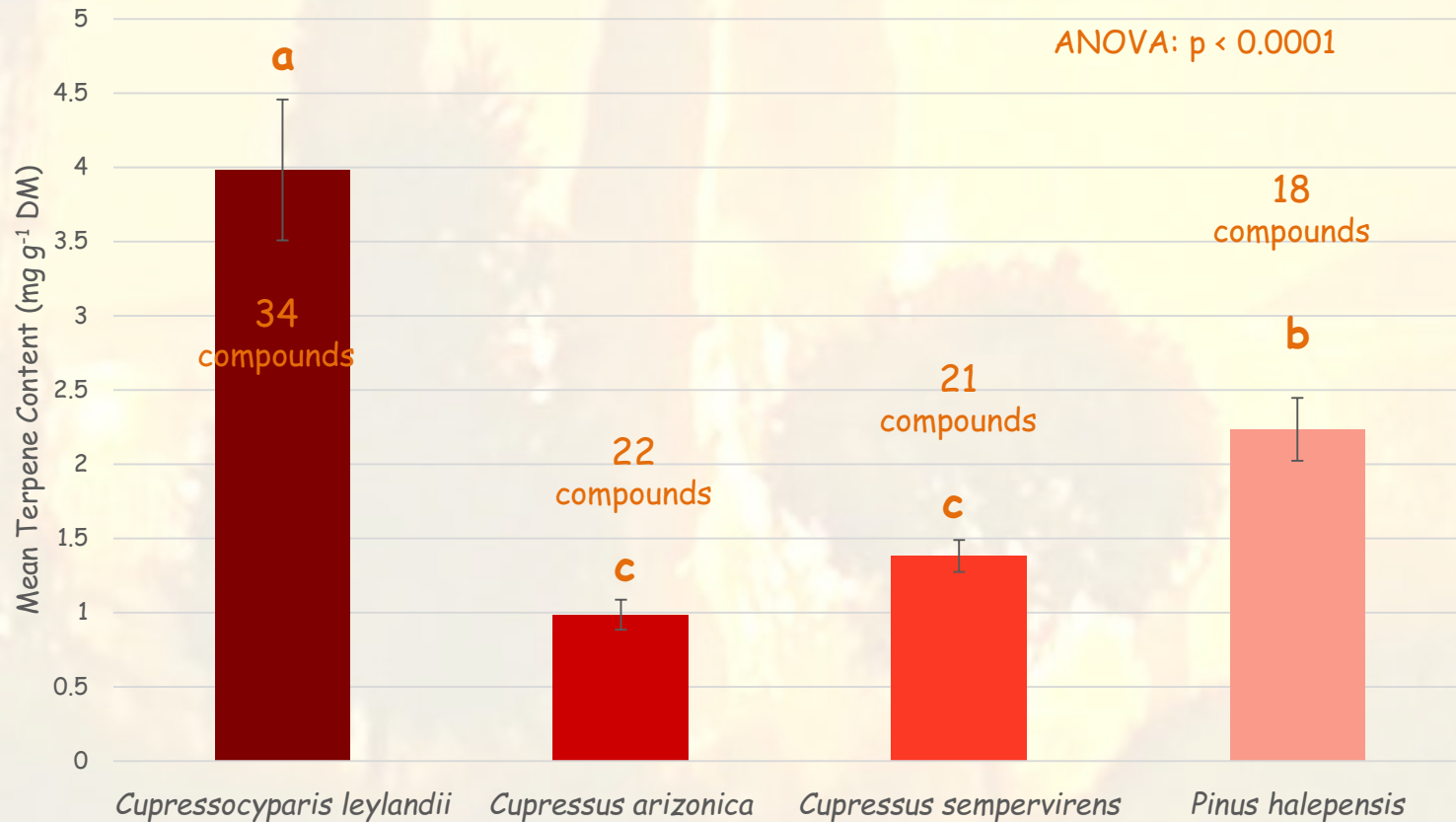
6 mono-, 8 sesqui-, 7 di-

18 terpenes

7 mono-, 6 sesqui-, 5 di-

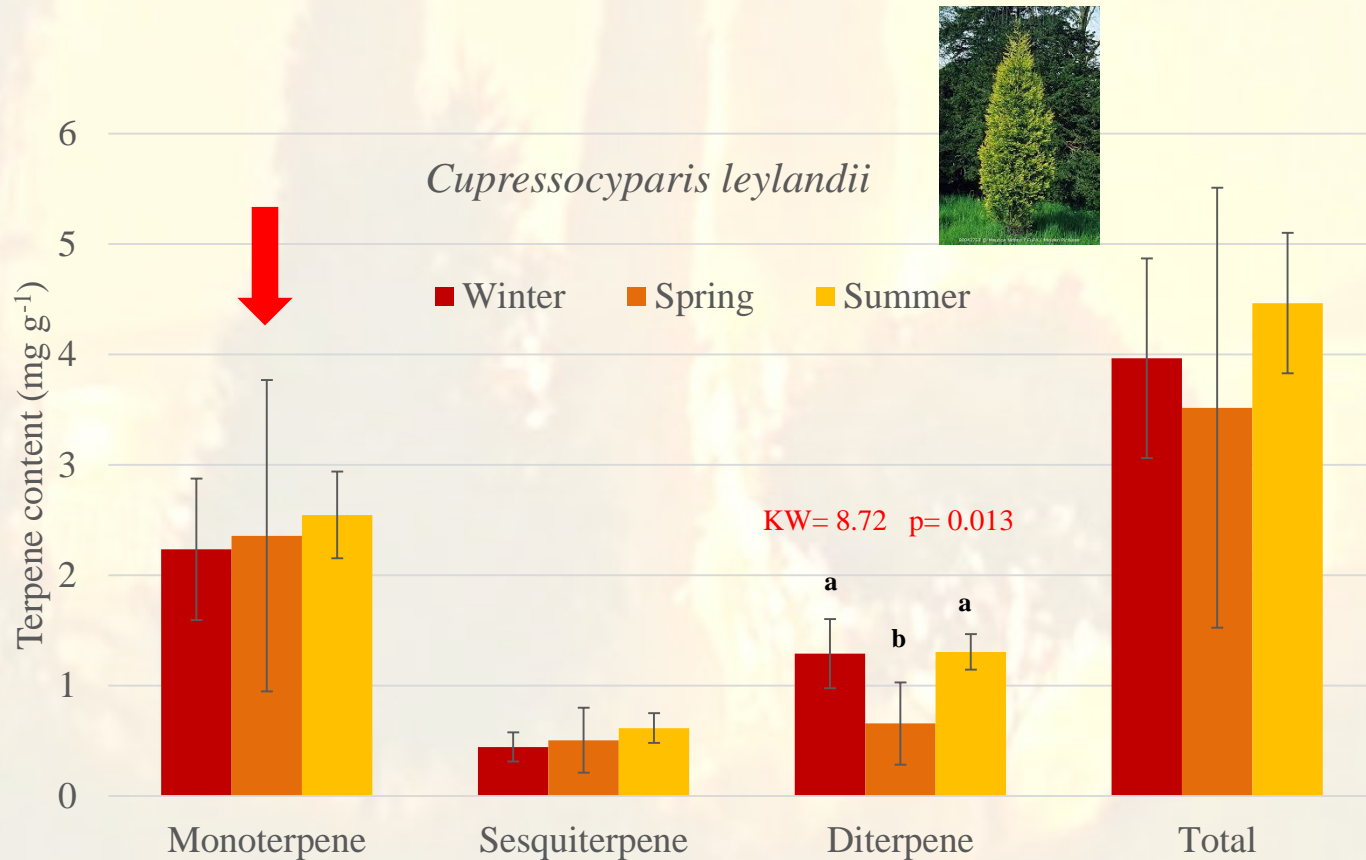
RESULTS

➤ Variation in Terpene Content according to Species



RESULTS

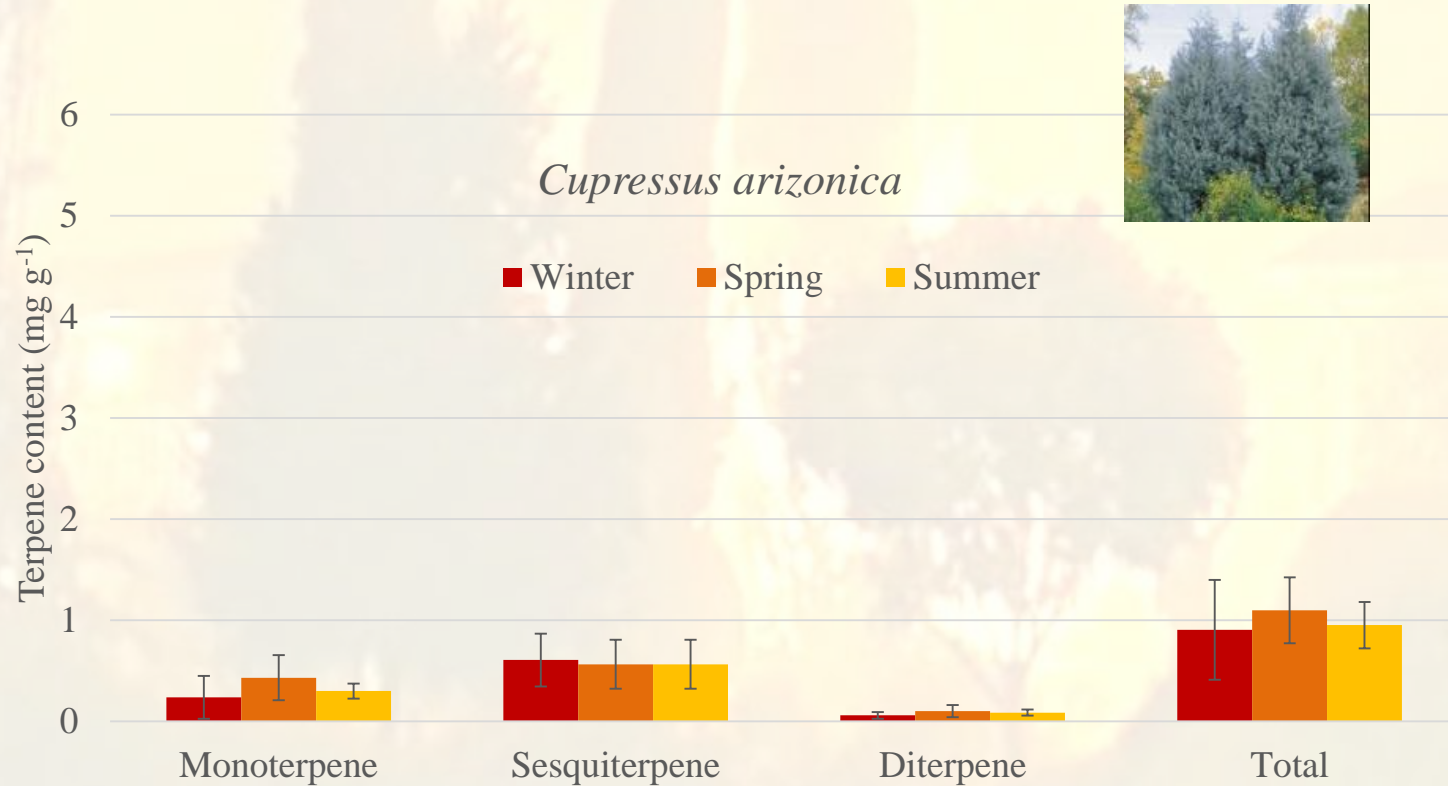
➤ Seasonal Variation in Terpene Content



Abietal 4 epi, cembrene, cembrene A, isophyllocladene, manool oxide, manool oxide 13 epi

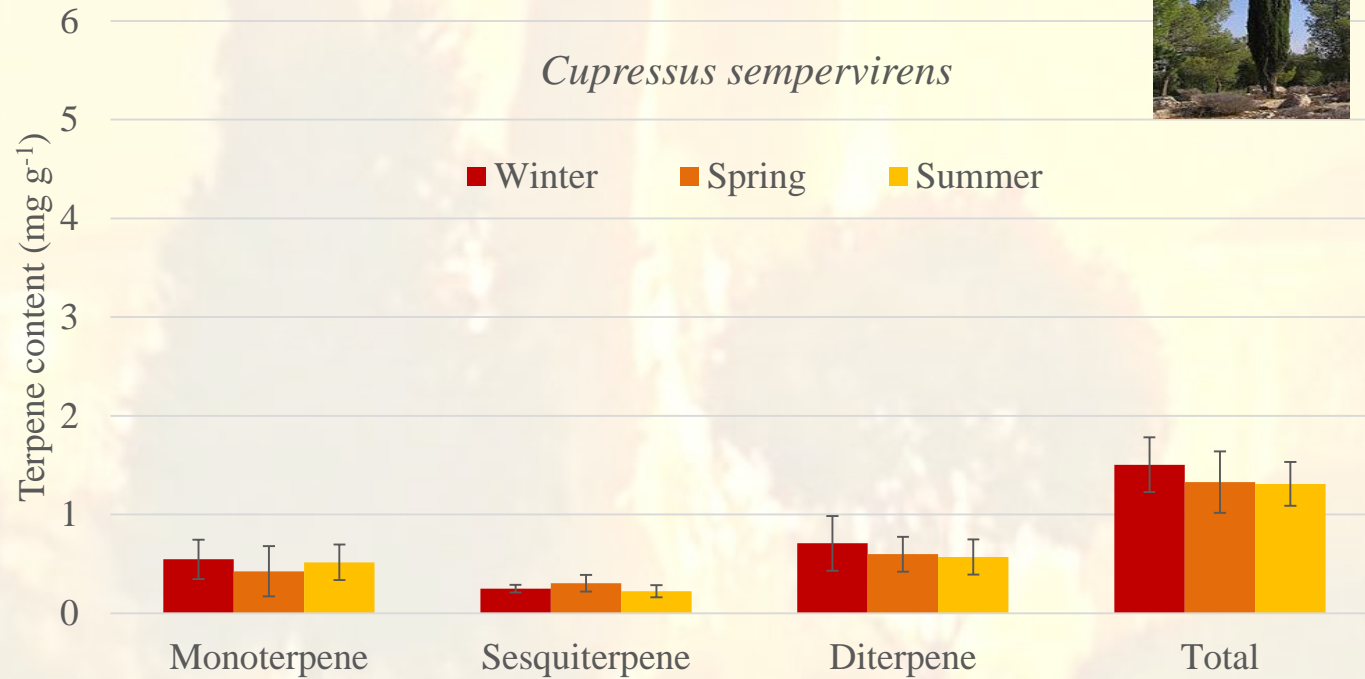
RESULTS

➤ Seasonal Variation in Terpene Content



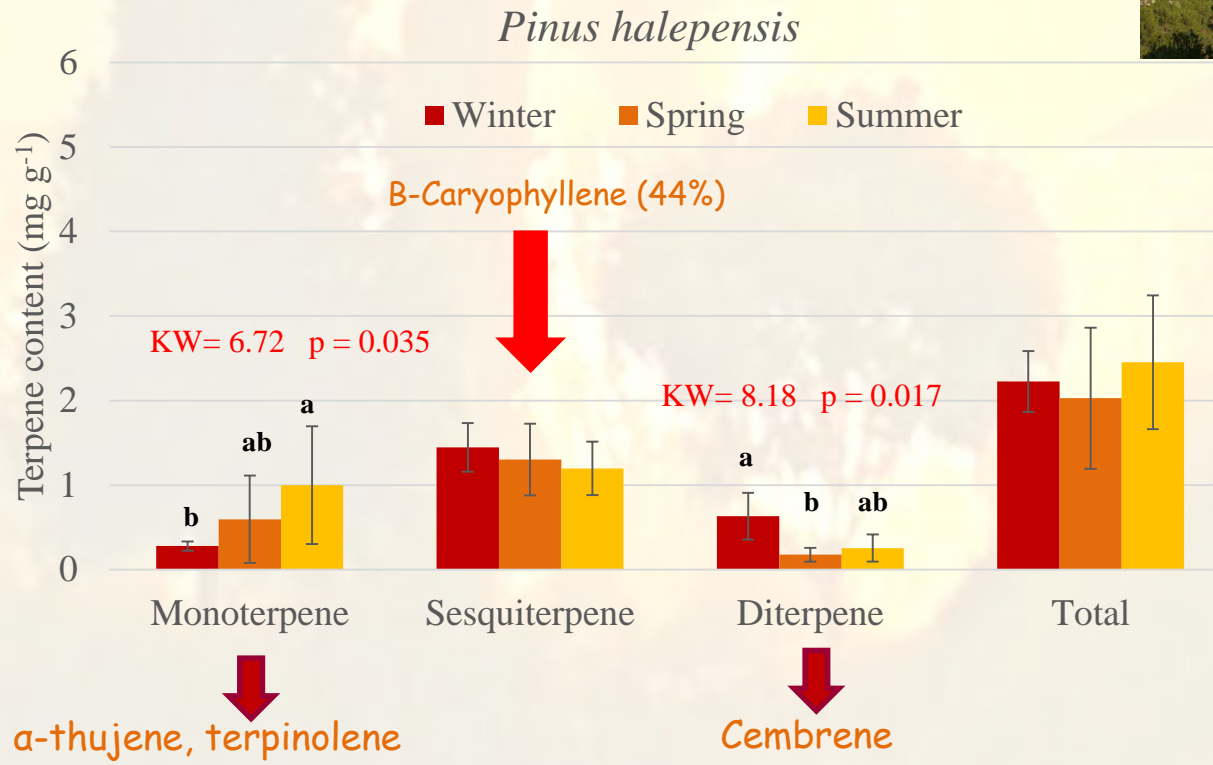
RESULTS

➤ Seasonal Variation in Terpene Content



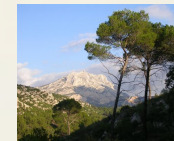
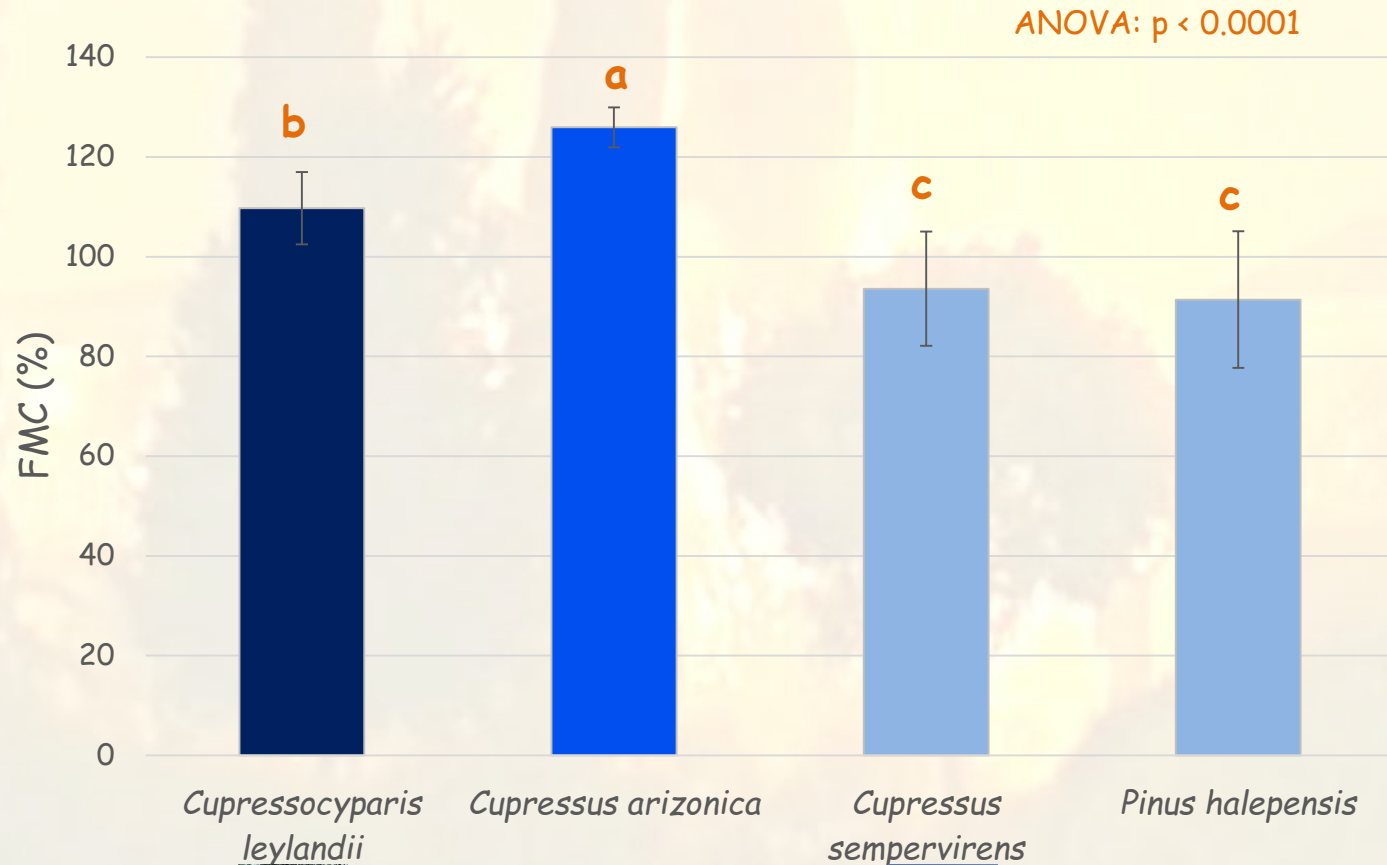
RESULTS

➤ Seasonal Variation in Terpene Content



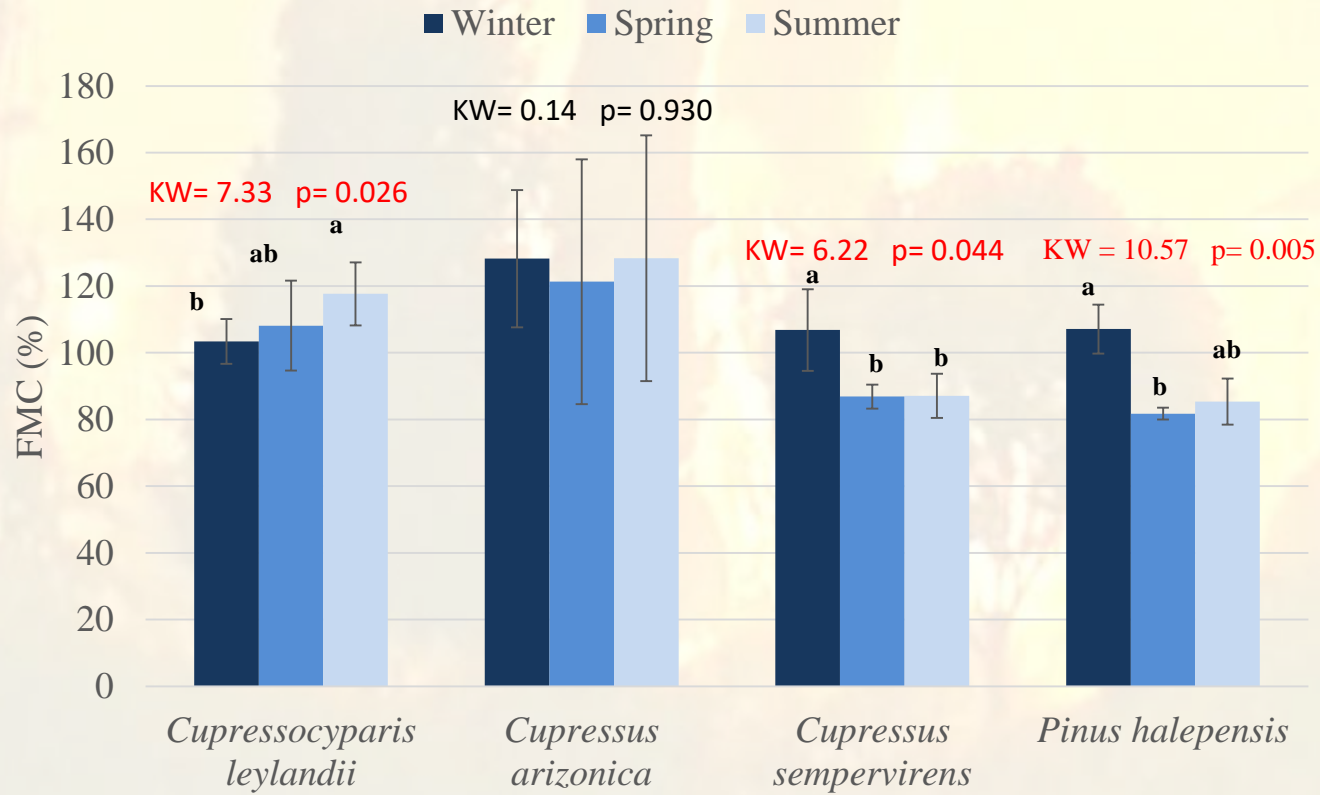
RESULTS

➤ Variation in FMC according to Species



RESULTS

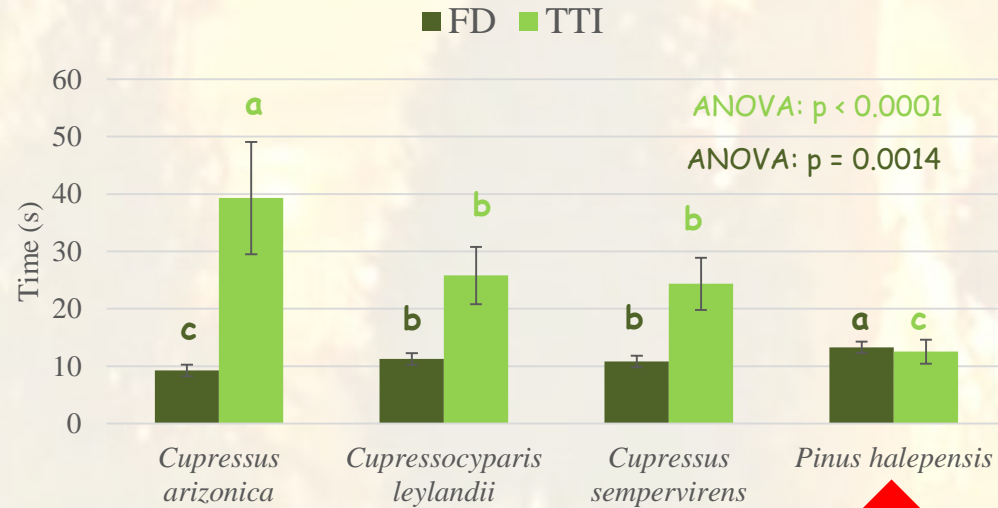
➤ Seasonal Variation in FMC



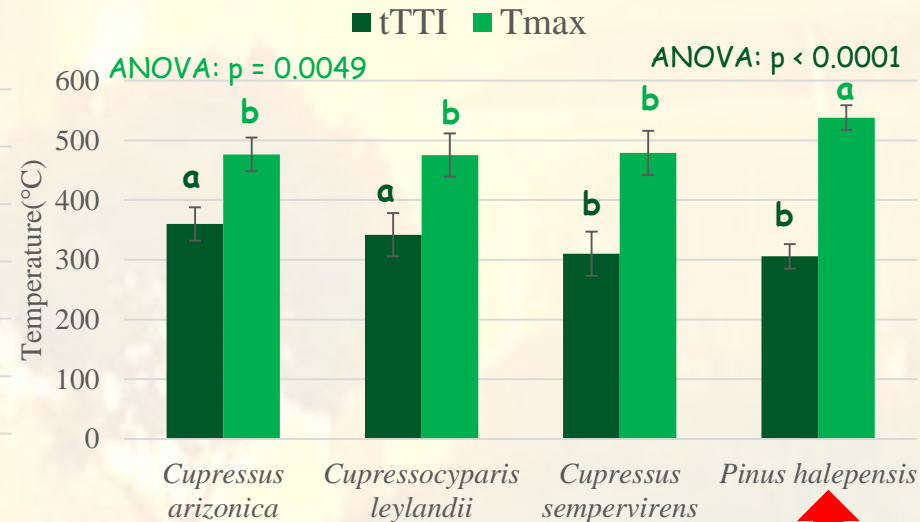
RESULTS

➤ Variation in Flammability according to Species

ANOVA: $p < 0.0001$



FD: Flaming Duration
TTI: Time-To-Ignition

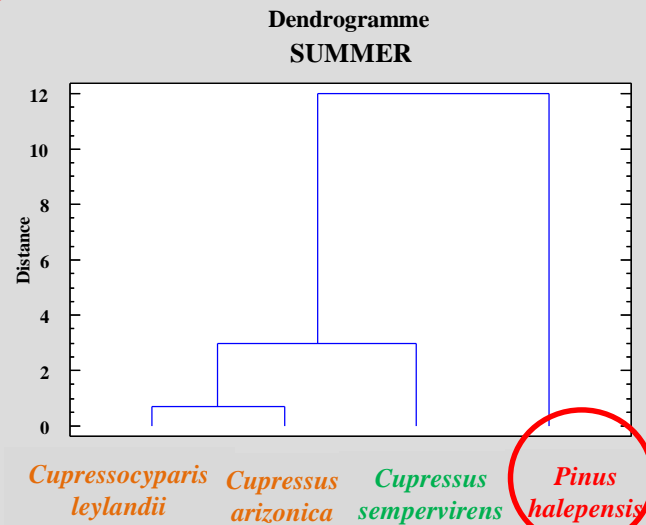
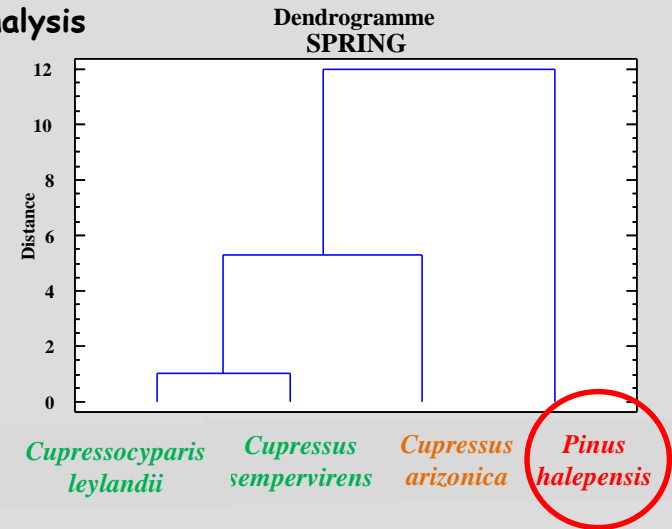
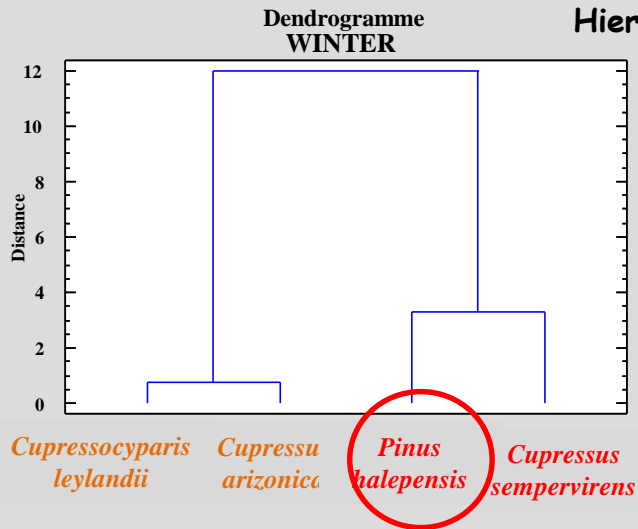


tTTI: Ignition Temperature
Tmax: Maximum Temperature

RESULTS

➤ Seasonal Variation in Flammability

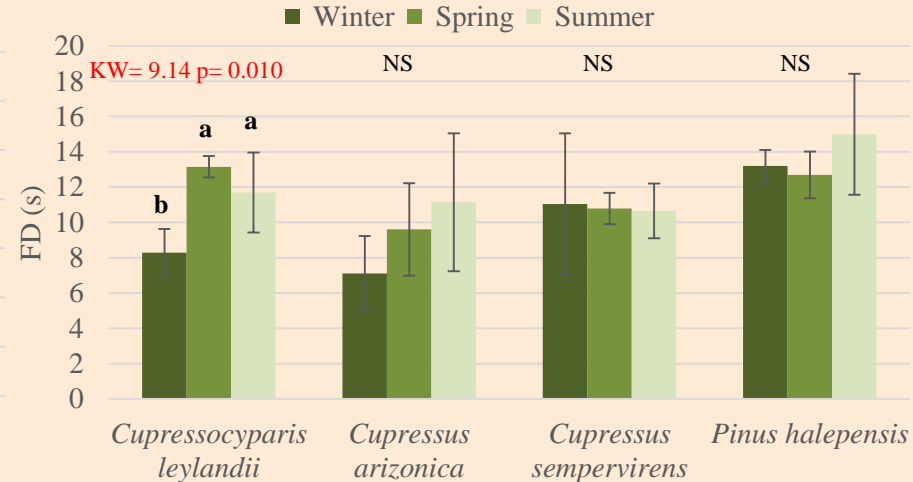
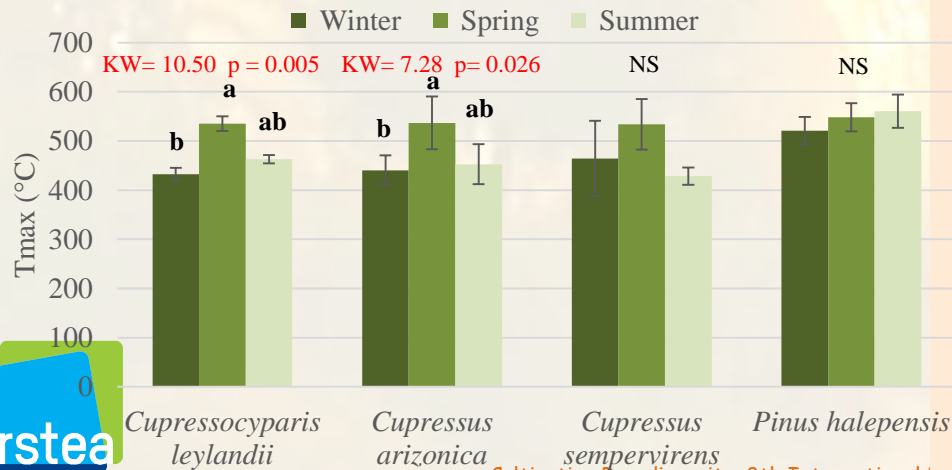
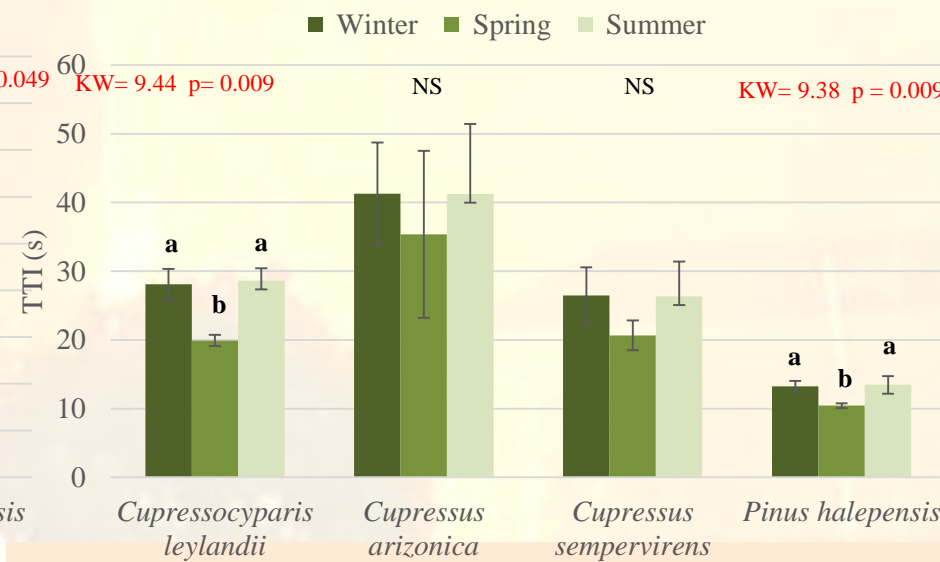
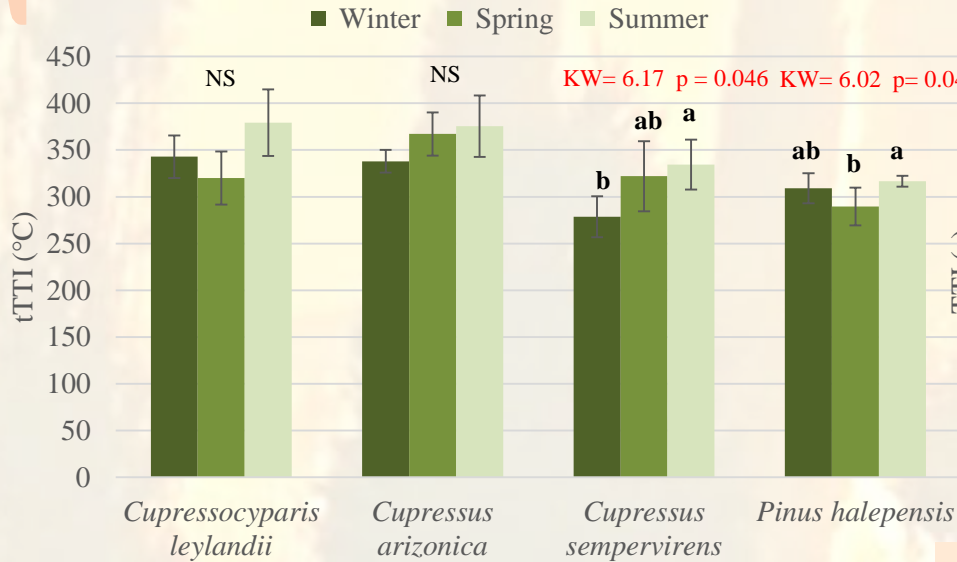
Regardless of the season, *P. halepensis* is the most flammable species



High flammability
Moderate flammability
Low flammability

RESULTS

➤ Seasonal Variation in Flammability



RESULTS

➤ Drivers of Species Flammability

➤ Significant relationships between flammability and leaf parameters (FMC, terpene subgroup and compound content) ?

➤ Which are responsible for decreasing/enhancing flammability according to season?

=> Flammability Drivers varied according to the Species, Season, and Variable considered

RESULTS

➤ Drivers of Species Flammability

Pinus halepensis



Annual correlations

FD_ST **germacrene**
TTI_MT **myrcene**

Seasonal correlations

Winter:

FD_MT **α-pinene**
FD_MT **β-pinene**
FD_ST **germacrene**
Tmax_MT **myrcene**
†TTI_DT ←



Spring:

TTI_MT
TTI_MT **β-pinene**
→ †TTI_ST
→ †TTI_ST **α-humulene**
→ †TTI_ST **β-caryophyllene**
→ †TTI_DT
→ Tmax_FMC

Summer: TTI_MT **myrcene**
†TTI_ST ←
FD_ST **germacrene**

Positive effect on flammability
Negative effect on flammability

MT: Monoterpene
ST: Sesquiterpene
DT: Diterpene
TT: Total Terpene

RESULTS

➤ Drivers of Species Flammability

Annual correlations

FD_DT	Tmax_DT	
FD_DT Cembrene	Tmax_DT Cembrene	
FD_DT Isophyllocladene	Tmax_DT Isophyllocladene	TTI_DT
FD_DT Manool oxide	Tmax_DT Manool oxide	TTI_DT Abietal-4-epi
FD_DT manool oxide 13 epi	Tmax_DT manool oxide 13 epi	TTI_DT Cembrene A

Cupressocyparis leylandii



Seasonal correlations

Winter:

→ FD_DT nezukol
 → TTI_DT manool oxide
 +TTI_DT manool oxide
 +TTI_DT totarol
 Tmax_DT nezukol



Summer:

→ TTI_DT
 TTI_DT cembrene
 TTI_DT isophyllocladene
 TTI_DT manool oxide
 TTI_DT manool oxide-13epi

MT: Monoterpene
 ST: Sesquiterpene
 DT: Diterpene
 TT: Total Terpene

No effect of terpenes on flammability in spring

No effect of FMC on flammability

Positive effect on flammability
 Negative effect on flammability

RESULTS

➤ Drivers of Species Flammability

Cupressus arizonica



Annual correlations

Tmax_MT α-pinene

Seasonal correlations

→ Summer: TTI_FMC

Positive effect on flammability
Negative effect on flammability

No effect of terpenes on flammability according to season

MT: Monoterpene
ST: Sesquiterpene
DT: Diterpene
TT: Total Terpene

RESULTS

➤ Drivers of Species Flammability

Cupressus sempervirens



Annual correlations

➔ TTI_FMC
FD_DT
FD_DT Tatarol

Seasonal correlations

➔ Winter: TTI_FMC

Spring: FD_DT
TTI_MT δ -3 carene

Summer: FD_DT
FD_DT totarol
TTI_MT α pinene
TTI_TT



Positive effect on flammability
Negative effect on flammability

MT: Monoterpene
ST: Sesquiterpene
DT: Diterpene
TT: Total Terpene

CONCLUSIONS

Regarding terpenes

- **Terpene diversity and content varied among species**
 - *Cupressocyparis leylandii* => highest diversity of terpenes
 - => highest contents of **mono-** and **diterpenes**
 - *Pinus halepensis* => highest content of **sesquiterpenes** (β -caryophyllene)
- **Seasonal variation in Terpenes => variation in composition throughout the year**
 - *Cupressocyparis leylandii* => Only diterpenes varied
 - *Pinus halepensis* => Mono- and diterpenes varied

CONCLUSIONS

Regarding FMC

- **FMC varied between species**
 - *Cupressus arizonica* => highest values
 - *Pinus halepensis* => Lowest values
- **FMC varied according to season in all species except *C. arizonica***

Highest FMC in Winter and lowest in Summer except in *Cupressocyparis leylandii*

Regarding leaf flammability

- ***Pinus halepensis* was the most flammable species** regardless of the season
- **Seasonal variation in flammability => highest mostly in spring**

CONCLUSIONS

- Effect of terpenes on flammability differed among species

- Negative effect of FMC on flammability...

... in Spring

ST germacrene



Pinus halepensis

DT totarol



Cupressus sempervirens

Contrasted effect of terpenes on flammability according to the season

... in Winter

DT manool
oxide-13-epi



Cupressocyparis leylandii

Negative effect of terpenes on flammability regardless of the season

... no effect

MT α -pinene



Cupressus arizonica

No effect of terpenes on flammability regardless of the season

... in Summer

- Main terpene compounds driving flammability differed among species



Thank you for your attention !

