Bambara groundnut: An African crop for the future

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An African crop for the future
% change in crop yields from present and 2050 (atmospheric CO₂ at 520-640 ppm)
• 95% of farmed land in Africa is rain-fed
• Agriculture dominant contributor of GDP in African countries
• Future African climates expected to be hotter and drier: at least 2°C by end of 2100
• Erratic precipitation
• More semi-arid land
• Yield losses of staple crops
• Greater risk of drought and soil erosion
• Malnutrition
Bambara groundnut: an African crop for the future

‘the seed that satisfies’

Sole-crop or intercrop

Drought tolerance & nitrogen-fixing

African food systems

Better use of water resources

Improved nutritional security

Resilience to shocks of climate change
Drought tolerance
• Drought tolerance, resistance and/or avoidance
  • Morphological, phenological & physiological
    • Highly compressed stems
    • Early flowering
    • Reduced canopy size
    • Stomatal control, proline levels, chlorophyll content
• WUE is \( \approx 2.1 \text{ g mm}^{-1} \text{ m}^{-2} \), a value comparable to that of other legumes
  • 2.24 & 1.20 at 30% optimal water; 2.46 & 1.10 at 60%; and 1.86 & 1.00 at 100% (Mabhaudi et al. 2013)
  • WUE versus yield potential
• Timing, severity, frequency
• High temperatures & low humidity levels (Berchie et al. 2012)
• Drought tolerance is decent but there is still room for improvement
Grain yield
<table>
<thead>
<tr>
<th>Author</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>Location</th>
<th>Research Focus</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berchie et al. (2010)</td>
<td>1,300</td>
<td>2,400</td>
<td>1,661</td>
<td>Ghana</td>
<td>Yield evaluation</td>
<td>Mean values of 5 landraces</td>
</tr>
<tr>
<td>Kouassi &amp; Zorobi (2011)</td>
<td>1,310</td>
<td>5,100</td>
<td>2,670</td>
<td>Nigeria</td>
<td>Effect of genotype &amp; planting density</td>
<td>Mean of 2 genotypes at 2 plant population</td>
</tr>
<tr>
<td>Ouedraogo et al. (2008)</td>
<td>110</td>
<td>1,440</td>
<td>830</td>
<td>Burkino Faso</td>
<td>Characterization &amp; evaluation</td>
<td>Mean of 310 landraces</td>
</tr>
<tr>
<td>Touré et al. (2012)</td>
<td>79</td>
<td>459</td>
<td>278</td>
<td>Ivory Coast</td>
<td>Yield and characterization</td>
<td></td>
</tr>
<tr>
<td>Karikari &amp; Tabona (2004)</td>
<td>308</td>
<td>1,477</td>
<td>756</td>
<td>Botswana</td>
<td>Constitutive traits &amp; selection indices</td>
<td>Mean of 12 landraces for 2 seasons</td>
</tr>
<tr>
<td>Pungulani et al. (2012)</td>
<td>485</td>
<td>1,322</td>
<td>824</td>
<td>Malawi</td>
<td>Yield evaluation</td>
<td>Mean of 8 landraces across 3 sites</td>
</tr>
<tr>
<td>Makanda et al. (2009)</td>
<td>1,100</td>
<td>2,300</td>
<td>1,590</td>
<td>Zimbabwe</td>
<td>Agronomic evaluation</td>
<td>Mean of 20 landraces</td>
</tr>
<tr>
<td>BAMFOOD</td>
<td>476</td>
<td>1,892</td>
<td>1,116</td>
<td>Swaziland</td>
<td>Multi-location evaluation</td>
<td>Mean of 8 landraces across 2 sites</td>
</tr>
<tr>
<td>BAMFOOD</td>
<td>269</td>
<td>776</td>
<td>508</td>
<td>Namibia</td>
<td>Multi-location evaluation</td>
<td>Mean of 8 landraces across 2 sites</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>604</td>
<td>1,907</td>
<td>1,137</td>
<td></td>
<td>*yield values are in kg ha(^{-1})</td>
<td></td>
</tr>
</tbody>
</table>
Grain Yield (kg/ha)

*Non-Bambara groundnut statistics are taken from FAOSTAT database (2009-2011)
• Positive correlation of traits to yield
  • Plant height, canopy spread, days to 50% flowering, days to maturity, leaves/plant, number of flowers/plant, pods/plant, stems/plant, seed/pod, 100 pod/seed weight etc.

• Path coefficient analysis & direct yield components in declining order of importance
  • Pods/plant
  • seeds/pod
  • 100 seed weight
• Grain yield is favourable for an unimproved legume

• All the developmental processes have direct/indirect functional contribution/effect to grain yield

• Grain yield depends largely on the direct effect of its components, i.e. pod/plant, seed/pod and 100 seed weight

• Literature lacks consistency, uniformity and coordination

• Ranking of the commonly known landraces and selecting potential parental might be highly inconclusive
Future developments
• Breeding targets
  • Tolerance to increased severity and duration of drought
  • Tolerance to excess water
  • Increased height & stem number, early flowering & establishment
    (Onwubiko et al. 2011)

• Optimal HI is 0.4-0.5 (Mwale et al. 2007) vs 0-0.08 under drought (Collinson et al. 1999)
  • Pod number, seed weight, shelling percentage → sink intensity
  • Root heavy

• BamYIELD and CFFRC
  • PhD projects
Bam1-001: Productivity and N\textsubscript{2} fixation (Mukhtar Musa)

Bam1-006: Breeding approaches using MAGIC population (Siise Aliyu)

Bam1-008: Canopy modeling for ideotypes (Josie Dodd)

Bam1-009: Fertility in bambara groundnut (Bhavya Dhanaraj)

Bam1-003: Adaptation to different environments (Philip Cleasby)

Surveys in Nigeria and Ghana

Bam1-007: Combining multiple data types (Faraz Khan)

Bam1-004: Machine learning to detect drought tolerance (Venkata Suresh)

projects in development

Machinery and processing

Drought tolerance and nodulation

Agronomy and physiology

Socio-economic

Fertility and photoperiod

Genetics and breeding

Translation Projects

Co-op setup for production in Indonesia
• Breeding targets
  - Tolerance to increased severity and duration of drought
  - Tolerance to excess water
  - Increased height & stem number, early flowering & establishment (Onwubiko et al. 2011)

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• BamYIELD and CFFRC
  - PhD projects
  - Flagship projects
Breeding for enhanced resilience
N.B. Starting point is farmer preferences

1. Short maturity period
2. Easy to cook (short cooking time)
3. Cream coloured testa
4. Larger seed
5. High yielding
6. Taste
<table>
<thead>
<tr>
<th>Trait</th>
<th>Botswana</th>
<th>Namibia</th>
<th>Swaziland</th>
<th>Agreement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High yield</td>
<td>_</td>
<td>+</td>
<td>+</td>
<td>2/3</td>
</tr>
<tr>
<td>Large pods</td>
<td>_</td>
<td>_</td>
<td>+</td>
<td>1/3</td>
</tr>
<tr>
<td>Large seed</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>3/3</td>
</tr>
<tr>
<td>Rapid and uniform emergence</td>
<td>_</td>
<td>_</td>
<td>+</td>
<td>1/3</td>
</tr>
<tr>
<td>Spreading growth habit</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>3/3</td>
</tr>
<tr>
<td>Early Maturity</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>3/3</td>
</tr>
<tr>
<td>Pod retention (strong pegs)</td>
<td>+</td>
<td>_</td>
<td>+</td>
<td>2/3</td>
</tr>
<tr>
<td>Cream Seeds</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>3/3</td>
</tr>
<tr>
<td>Easy-to-cook</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>3/3</td>
</tr>
<tr>
<td>Low anti-nutritional factors</td>
<td>_</td>
<td>_</td>
<td>+</td>
<td>1/3</td>
</tr>
<tr>
<td>Sweet taste</td>
<td>+</td>
<td>+</td>
<td>_</td>
<td>2/3</td>
</tr>
</tbody>
</table>

BAMFOOD project- INCO-DC/EU technical report
<table>
<thead>
<tr>
<th>Source</th>
<th>Country</th>
<th>Trait preferences and ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abu and Buah (2011)</td>
<td>Ghana</td>
<td>• Fast cooking (42%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Early maturity (21%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Large seeds (17%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Cream/white testa (11%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• High yield (6%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sweet taste (3%)</td>
</tr>
<tr>
<td>Pungulani et al. (2012)</td>
<td>Malawi</td>
<td>• Plant Vigour</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Maturity period</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Grain Size</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Taste</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Cooking time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• No mounding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Seed Colour</td>
</tr>
</tbody>
</table>
Conclusions & opportunities
• Low maintenance, water saving crop
• Complete food
• Sensitive stomatal controls
• High genetic diversity
• Quick to achieve homozygosity
• Drought tolerance still has room for improvement
• Present landraces show favourable yield values
• How to increase drought tolerance?
• How to increase yield *per se* as well as under drought?

**Would people go for bambara groundnut?**
...And over to Wale...
Reasons for Neglected Underutilized Species

• “neglect by researchers and policymakers, genetic erosion, loss of local knowledge, marketing and climate change” – Padulosi et al., 2013

• Changing socio-economic & environmental characteristics

• Disconnect between policy and practice (farmers)

• Inappropriate farming practice & technology

• Disconnect in the continuum between cultivation and consumption

• Lack of relevant and evidence-based research
From cultivation to consumption

Cultivation

- Plant Physiology
- Gene Networks
- Breeding
- Post Harvest Processing
- Marketing

Food

- Agriculture
- Food

Nutrition

- Marketing
- Nutrition
- Health

Consumption
Bambara Groundnut in Nigeria

• Bambara groundnut (Vigna subterranea (L.) Verdc) originates from West Africa (http://en.wikipedia.org/wiki/Vigna_subterranea)

• Nigeria is the highest producer of Bambara groundnut in Africa (Hillocks et al., 2012)

• In Nigeria, it is mainly cultivated and consumed in the northern parts by small farm-holders

• Its gross energy exceeds that of other common pulses such as cowpea, lentils and pigeon pea (FAO, 1982), and it also contains sufficient quantities of protein, carbohydrate and fat (Goli, 1997)
Socio-economics Study in Nigeria

• Benue State

• Local government areas (Gboko & Kwande)

• Geo-referencing of villages

• Household & market surveys

• Descriptive and regression analyses (demography, production, processing, perceptions & marketing)
Preliminary Findings (Perceptions)

- Matures early compared to other legumes:
  - Agree: 59.0%
  - Disagree: 40.7%
  - Don't Know: 3.3%

- High yields compared to other legumes:
  - Agree: 66.7%
  - Disagree: 33.0%
  - Don't Know: 0.3%

- Cooks fast compared to other legumes:
  - Agree: 37.7%
  - Disagree: 60.7%
  - Don't Know: 1.7%

- More nutritious compared to other legumes:
  - Agree: 48.0%
  - Disagree: 39.0%
  - Don't Know: 13.0%
Conclusions & opportunities…2

• BG possesses good phenotypic and growth characteristics that maximizes labour and monetary returns (matures early compared to other legumes & high yields compared to other legumes)

• BG is a potential food security crop (availability, accessibility & affordability), and consistent with local agri-CULTURE practices

• BG requires low external inputs (saving costs and bottlenecks of fertilizers)

• BG has high potentials for transformation (produce-products)

• However, there are unresolved policy barriers

• Would you like to join the BringBackBambara Research Team?
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