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Bambara groundnut (*Vigna subterranea* (L.) Verdc)

Winged bean (*Psophocarpus tetragonolobus*)

- an overview of past, present and future research direction



Community Interest Company (CIC), UK



Festo Massawe

University of Nottingham Malaysia



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University of Nottingham – three Campuses



University of Nottingham, UK

University of Nottingham, China (Ningbo)

University of Nottingham, Malaysia (Semenyih)



University of Nottingham, Malaysia (Semenyih)



Outline and key messages

Bambara groundnut research - part of food/crop diversification – also other crops such as winged bean, amaranth, foxtail millet etc.

This presentation - selective: University of Nottingham and partners ... other researchers and teams are doing great work ...

Bambara groundnut research - an example of international research commitment to an underutilised crop: [1992-2023](#)

Key things to note - partnerships, genetic resources (core collection, breeding lines, structured populations – for genetic analysis and variety development), traits studied, tools developed, ...

Training the next generation of researchers and research leaders

What next: breeding; markers-assisted breeding; training, ...





Crop diversification through a wider use of agrobiodiversity: **minor, underutilized crops**

A wide range of nutritious, sustainable options to choose from that meet diverse cultural and taste preferences

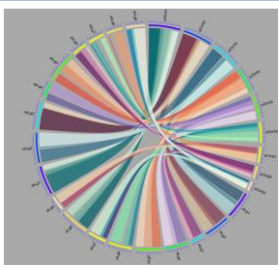
Local food biodiversity: available, accessible, affordable

Often well adapted to local environments including soils and climate

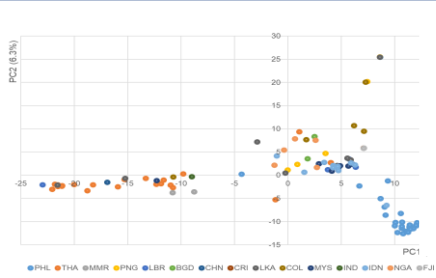
Grown by small holders - **receive little attention ...**



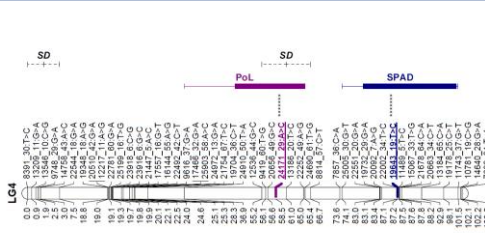
Crops such as Bambara groundnut, amaranth and winged bean, foxtail millet, taro ...



Genome sequencing



Crop diversity analysis



Genetic trait analysis



physiology



Field selection



Pre-breeding lines

Plant protein from resilient and nutritious crops

Two examples:

1) Bambara groundnut (*Vigna subterranea*) - a drought tolerant African legume (**seed protein varies from 9.0-30.7%**)

2) Winged Bean (*Psophocarpus tetragonolobus*) - a high protein tropical legume (**seed protein up to 40%**)



Sean Mayes, Wai Kuan Ho, Hui Hui Chai, Tian Yuet Chong, Alberto Tanzi, Kumbirai Mateva, Presidor Kendabie, Alberto Tanzi, Luis Salazar Licea, Niki Tsoutsoura and many others

Regine Zeng, asiangardens2table.com; DF Herridge; GE Eagleton



Bambara groundnut (*Vigna subterranea* (L.) Verdc)



Congo groundnut, Congo goober, earth pea/underground bean, njugo bean, **Kacang bogor**/peanut bean; njugu mawe; nzama, nyimo bean, indhlubu,

an example of **international research** commitment to an underutilised crop

Grown mainly in Africa but also grown in a number of countries worldwide e.g. Indonesia.



<https://www.youtube.com/watch?v=vdB5L1nsDlo>

[Artificial hybridisation protocol](#)



Grown primarily by subsistence farmers

Seeds are a reasonably balanced, nutritious food - represents an important source of protein

The crop is **drought resistant**, relatively free of diseases and pests

No improved varieties, only landraces

Yields are variable



Understanding the genetic relationships between Indonesian bambara groundnut landraces and investigating their origins

Authors: [E.S. Redjeki](#), [W.K. Ho](#), [N. Shah](#), [O.O. Molosiwa](#), [N.R. Ardiarini](#), [Kuswanto](#), and [Sean M](#)

Publication: Genome • 25 February 2020 • <https://doi.org/10.1139/gen-2019-0137>

Ho Wai Kuan



Yield and nutritional composition

Table 1. Total area harvested, production and average yields for Bambara groundnut in 2019

Country	Area harvested (ha)	Production (t)	Yield (t/ha)
Burkina Faso	59 926	58 435	0.975
Cameroon	66 675	51 265	0.769
Mali	38 789	26 076	0.672
Niger	68 073	44 807	0.658
Togo	26 422	20 154	0.763
Zimbabwe	83 750	17 182	0.205
Democratic Republic of Congo	27 318	11 001	0.403

Source: FAOSTAT (2018).

Yields range from 0.5 to 3 t/ha; average 0.85 t/ha

Maphosa et al. (2022). <https://doi.org/10.1017/S0021859622000521>

Table 2. Proximate nutritional composition of Bambara groundnut seeds

Nutrient	Composition (g/100 g) (amino acids expressed in mg/g of protein ^a)
Fat	1–12
Carbohydrates	55–71
Protein	17–26
Starch	22–50
Dietary fibre	5–12
Soluble fibre	1–24
Insoluble fibre	10–16
Sugars	2.4
Ash	3–12
Moisture	13–1
Essential amino acid ^a	67.28
Non-essential amino acid ^a	32.72

^aEssential and non-essential amino acids expressed in mg/g of protein. Adapted from: Murevanhema and Jideani (2013); Olaleye et al. (2013); Maphosa (2016); Yao et al. (2015); Khan et al. (2007); Majola et al. (2021).



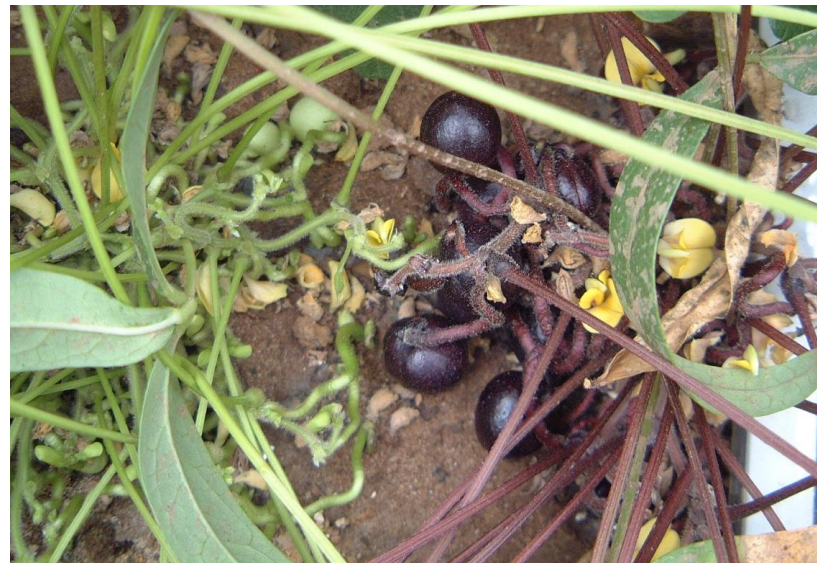
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Bambara groundnut research



University of Nottingham, Crops For The Future and partners across the globe

from basic plant science to product development and socio-economic studies



EU Project 1: 1992-1996 (BAMGROW)

Agroecological and food potential of bambara groundnut

- genetic diversity, yield potential; **photoperiod**, genetic resources -



Photoperiod:
flowering and
podding

Linneman *et al.*, 1994;
1995; Brink *et al.*, 1997 ...

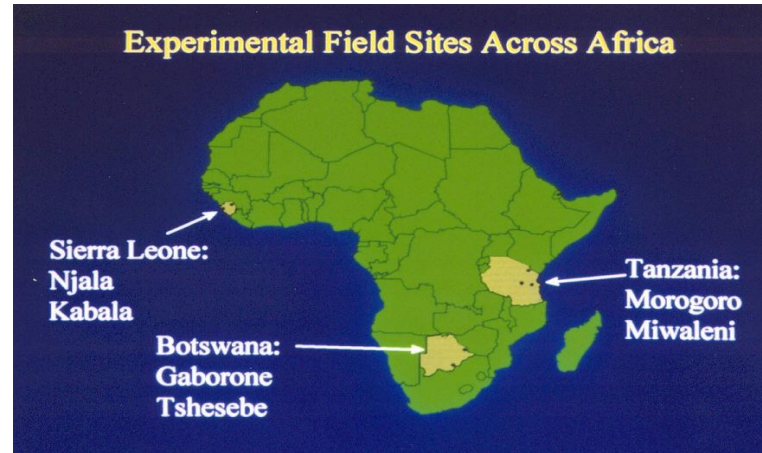


Research stations in Africa

Controlled-environments – UK; the Netherlands



Farmers knowledge: sowing date, earthing up ...



Collinson *et al.*, 1996; 1997; 2000

Key Landraces

Lun T - Sierra Leone

DipC - Botswana

Dod Red – Tanzania

Dod Cream – Tanzania

Yield and harvest indices

2.87 (DodR and 1.42 (Dod
C) t ha⁻¹

Pod harvest indices of 0.56
and 0.34, respectively

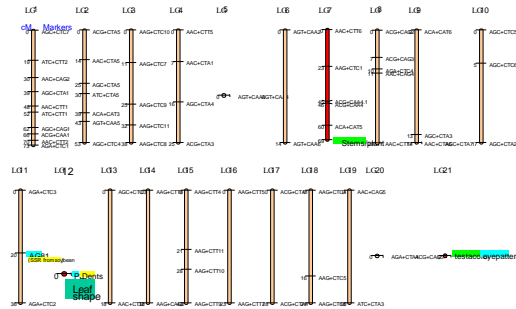
Rainfall, temperature ...

EU Project 2: 2000-2004 (BAMFOOD)

Increasing the productivity of bambara groundnut for sustainable food production in semi-arid Africa

Farmers/traders ideotypes

- Early maturity
- Large seeds
- Fast cooking
- Sweet taste
- High yield



First Genetic Linkage Map

Key Landraces

DipC - Botswana

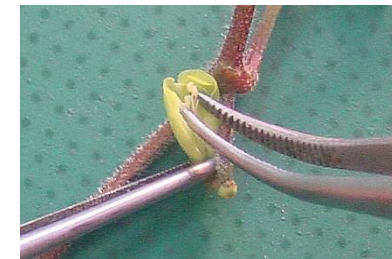
S19-3 - Namibia

Uniswa R - Swaziland

1st Crosses - e.g., Tiga
Nicuru x DipC



X

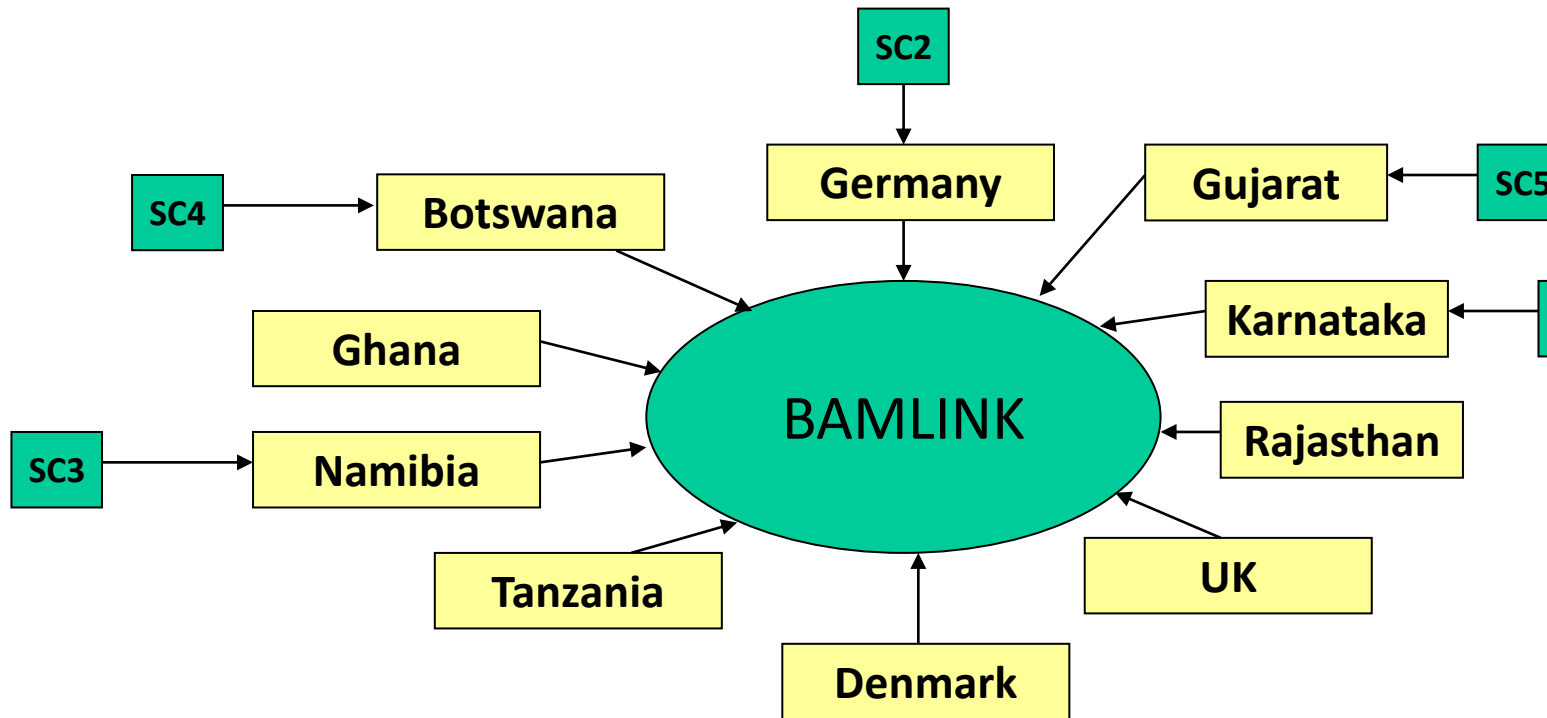


method of cross-breeding

Partners:
Swaziland/Eswatini
Botswana Namibia
UK (UoN) Germany
(TUM)

EU Project 3: 2006-2009 (BAMLINK)

Molecular, Environmental and Nutritional Evaluation of Bambara Groundnut for Food Production in Africa and India



Landraces	Origin	Region
DodR	Tanzania (TZA)	East Africa
DodC	Tanzania (TZA)	East Africa
AS17	South Africa (RSA)	Southern Africa
DipC	Botswana (BWA)	Southern Africa
SwaziRed	Swaziland (SWA)	Southern Africa
TicaNicuru	Mali (MLI)	West Africa
Ramayana	Indonesia(IND)	Asia
LunT	Sierra Leone (SLA)	West Africa
Vssp6	Cameroon (CMR)	West Africa
Nav 4	Ghana (GHA)	West Africa
Nav red	Ghana (GHA)	West Africa
Mahenene black	Namibia (NAM)	Southern Africa
S19/3	Namibia (NAM)	Southern Africa
S19-3	Namibia (NAM)	Southern Africa
UniswaRed	Swaziland (SWA)	Southern Africa
SB16 5A	Namibia (NAM)	Southern Africa
AHM968	Namibia (NAM)	Southern Africa
NAM 1761/3	Namibia (NAM)	Southern Africa
Malawi 3	Malawi (MW)	Southern Africa
Tvsu 569	Cameroon (CMR)	West Africa
Tvsu 610	Nigeria (NGA)	West Africa
Tvsu 747	Zambia (ZMB)	Southern Africa
GabC	Botswana (BWA)	Southern Africa
Tvsu 999	Zimbabwe (ZWE)	Southern Africa

- Nutrition and product development
- Criteria and genotypes for breeding programme
- Drought, heat, cold, daylength and pod filling
- Genetic Linkage maps - 'Wide' and 'Narrow' cross

Basu et al., 2007a, b, c; 2008; Jørgensen et al., 2009; Jørgensen et al., 2010; Mayes et al., 2013; Ahmad et al., 2013; Chai et al., 2013; Molosiwa et al., 2015.

BamYIELD (2011-2020)

BamNetwork – www.bambaragroundnut.org

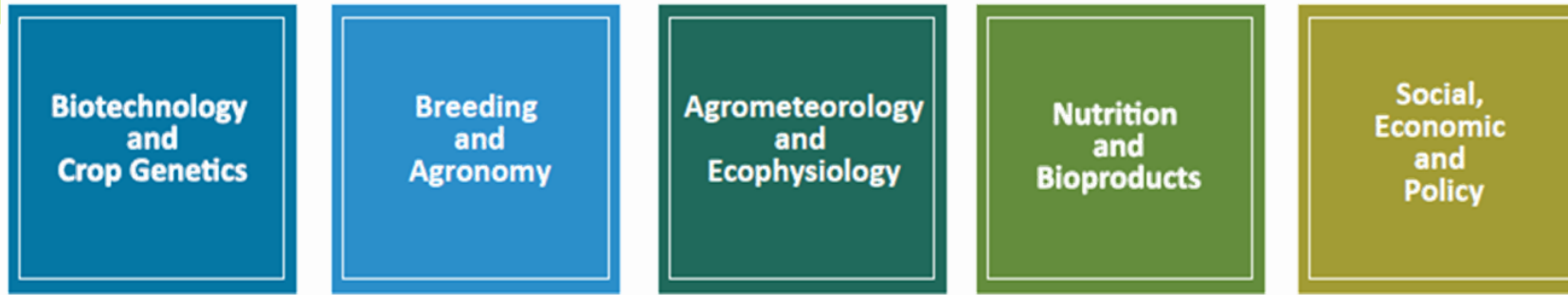
Sean Mayes



Research community outreach

Knowledge exchange and dissemination

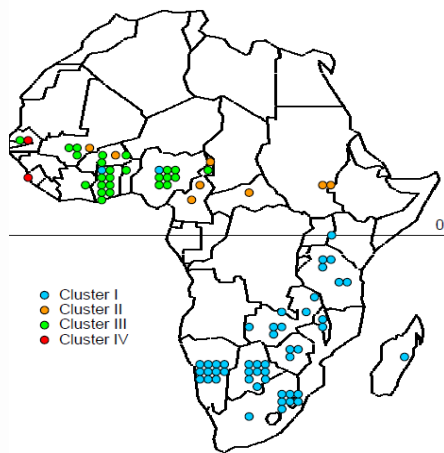
Research Value Chain



Name	Origin
Ankpa4	Nigeria
DipC	Botswana
DodR	Tanzania
Getso	Nigeria
Gresik	Indonesia
IITA-686	Tanzania
LunT	Sierra Leone
S19-3	Namibia
Tiga Nicuru	Mali
Uniswa Red	Swaziland

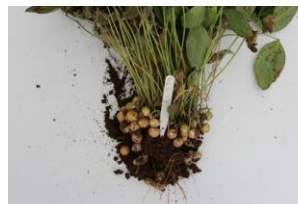
Diversity of germplasm

Development of segregating populations



● Cluster I
● Cluster II
● Cluster III
● Cluster IV

DArT Seq



Dip C (♀)



Ankpa 4 (♂)



IITA-686 (♀)



Ankpa 4 (♂)

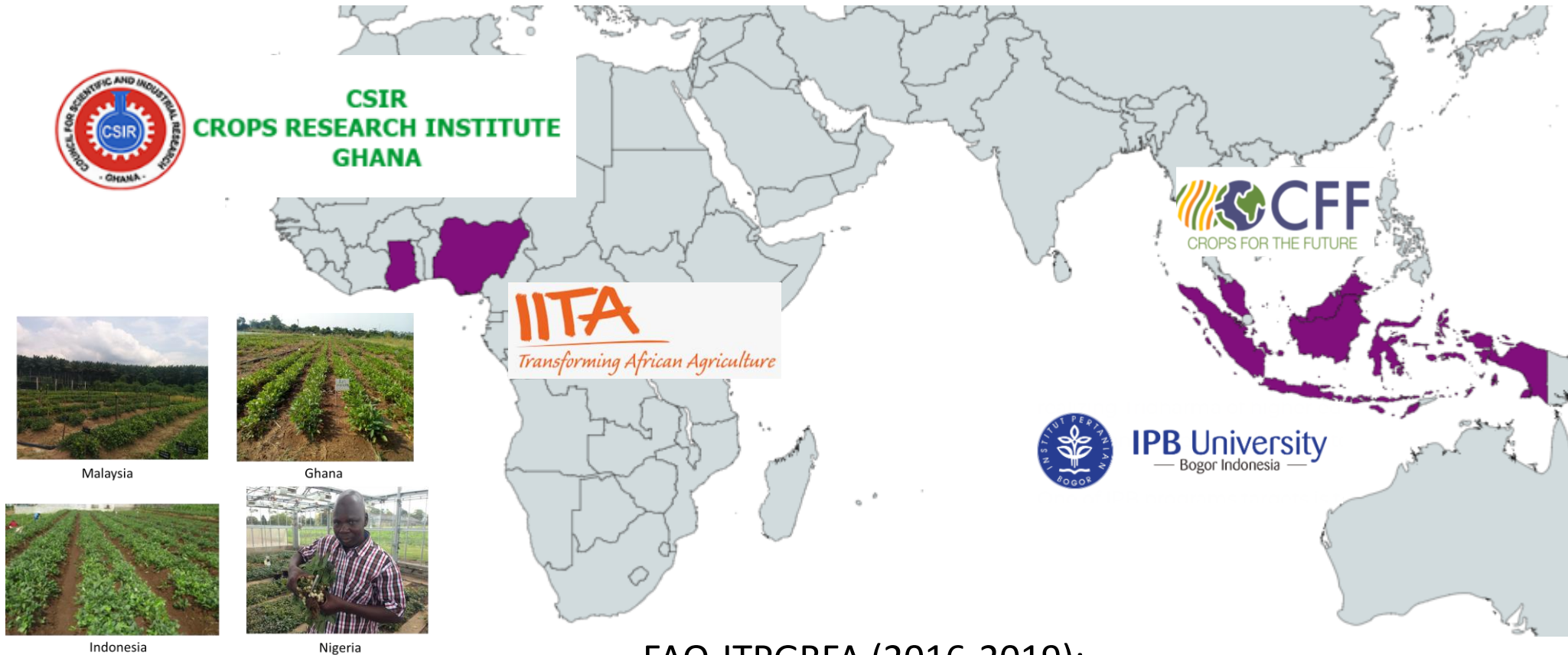


F₁ Hybrid



F₁ Hybrid

Aliyu et al., 2015; Siise et al., 2016; Ahmad et al., 2016; Ho et al., 2016; 2017; Chai et al., 2017; Kendabie et al., 2014; 2020, ..., ...



FAO-ITPGRFA (2016-2019):

A West Africa - Southeast Asia collaboration (Ghana, Nigeria, Indonesia and Malaysia)

- developing pre-breeding materials with partners at field sites, in parallel with local germplasm



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BamBREED - bambara groundnut breeding programme (2019-2024)

South Africa

Tafadzwanashe Mabhaudhi, Admire Shayanowako and others



Drought resistant, photoperiod and hard to cook, ...

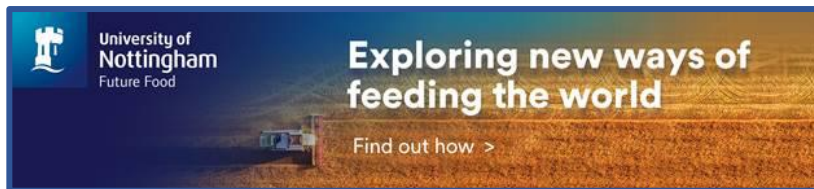


Ghana



CSIR Crops Research Institute
Ghana

Kennedy Agyman, Joseph Berchie and others





Selection of breeding lines: improved cultivars with traits of interest

GENOTYPE	TRAITS OF INTEREST
Mottled cream	Early maturing; drought tolerance
Nav red	High yielding
Uniswa red	High yielding; drought tolerance
Nav 4	Cream-coloured seed; high yielding
Bolga red	High yielding; big seed size
Burkina	Drought tolerance; cream-coloured seed
Zebra coloured	Early maturing

University of KwaZulu-Natal, Cedara Research Station, Capstone Seeds (Howick), and University of KwaZulu-Natal Controlled facilities.



University of KwaZulu-Natal, South Africa

Multi-locational trial: 2021-2022 summer growing season.



Crop Research Institute, Ghana – on-station evaluation trial in September 2021

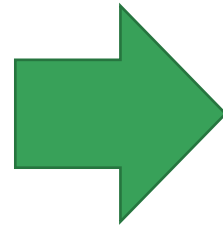
Multi-locational trial in September 2022 (two seasons across agroecological zones) and variety registration.

Develop germplasm with improved cooking qualities
Lines from Tiga nicuru x Dip C; S19-3 x Ankpa4; IITA-686 x LunT

Core germplasm and structured populations

core germplasm

Name	Origin
Ankpa4	Nigeria
DipC	Botswana
DodR	Tanzania
Getso	Nigeria
Gresik	Indonesia
IITA-686	Tanzania
LunT	Sierra Leone
S19-3	Namibia
Tiga Nicuru	Mali
Uniswa Red	Swaziland



controlled crosses from core parents

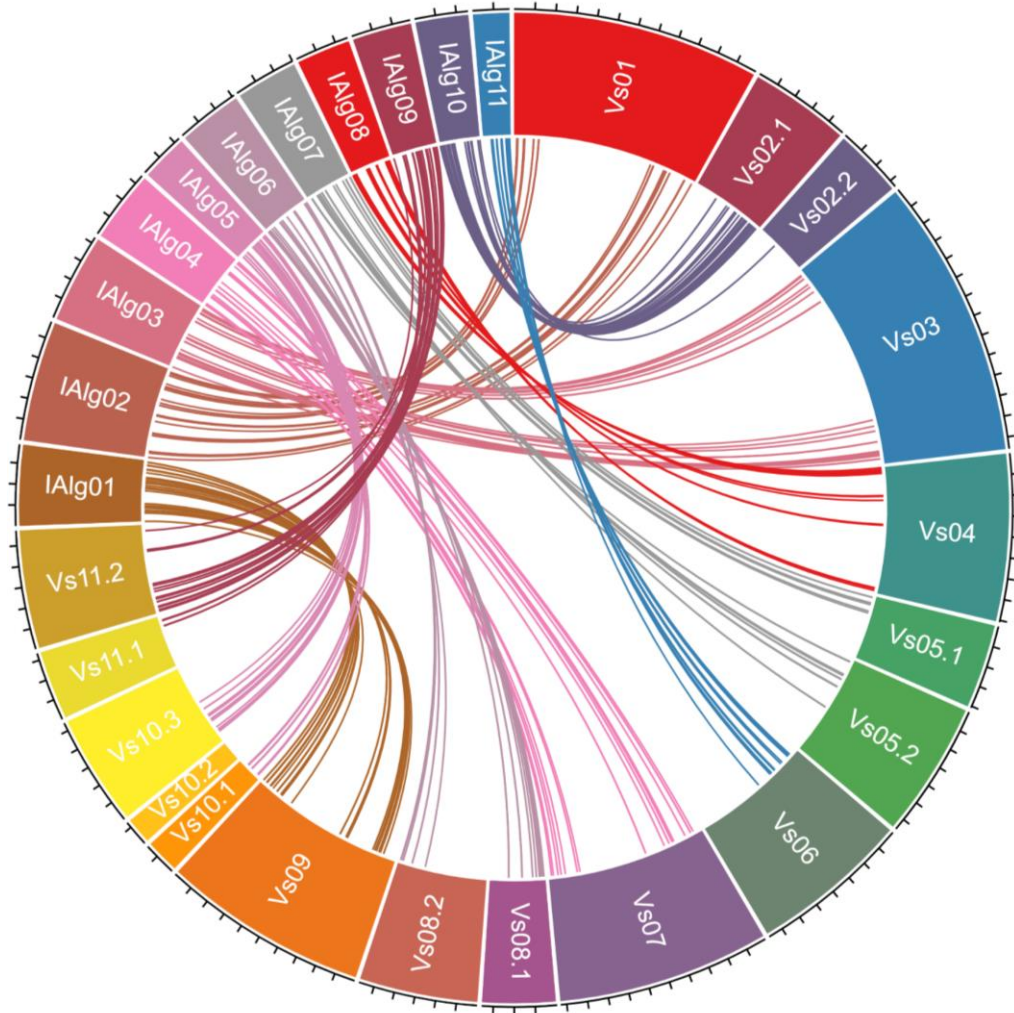
Cross	Generation	Cross	Generation
Ankpa4 x IITA-686 (& reciprocal)	F ₃ /F ₄	Tiga Nicuru x DipC	F ₇ /F ₈
S19-3 x Ankpa4	F ₃ /F ₄	S19-3 x DodR	F ₄ /F ₅
DipC x Ankpa4	F ₂ /F ₃	IITA-686 x Getso	F ₂
IITA-686 x LunT	F ₄ /F ₅	IITA-686 x Tiga Nicuru	F ₂
Ankpa4 x DodR	F ₁	S19-3 x Getso	F ₁
Uniswa Red x Getso	F ₁	S19-3 x Ankap4	F ₄ /F ₅
Ankap4 x DipC (& reciprocal)	F ₁	Uniswa Red x DodR	F ₁



Association Genetic Panel:

422 genotype lines from genebank, farmers, researchers, UoN materials

community website: <http://bambaragroundnut.org/>



genome size = ~550Mb (K-mer (K=17) analysis, Chang et al., 2019)

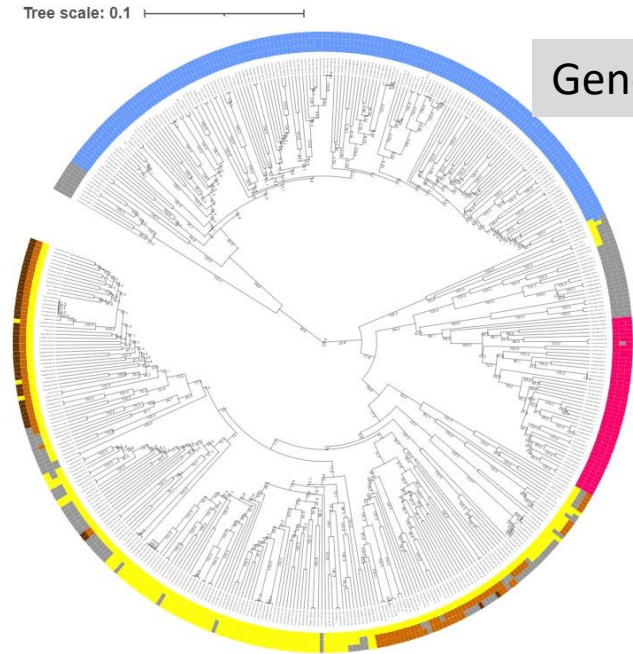
Genome assembly	AOCC (Chang et al., 2019)	S19-3 (unpublished)
Platform	Illumina	Illumina ONT BioNano OM
No. of scaffolds	65,586	23
Longest scaffold (bp)	3,684,321	67,847,779
N50 scaffold length (bp)	640,666	38,635,177
Total nucleotide (bp)	535,052,523	552,045,261
At pseudo-chromosomal level (3 sets of genetic maps)		
No. of scaffolds		17
Total nucleotide (bp)		530,084,832
Unassigned (bp)		15,960,429
Coverage		97.5%



Bambara groundnut – what next?

Some ingredients: partnerships (Africa and SEA), genetic resources (structured populations, ...), potential traits, genomic tools ...

diversity and population structure



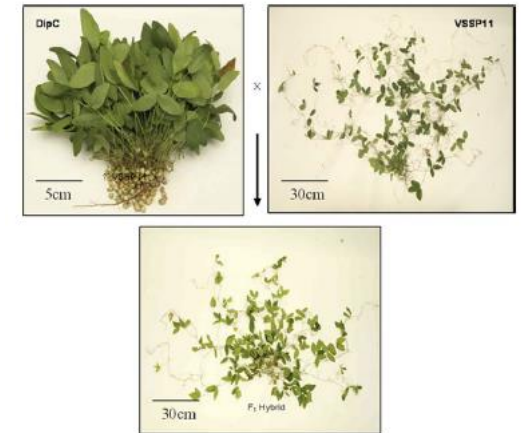
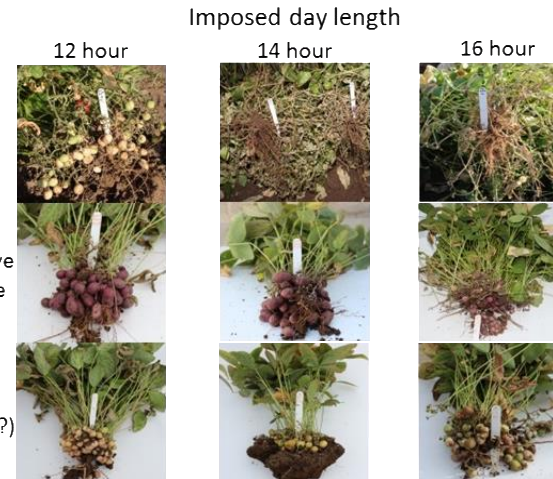
n = 422 (SSD), SNP = 4162, 2500 bootstrapping

Genetic maps

0.0	SNP100015426 F 0-25
7.0	bgPabg-597086-1
8.5	bgPabg-593892-1
11.6	SNP100024750 F 0-20
13.6	SNP100034475 F 0-63
15.0	SNP100009818 F 0-51
16.5	SNP100016201 F 0-55
18.8	SNP100025248 F 0-24
20.9	SNP100010701 F 0-45
23.1	SNP100030004 F 0-31
24.9	SNP100018718 F 0-23
29.2	SNP100007045 F 0-28
33.9	DQ100023869
36.5	SNP100031337 F 0-16
38.6	SNP100009992 F 0-17
39.8	SNP100030038 F 0-29
41.6	SNP100032264 F 0-17
44.4	SNP100028074 F 0-6
45.9	SNP100027856 F 0-9
46.8	SNP100031378 F 0-15
48.3	bgPabg-596774-1
48.8	DQ100023811
49.2	DQ100009408
49.4	SNP100027558 F 0-34
50.1	SNP100027153 F 0-44
51.3	SNP100006188 F 0-55
55.1	SNP100009979 F 0-21
56.2	SNP100027142 F 0-41
57.5	SNP100028068 F 0-20
58.4	bgPabg-593965-1
59.2	SNP100035761 F 0-63
60.9	SNP100003688 F 0-57
62.3	SNP100028865 F 0-42
63.7	SNP100022041 F 0-35
64.1	DQ100043801
65.5	SNP100015620 F 0-9
68.9	SNP100029678 F 0-34
71.5	SNP100011727 F 0-22
71.9	SNP100020429 F 0-63
75.5	SNP100021699 F 0-54
76.3	SNP100030948 F 0-16
78.1	SNP100025104 F 0-52
81.5	SNP100021988 F 0-34
82.2	SNP100005817 F 0-54
84.4	SNP100021970 F 0-59
85.2	DQ100020097
86.2	DQ1000117971
90.5	SNP100020997 F 0-38
94.0	GH-19-B2-D9-1
96.5	PRIMER26-1
101.0	mBam3co7-1
102.2	SNP100030604 F 0-62
107.1	SNP100006888 F 0-36
116.9	SNP100018662 F 0-49
128.7	SNP100031948 F 0-40
130.9	DQ100010829
131.5	DQ100010742
132.4	DQ100011481 SNP100033358 F 0-65
134.8	SNP100034020 F 0-65

photoperiod sensitivity & flowering & maturity time variations

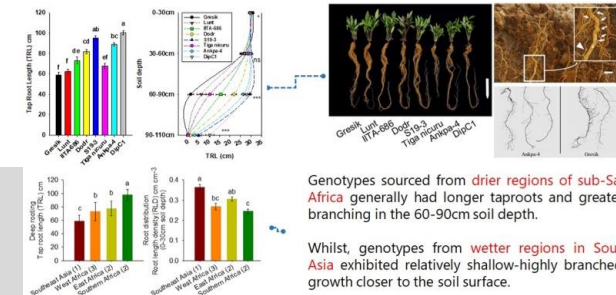
- (1) qualitative short-day type
- (2) quantitative short-day type
- (3) Insensitive (?)



growth habit: bunch vs spreading types



Drought related traits

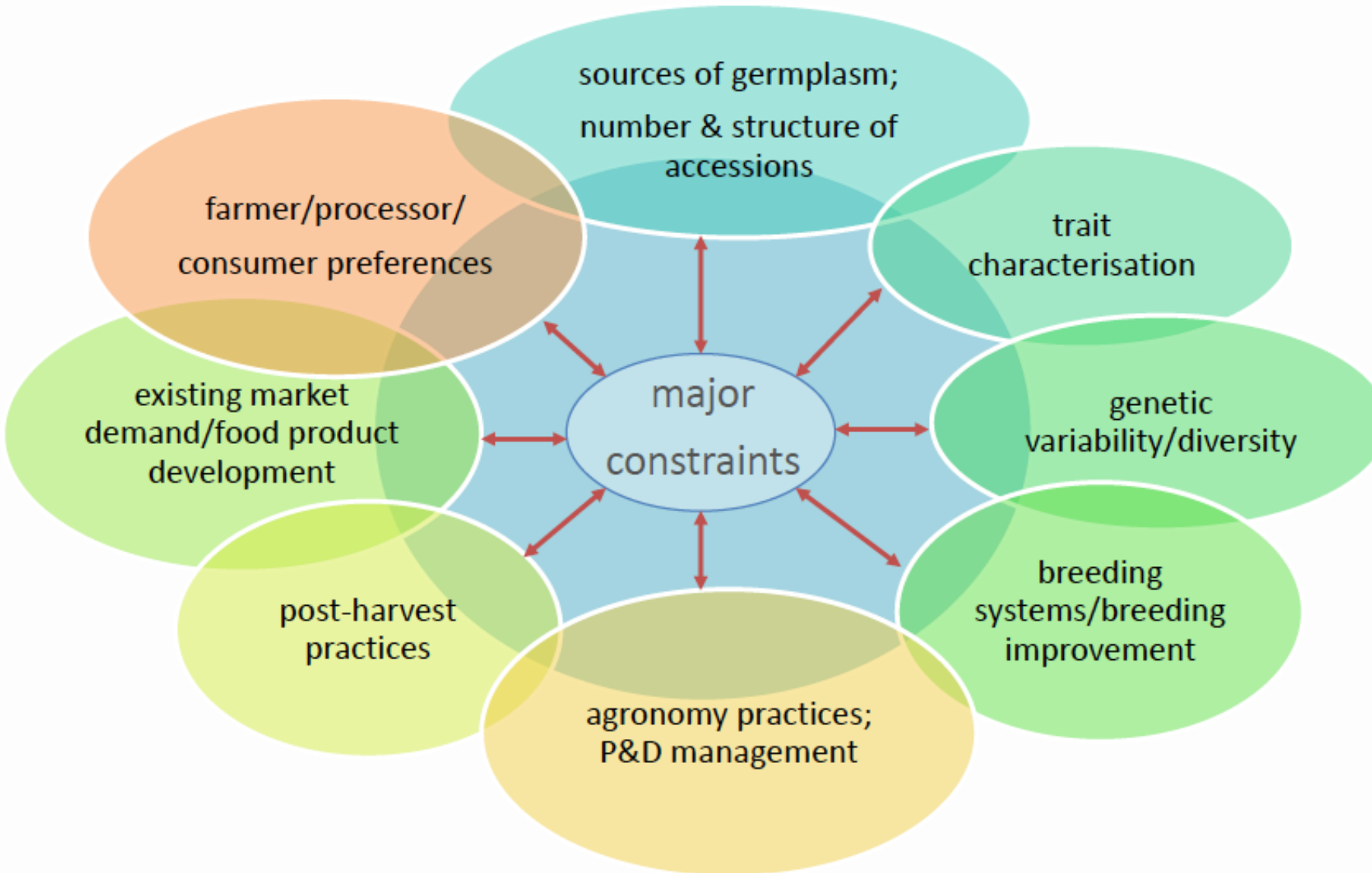


Genotypes sourced from drier regions of sub-Saharan Africa generally had longer taproots and greater root branching in the 60-90cm soil depth. Whilst, genotypes from wetter regions in Southeast Asia exhibited relatively shallow-highly branched root growth closer to the soil surface.

seed coat, size, hard-to-cook (HTC) ...



Some of the constraints in underutilised crops/species: **what next for Bambara groundnut**

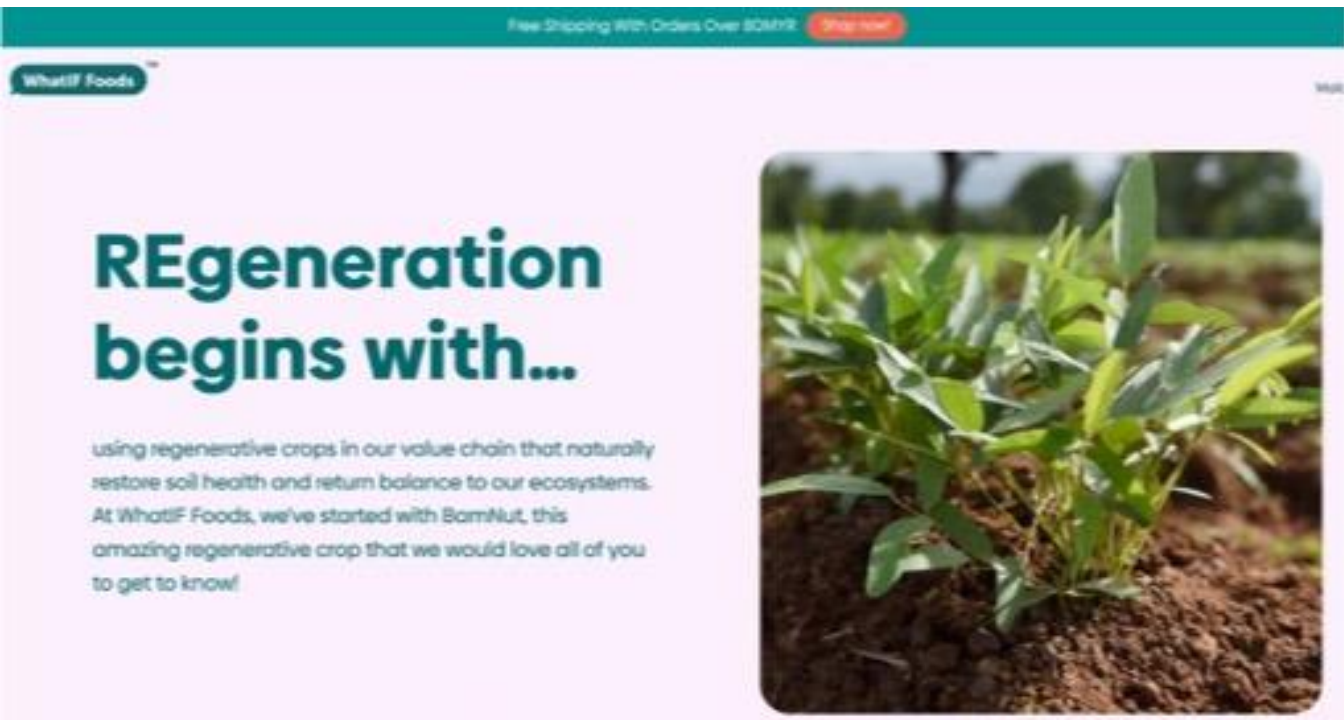


New improved varieties

Crop management

Product development and value chains

Long term research for development efforts



plant-based products



NamZ



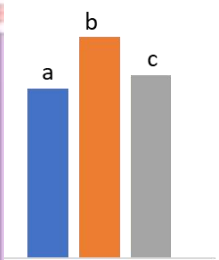
00% Wheat
 0% Wheat:20% Bambara groundnut flour



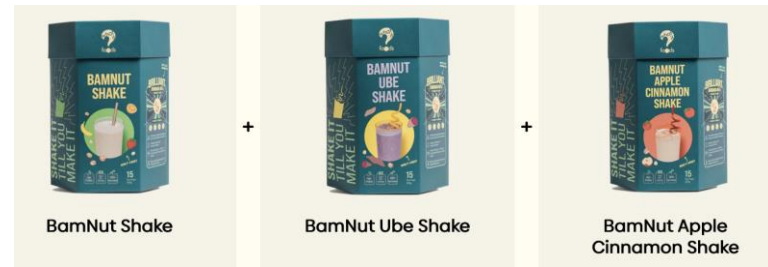
Bambara Milk and Noodles



4% Wheat : 6% Moringa leaves powder



and 6% moringa leaf powder



<https://whatif-foods.com/pages/what-is-bamnut>



Committee Paper for Discussion - ACNFP/152/04

Advisory Committee For Novel Foods and Processes

Traditional Food Notification Number RP1086 – Bambara groundnut

Issue

1. A notification for Bambara Groundnut (*Vigna subterranea*), a traditional food from a third country, has been received under Regulation (2015/2283) (EU retained law).
2. The Committee is asked whether there are safety concerns with the proposed use of this traditional food in the UK market. The information from the Committee will provide the basis for risk management decisions made by the UK.

Background

<https://acnfp.food.gov.uk/BambaraGroundnut>

3. On the 10th of May 2021, the FSA received a notification from Bio-Innovation Zimbabwe for

... intends to market product in dried, roasted and canned forms ...

the specification and conditions of use detailed in the dossier. A risk assessment on the safety of this traditional food is requested to inform this process.

5. The notification dossier is attached as Annex A. Relevant supporting information is attached as Annex B and C. These annexes contain confidential information.

Consideration by the ACNFP of Bambara Groundnut (*Vigna subterranea*) as a traditional food from a third country

Bambara Groundnut Summary

Last updated: 19 January 2023



View as PDF



Print this page

Background

At the 152nd meeting of the Advisory Committee on Novel Foods and Processes (ACNFP) the traditional food from a third country notification dossier for Bambara Groundnut (*Vigna subterranea*) was considered. Bambara groundnut, also referred to as Bambara bean, is a tropical legume crop that grows underground and has many names depending on region of prevalence.

The applicant is requesting authorisation within the UK market for the product in four forms i.e., dried hulled & dehulled, roasted dehulled salted & unsalted, canned in salt water and ground to a flour with adults as the target population. The summary of the application can be found on the [ACNFP website](#).

The advice of the Committee to the Food Standards Agency is summarised below. Please note the Committee did not consider any potential health benefits from consuming the food as the focus of the novel food assessment is to ensure the food is safe, not misleading and not putting consumers at a nutritional disadvantage.

<https://acnfp.food.gov.uk/BambaraGroundnutSummary>



Disrupting the current food system ... *to offer consumers biodiverse products and ingredients that are contributing to a food system that's better for people and planet*



Believe in Bambara is a supplier of the most sustainable plant-based protein, derived from the bambara bean.

Climate Smart Agriculture

Women's Empowerment

Rural Development

Built on the belief that greater cultivation of indigenous crops can not only *provide a secure, local food source,*

... but also generate economic, environmental, and social benefits to farmers

BiB serves as a catalyst to increase the production and demand for bambara groundnut ...

Fighting inequalities by sourcing beans directly from smallholder farming cooperatives, offering them a reliable buyer for their beans, and a secure source of foreign investment ...



BelieveinBambara

ONLINE STORE NOW OPEN 🛒 The wait is over! Our online shop is now open for bambara flour & bean orders.... <https://t.co/MokZLaClyG>

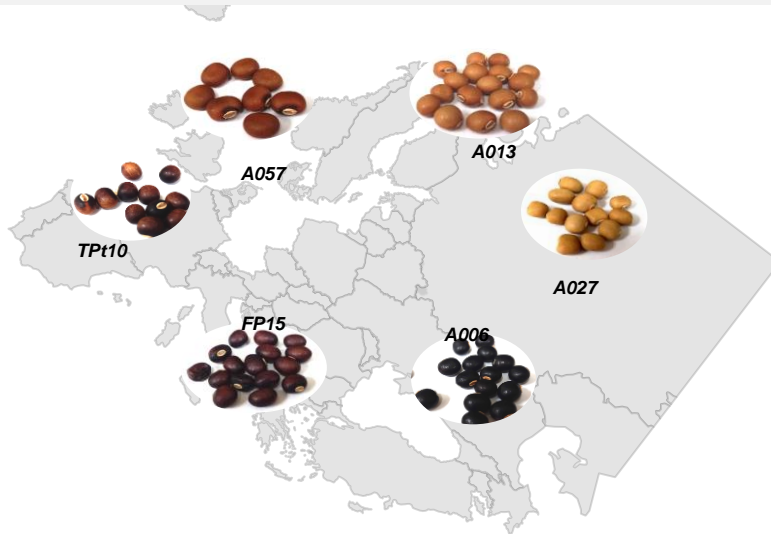
Jun 18, 2019, 4:56 PM

<https://www.believeinbambara.com/>

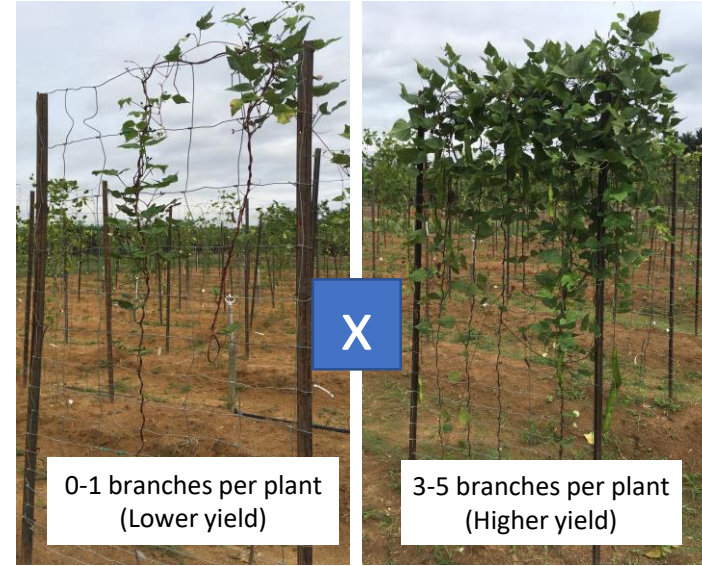


Translating to other under-researched species: winged bean (*Psophocarpus tetragonolobus*)

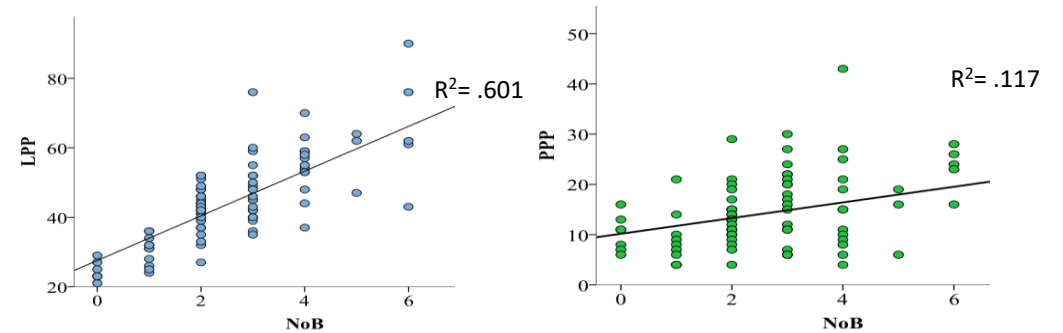
Kachang botor/botol, winged pea, goa bean, Manila bean, Asparagus pea, Prince's pea, princess pea, Dambala, four-angled bean, ...



Parental lines, structured populations and breeding lines



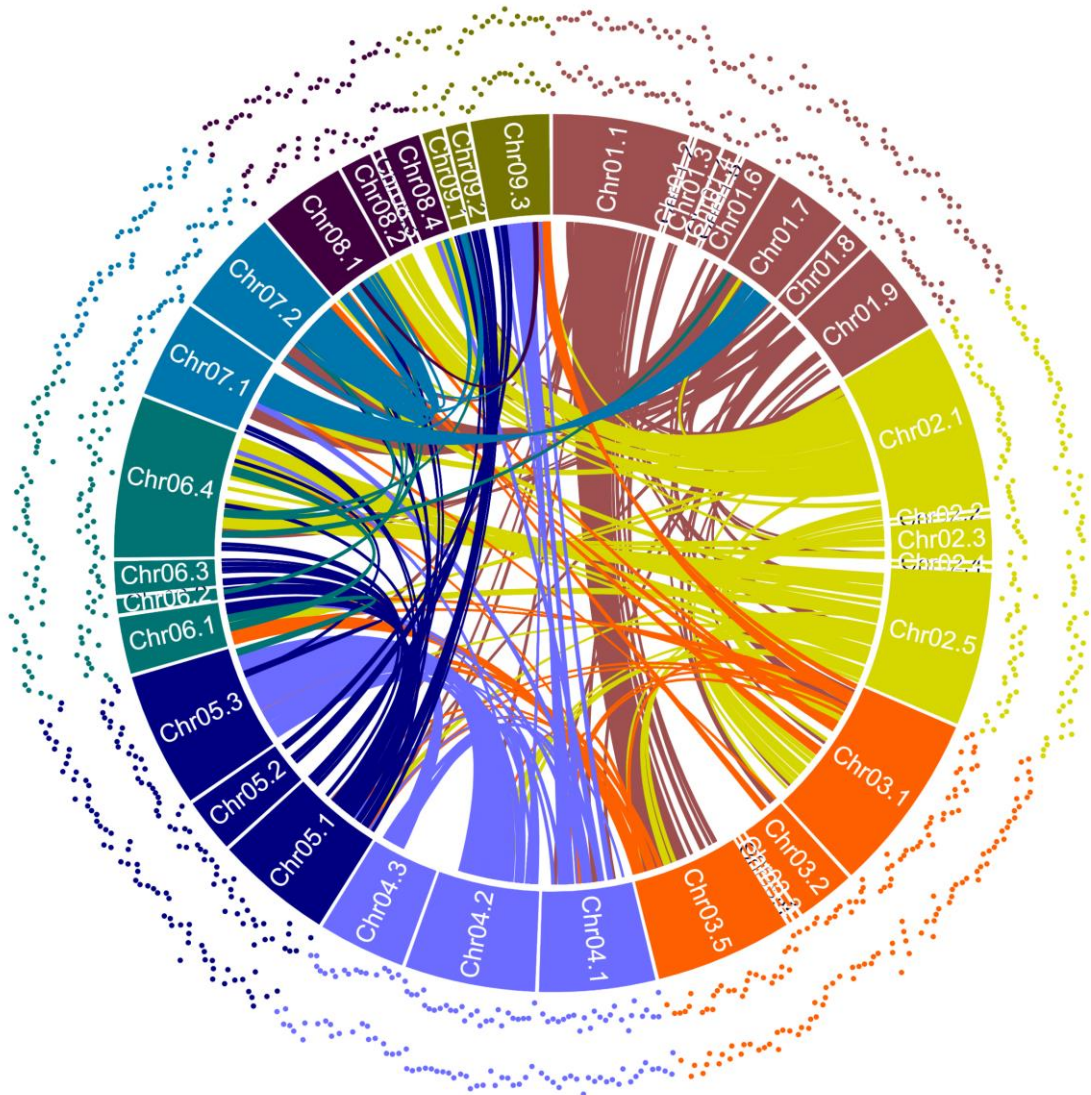
Winged bean plant architecture – differences in number of branches in relation to yield



Plant architecture, early maturity, high yield, quality traits (e.g., protein content; antinutritional factors)



winged/goa bean (*P. tetragonolobus*) ($2n = 2x = 18$) - genome summary



Summary

Hybrid scaffolds (ONT, Illumina, BioNano OM),	
No. of scaffold	48
Min length (Mbp)	0.123
Median length (Mbp)	6.699
Mean length (Mbp)	11.169
N50 length (Mbp)	23.875
Max length (Mbp)	38.637
Total length (Mbp)	536.132
Pseudochromosome, using genetic maps,	
Scaffolds assigned to LGs	
Cross XB (FP15 x Ma3)	32
Cross XT (Tpt10 x Ma3)	38
Unassigned scaffolds to LGs	10
Length of assigned sequences to LGs	530,283,461 bp
Length of unassigned sequences to LGs	5,848,080 bp
N50 pseudochromosome length	23,875,316 bp
K-mer analysis; flow cytometry	~569 Mb; ~782 Mb
Coverage	~ 67.8 - 93.2%



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Training: Doctoral Training Programme/ECRs



A community for
exchange of ideas and
experiences

Training programmes on
transdisciplinary research
approaches and
transferable skills



CFF-UNM Doctoral Training Partnership
Student engagement and capacity development for future agriculture

The research teams usually comprise of:
Dual (or more) supervisory teams; international research teams across different disciplines and/or institutes

Multi-site research activities (frequent mobility between institutes) - communication with experts and non-experts



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AOC African Orphan Crops Consortium
Healthy Africa through nutritious, diverse and local food crops

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TUM TECHNISCHE UNIVERSITÄT MÜNCHEN

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THE INTERNATIONAL TREATY ON PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

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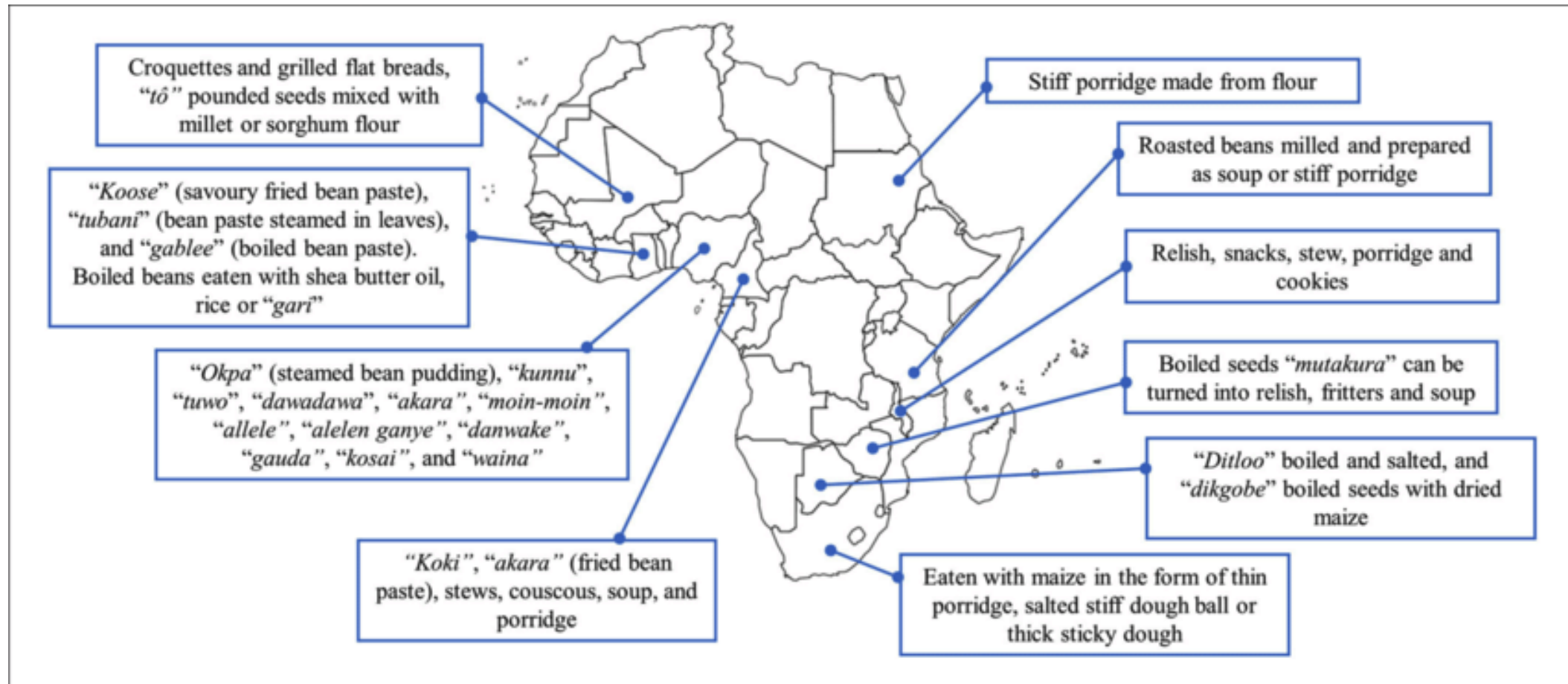
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Winged bean





Traditional local- delicacies in different African countries prepared from Bambara groundnut





An overview of the challenges and opportunities of utilizing Bambara groundnut

