Fast-track breeding of high-yielding varieties of *Artemisia annua*

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Aims of the CNAP Artemisia Research Project

- to identify plants of *A. annua* with increased yields of artemisinin.
- to field trial plants, confirm heritability of high yield trait and select the best lines
- to develop robust and stable high yield varieties which will slot into the current supply chain for ACTs
- to deliver high-yielding seed to the ACT supply chain in as short a timeframe as possible
- to reduce the cost of ACTs
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Scientific strategy

- Induced variation
  - Forward (trait) screen
  - Reverse (genetic) screen
- Natural variation
  - Marker assisted breeding
- Identify individuals with high artemisinin yield
- Develop robust new varieties
Starting material

• Artemis - developed by Mediplant and currently used commercially. Yielding from 0.6 to 1.2% depending on the location

• collection of other varieties from various locations including Vietnam and East Africa
Summary of Breeding Routes

Route 1: Forward Screen
Route 2: Natural variation from the Artemis gene pool
Route 3: QTL analysis of Artemis
Route 4: Use of natural populations
Route 5: Association study of natural variation
Route 6: Heteroduplex mapping
Route 7: Combining traits

Induced variation
Natural variation
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**Delivery timeline**

- **Phase 1**: Routes 1, 2 & 3a (2008)
- **Phase 2**: Routes 3b-6 (2011-2012-2013)
- **Phase 3**: Route 7 (2014-2015)

% Artemisinin / unit dry weight

- 1
- 2
- 3
- 4
- 5
- 6

Timeline:
- 2008
- 2011
- 2012-2013
- 2014-2015
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Scientific strategy

- **induced variation**
- **natural variation**

- **forward (trait) screen**
- **reverse (genetic) screen**

- marker assisted breeding

- identify individuals with high artemisinin yield

- develop robust new varieties
Route 1: Forward (trait) Screen

- high throughput screen of M2 (selfed) plants for artemisinin yield
  - Chloroform dip
  - UPLC MS with 2.5 min run time

- identify high yielding individuals and confirm trait in the field

- ~1000 plants screened every two / three weeks.
Forward Screen Update

- screened 21,000 / 25,000 plants
- identified 230 high yield individuals (between 1.5 and 3 fold higher than Artemis)
Forward Screen Status

- experimental trials will characterise
  - metabolite content
  - trichome density
  - biomass traits (height, fresh weight, leaf area, nodes)
  - vegetative stage
  - plant architecture

  to determine field performance and establish basis of high yield trait
Project status

• multiple lines exhibiting increased yield in artemisinin identified using a forward screen.
• first heritability data suggests a significant proportion of these are due to genotype
• mapping populations established in 3 different environments and genetic map constructed.
• mutations in target genes identified with potential to increase yield of artemisinin
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Potential yield improvement from Phase 1 routes already known ~ 2-4% artemisinin per unit dry weight

Potential High Yielder identification

Heritability testing/Backcrossing

Potential yield known

Experimental Field Trials

Commercial Field Trials

True yield known

Hybrid seed for field trials

Earliest date to market

EARLIEST DELIVERY - 2011

Minimum target yield improvement is double the yield of Artemis
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