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Burning Characteristics of Multiple Moist Forest Fuel Samples

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Background

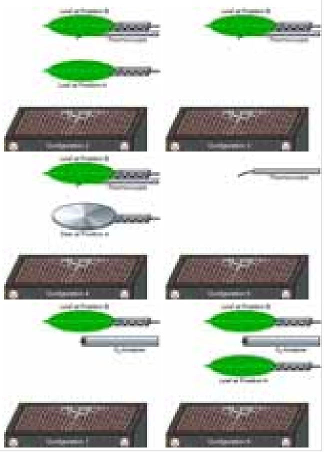
- Fire suppression has caused fuel accumulation in forests
  - High fuel loads cause high-intensity fires – damage to property and ecology
  - Prescribed burns are used to reduce fuel accumulation
- Current fire spread models are based on extensive empirical correlations
  - Correlations were performed on dry, dead fuels
  - Spread models do not accurately predict the effects of moisture in live vegetation
- Improve current models with combustion data for live vegetation using multiple leaves
  - Understand flame interaction between leaves
  - Scale-up to model a burning bush
- Improve overall understanding of combustion of moist fuels in wildland fires

Experimental Apparatus

Flat Flame Burner

- Gases
  - Fuels (H_2, CH_4)
  - Oxidizer (Air)
  - Inert (N_2)
- Stoichiometry altered to obtain post-flame conditions
  - Temperature ~ 1000°C
  - O_2 Concentration ~ 10 mol%
  - Flame length ~ 1-3 mm
- Repeatable experiment

Configurations



- Equipment
  - Leaf sample – ignites and burns during experiment
  - Thermocouple – measures gas temperature
  - Metal disk – obstruction to alter flow dynamics
  - O_2 analyzer – measures O_2 content (mol%)
- Positions
  - A – 4.0 cm above FFB
  - B – 2.5 cm above position A
  - Between A & B – placement of O_2 analyzer

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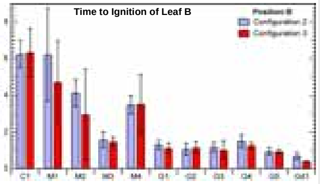
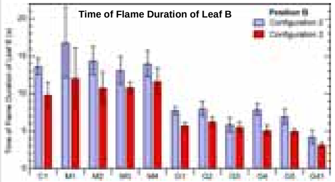
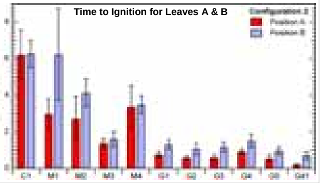
Configurations 2 & 3



- Time to ignition of leaf B
  - Only significant difference was for dry gambel oak
  - Leaf A present delays ignition of leaf B
  - Lack of moisture delays ignition of leaf B

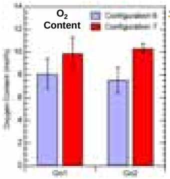


- Time of flame duration of leaf B
  - Nearly all significant
  - Leaf A present prolongs burning of leaf B
- Possible causes
  - O_2 consumption of leaf A
  - Flow dynamic effect



- Time of ignition (leaves A & B)
  - Significant for gambel oak
  - Nearly significant for manzanita
  - Could be due to size of leaf (small ceanothus)
- Ignition delay defined $(t_{ig}^{B} - t_{ig}^{A})$

Configurations 6 & 7



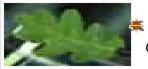
- O_2 concentration
  - Recorded as a minimum value
  - Place between position A & B
  - Delay of 3-4 s after ignition
- O_2 content (mol%)
  - 20 % lower with leaf A present
  - Leaf A consumes O_2
  - Less available to leaf B

Experimental Runs

Species

- Ceanothus
  Ceanothus crassifolius

- Manzanita
  Arctostaphylos glandulosa



- Gambel Oak
  Quercus gambelii Nutt.

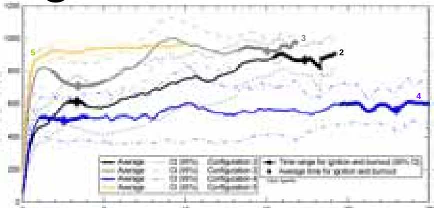
Symbols

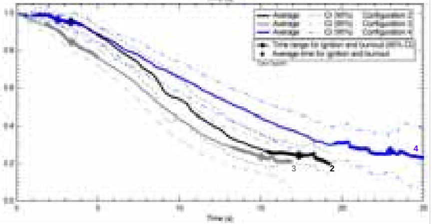
Species	Symbol
Ceanothus	C*
Manzanita	M*
Gambel Oak	G^*
* ⇒ Number of experimental run ^ ⇒ o = O_2 analyzer, d = dry leaves	

Data Obtained

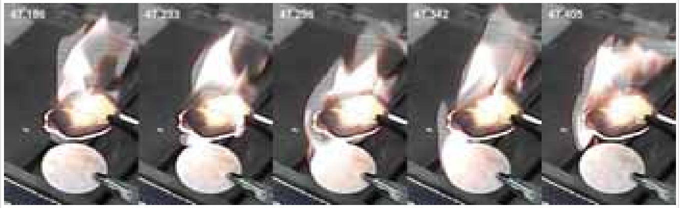
Measured Quantity	Definition	Experimental Method
Time to ignition (t_{ig})	Difference in time from start of particle heating until first visible flame on or near the leaf surface (either leaf A or B)	Frame-by-frame inspection of video images for presence of sustained, initial flame
Ignition temperature (T_{ig})	Particle temperature at which first visible flame is observed on or near the leaf surface (either leaf A or B)	IR camera, time-synched with the video and focused on the appropriate leaf tip
Gas temperature (T_{gas})	Gas temperature from FFB gases and volatiles from leaf A	Thermocouple, corrected for radiation
Flame duration (t_{fd})	Time difference between burnout and ignition	Frame-by-frame inspection of video for presence of flame
Ignition delay time (t_{id})	Time difference between the ignitions of leaves B & A	Frame-by-frame inspection of video for presence of flame

Configuration 4





- Gas temperature profile
  - Initially (1-2 s) 3 higher than 2 & 4
  - Dip in 3 – due to leaf B (different than 5)
  - 2 & 3 eventually reach 5 level (950°C)
  - 4 remains constant (550°C)
  - 4 burns longer
- Normalized mass profile
  - Initially (4-5 s) 3 lower than 2 & 4
  - Initially 2 & 4 behave similarly
  - 2 decreases more rapidly after 4-5 s – acts like 3
  - 2 always lower than 4
  - 3 lower than 4 just below burnout
- Obstructions change laminar flow to turbulent
  - More significant with metal disk (observed)
  - Movement of leaf A during burn gives more laminar-like flow
- Change in flow dynamics can alter combustion behavior



Conclusions

- Leaf A present (vs. when no leaf A is present)
  - Longer flame duration of leaf B – prolonged combustion
  - Lower gas temperature during pre-ignition and ignition at position B
  - Lower O_2 content – leaf A consumes O_2
- Significant ignition delay for larger species
- Obstructions
  - Change laminar flow to turbulent
  - Alters temperature and mass of leaf B
- Important for modeling of a burning bush

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