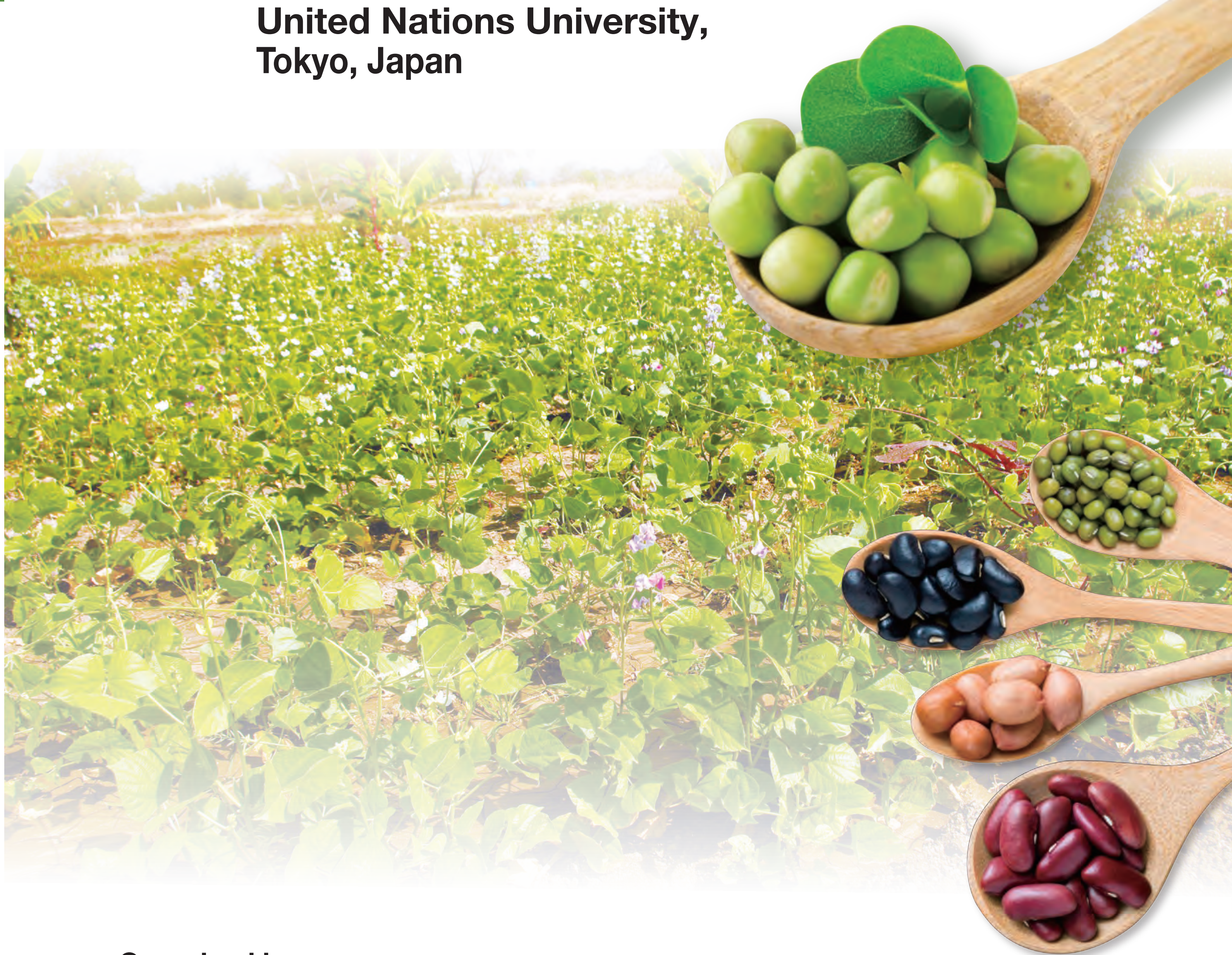
JIRCAS International Symposium 2016

Legumes Improve Our Livelihood!

Proceedings

Date : December 2, 2016

Venue : U Thant International Conference Hall, United Nations University, Tokyo, Japan



Organized by

Japan International Research Center for Agricultural Sciences (JIRCAS)

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JIRCAS International Symposium 2016
United Nations University, Tokyo, Japan
December 2, 2016

Opening Remarks

Masa Iwanaga
President, JIRCAS

Ladies and gentlemen, good morning. On behalf of the organizers, it is my great honor and privilege to open the JIRCAS International Symposium 2016, themed “Legumes Improve Our Livelihood!” This symposium is organized by Japan International Research Center for Agricultural Sciences (JIRCAS) and co-organized by the United Nations University Institute for the Advanced Study of Sustainability (UNU-IAS), together with the generous support of the Research Council Secretariat of the Ministry of Agriculture, Forestry and Fisheries (MAFF, Japan), the National Agriculture and Food Research Organization (NARO), Japan Pulse Foundation, Japan Liaison Office of the Food and Agriculture Organization (FAO) of the United Nations, and the Japan Forum on International Agricultural Research for Sustainable Development (J-FARD).

First of all, I would like to extend my cordial welcome to all guests and participants, particularly those who came from overseas. I would also like to express my sincere gratitude to our prominent keynote speakers – Dr. David Bergvinson, the Director General of International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), which has its headquarters in India, and Professor Kazumi Maeda, Professor Emeritus of Kochi University, Japan.

My appreciation is also extended to the other speakers, Chairs, and participants in the following sessions today.

This year, 2016, is the International Year of Pulses as declared by the United Nations. To celebrate this auspicious occasion, we decided the theme of this year’s symposium to revolve around legumes. Legumes is a term that refers to a broader range of leguminous crops as compared to pulses. Legumes include soybean and groundnut, both of which are significant as food and nutrient sources in Asia. We can expect a clear description of this in the keynote speech by Professor Maeda.

2016 is also the year that we begin our efforts to achieve the Sustainable Development Goals or SDGs. Legumes are expected to contribute chiefly to the second SDG, that is, to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture.

In this symposium, we will evaluate the wonderful nature of leguminous crops as explored from different viewpoints - for instance, in history, diversity, and utilization, food security and human health, environment and land sustainability, and value-adding products - to enhance local and international economy through the keynote speeches and three sessions that follow. Then, we would discuss about the future and ways toward further utilization of legumes for global development in line with the aims set out by the SDGs.

Also, please note that we at JIRCAS have started our new research programs which include leguminous crops as an important component of a few projects. It is a timely and relevant opportunity for us to recognize the power of legumes, share experiences, and address important issues in studies related to legumes, as well as to explore new directions for our partnerships.

Finally, I would like to express my sincere hope that with your precious contribution, this symposium will be fruitful and will achieve the objective for which it was organized. Thank you very much.

Welcome Address

Masamichi Saigo

Director General, Agriculture,
Forestry and Fisheries Research Council Secretariat,
Ministry of Agriculture, Forestry and Fisheries (MAFF)

Good morning, ladies and gentlemen. Welcome to the symposium. I would like to use Japanese language, so please use the earphones for English speakers.

Thank you very much for your kind introduction. My name is Masamichi Saigo from MAFF. To the organizers and participants of the JIRCAS International Symposium, I would like to say a few words. As President Iwanaga mentioned, we have been looking at the statistics of the food problem in the world. In 2050, the population will reach 9.7 billion, which is a little under 10 billion, and the emerging countries will continue to have increasing income levels; therefore, consumption is expected to dramatically change in the mid to long-term. There are concerns that the food supply and demand will become tighter. Under such circumstances, what will be the status of production? There is much potential; however, if you look at the situation for rice and wheat, we don't have much room to increase production. But the goals, most recently the SDGs or Sustainable Development Goals, have been developed in many areas and formally adopted last September by the UN under its 2030 Agenda; thus in the area of food and agriculture, we would like to know the status of the SDGs.

The previous goal under the MDGs, adopted at the time of the Millennium Agenda and carried out until last year, 2015, was to reduce the population suffering from starvation to half their number in 1990. That was our target, and we think that we have already achieved that goal. Some of you may consider that it has not yet been reached, but based on this, we are pursuing the new goal of putting an end to hunger as well as achieve food security and promote sustainable agriculture. These are outlined within the SDGs.

What we are going to take up in this symposium is the use of legumes and the utilization of legumes. So, in order to achieve the SDGs, this is going to be a very important area. As you know, this year has been specified as the International Year of Pulses by the United Nations and as you have seen at the entrance, there are different varieties of pulses and from the perspective of the Japanese people, we have a certain image; but, if you go to other parts of the world, they are quite different and it's quite profound and depending on the regions, they are deeply rooted in the lives of the people. In that respect, it is very important towards achieving sustainability in our society. Also, from the perspective of agriculture, it is very important because of nitrogen fertilizers and the capacity of legumes to fix nitrogen from the air. Apparently, legumes enhance the production capability of the soil, in addition to the fact that they are very nutritious as food.

As will be discussed today, we will focus on the importance of legumes and pulses in the area of food security and in improving food nutrition, and organizing this symposium enables us to disseminate various information from our side. Putting an end to hunger is such a major goal, and we must bear in mind that achieving this requires considerable investments, especially to developing countries. There are different countries around the world, and in countries with less than ideal conditions, we should be able to use not just our instinct and experience but also our scientific knowledge to develop legumes and pulses. This will be very important to the regions and to the world.

This is true for MAFF as well, and I think this is true to all developing countries, even as the official research budgets for these activities have been reduced and we have been causing so much inconvenience to all of you. It is not because of that background, but in principle, we have to work together with the private sector. The ODA will not be sufficient, thus we need to collaborate with the private sector or beyond different frameworks, and we need to promote investment in research. Yesterday, the Director of ICRISAT mentioned that in any kind of institution, collaboration with the private sector is very important and they are interested, so we would also like to pursue that possibility.

As I mentioned, we have a major goal and the world is currently making its utmost effort, so we shouldn't wait too much to implement this. We hope to have very lively discussions. Thank you very much.

Welcome Address

Kazuhiko Takemoto

Director,

Institute for the Advanced Study of Sustainability,
United Nations University (UNU-IAS)

Director General Saigo, Dr. David Bergvinson, Professor Maeda, excellencies, distinguished guests, ladies and gentlemen. On behalf of the United Nations University, I am very pleased to welcome you to this International Symposium. This conference is aimed to address sustainable development through enhancing food security by promoting the production of legumes. I am also very delighted to take this opportunity to celebrate the International Year of Pulses 2016.

In this symposium, we will revisit the value and deepen our understanding of leguminous crops in a wide range of perspectives through today's discussions.

As Dr. Iwanaga and Director General Saigo have already mentioned, last year, the United Nations General Assembly adopted the 2030 Agenda for Sustainable Development, including the Sustainable Development Goals or the so-called SDGs. The international community has already started working efforts to address these goals, including those on food security.

Our institute, the United Nations University Institute for the Advanced Study of Sustainability, is the leading research and teaching institute. It is our mission to advance efforts toward a more sustainable future through relevant policy, relevant research and capacity building development activities, focused on sustainability in three thematic areas namely sustainable societies, natural capital and biodiversity, and global change and resilience.

In light of this, I am very much looking forward to having dynamic discussions here today. We are very fortunate to have Dr. David Bergvinson and Professor Maeda here as the keynote speakers in this symposium. We expect professional and insightful input from these international experts.

Finally, ladies and gentlemen, I would like to conclude my remarks by wishing you a fruitful symposium as a very good start to further develop technologies for sustainable agriculture, forestry, and fisheries with your active participation. Thank you and welcome. Thank you very much.

Keynote Speech

Chair:

Kunihiro Doi, JIRCAS

POTENTIAL OF LEGUMES: GLOBAL NEEDS AND CHALLENGES

David J Bergvinson

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India
Email address: d.bergvinson@cgiar.org

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DAVID BERGVINSON, Director General of the International Crops Research Institute for the Semi-Arid Tropics. David joined ICRISAT on January 5, 2015 to lead its strategy development to ensure solid science, demand-driven innovation and strategic partnerships that translate science into prosperity for rural families in the dryland tropics of Asia and sub-Saharan Africa. During David's eight years at the Bill & Melinda Gates Foundation and now at ICRISAT, he continues to lead teams to leverage the power of digital technology to accelerate the development and delivery of farmer-preferred products and services to increase agriculture productivity of smallholder farmers in a sustainable and equitable manner in the developing world.

ABSTRACT

Hunger and malnutrition are preventing millions of children from realizing their full potential that will have long-term implications for society and economic development. Undernutrition contributes to the death of over 3 million children each year and for those who survive, robs them of reaching their full potential in life. Of the 795 million who suffer from undernutrition, 780 million live in developing countries (FAO, 2015). Therefore, it is essential to adopt an inclusive and demand-driven approach to accelerate the design, development and delivery of science-based solutions to address undernutrition. Pulses (or grain legumes) offer a rich source of protein and nutrients to combat undernutrition and contribute to a balanced diet (Foyer et al 2016), while also improving soil health and increasing the agro-biodiversity of our cropping systems around the world (Siddique et al. 2012). Enhancing public awareness on the contribution of pulses to modern food systems was the intent of the 68th UN General Assembly declaring 2016 as the International Year of Pulses (IYP).

Pulses make tremendous contributions to sustainable food production systems through their ability to fix symbiotic nitrogen from the atmosphere. This has important nutritional implications for humans, livestock and the soil. However, adoption of improved production technologies for pulse crops is not keeping pace with the major cereal crops (maize, wheat, and rice). The area planted to pulses has gradually increased over the past 50 years, but it is still only a quarter of that planted to maize, wheat and rice. While changes in agronomic practices and new varieties of pulses have occurred over the past two decades, increase in pulse production is not keeping pace with demand that is leading to price volatility, especially in developing countries. Pulses play a critical role in conservation agriculture (CA) by rotating them with cereals, enabling minimum tillage and improved soil health over time. Adoption of CA is slowly picking up in smallholder farming systems in Asia and Africa, with increasing availability of herbicides and development of implements suitable for minimum tillage and business models to make mechanization economically viable. Decision support systems are now being developed to support smallholder farmers in choosing cultivars, sowing date, and best agronomic practices that are fundamental to enhance pulse production and profitability for farmers.

Despite being important crops from different perspectives, the average productivity of pulse crops is very low as they are exposed to a number of biotic and abiotic stresses in sub-Saharan Africa and Asia. Therefore, with the objective of increasing production, reducing poverty, hunger, and malnutrition of smallholder farmers, while improving the health of humankind and the sustainability of farming systems in the next 10 years, ICRISAT is leading the CGIAR Research Program - Grain Legumes (CRP-GL) that is targeting research for development in eight major food legumes including chickpea, common bean, cowpea, faba bean, groundnut, lentil, pigeonpea, and soybean that are primarily grown by smallholder farmers in South and South East Asia, sub-Saharan Africa, Central and Western Asia, North Africa, Latin America and the Caribbean. The main aim of the CRP-GL is to combat poverty, hunger, malnutrition and environmental degradation by increasing productivity, profitability and consumption of grain legumes. During last four years, CRP-GL partners have leveraged their knowledge and research capacities by coordinating strategies with diverse public and private organizations. CRP-GL partners have released over 250 grain legumes varieties, 4 pigeonpea hybrids, and facilitated production of over 445,847 tons seeds of improved varieties of legumes. To create awareness among farmers, processors and policy makers, over 23,000 demonstration trials were conducted to support best management practices. In brief, 30,000 people (including 17,000 women) were trained in short-duration training courses.

With an objective to enhance genetic gains, the CRP-GL partners have also made significant advances in developing genomics tools, technologies and platforms for accelerating genetic gains and innovative seed systems to support the delivery of improved pulses to farmers. For instance, the genome sequences that are now available for legume crops include chickpea, pigeonpea, common bean, groundnut, and soybean, and efforts are underway in lentil and faba bean. Several thousands to millions of molecular markers are now available in legume crops (Varshney 2016). High-density genotyping platforms such as Affymetrix SNP arrays, Illumina arrays, genotyping-by-sequencing have

been developed for cost-effective genotyping in several legume crops. By using these genotyping platforms and precision phenotyping, a wide range of marker-trait associations have been established for grain legumes to enhance precision and efficiency of breeding programs. Successful examples of molecular breeding include the development of superior lines with enhanced drought tolerance, Fusarium wilt and Ascochyta blight resistant lines in chickpea, leaf rust and late spot resistant lines in groundnut, improved oil quality lines in groundnut and utilization of markers for assessing purity of hybrids/parental lines in pigeonpea (Varshney 2016). Hybrid pigeonpea is now available and being adopted in India and Kenya by seed companies and farmers, and Bt-chickpea and Bt-pigeonpea are being test in trials at ICRISAT.

During the past year, pulses have enjoyed increased demand by producer and consumers in response to the awareness of the nutritional and environmental benefits pulses offer – thanks in part to the International Year of Pulses. This in turn is leading to economic benefits for smallholder farmers in the developing world who can respond to market signals and access domestic and international market opportunities. However, more is required to support farmers access appropriate knowledge, inputs and mechanization to reduce production costs and equitable markets to translate increased productivity into profitability.

In summary, grain legumes, provide an opportunity to ensure nutritional security in both the developed and developing world and through increased demand, enhance farmers' income and profitability. With recent advances in modern tools for breeding, agronomy and market integration, it is now possible to unlock the full potential of grain legumes to support the realization of the Sustainable Development Goals within 14 years. To realize this, public-private-producer partnerships will be required that draw on science-based, demand-driven innovations and enabling policies to ensure pulses play an increasingly important role in global nutritional security that will enable us to live within the planetary boundaries.

KEYWORDS

pulses, grain legumes, pest and disease resistance, drought tolerance, genetic gains, conservation agriculture, inclusive market oriented development, nutritional security

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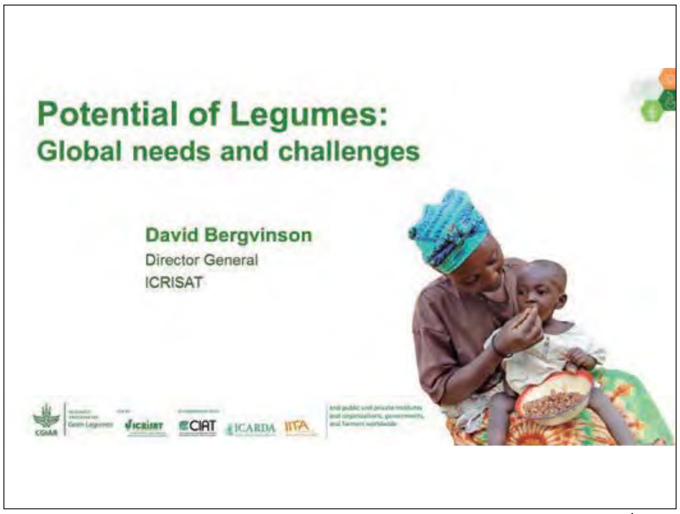
Varshney RK, 2016: Exciting journey of 10 years from genomes to fields and markets: Some success stories of genomics-assisted breeding in chickpea, pigeonpea and groundnut. Plant Sci. 242: 98-107.


Potential of Legumes:
Global needs and challenges
David Bergvinson
Director General
ICRISAT

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Outline
• IYP key messages
• Why pulses?
• Pulse global production, trade and consumption
• Health benefits of pulses – Chickpea & Pigeonpea
• Conclusions
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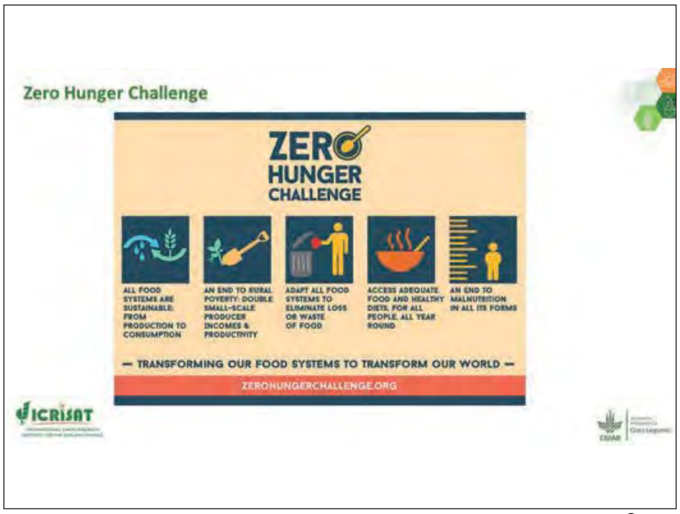
Zero Hunger Challenge
ZERO HUNGER CHALLENGE
ALL FOOD SYSTEMS ARE SUSTAINABLE: FROM PRODUCTION TO CONSUMPTION
AN END TO RURAL POVERTY: DOUBLE SMALL-SCALE PRODUCER INCOMES & PRODUCTIVITY
ADAPT ALL FOOD SYSTEMS TO ELIMINATE LOSS OR WASTE OF FOOD
ACCESS ADEQUATE FOOD AND HEALTHY DIETS, FOR ALL PEOPLE, ALL YEAR ROUND
AN END TO MALNUTRITION IN ALL ITS FORMS
— TRANSFORMING OUR FOOD SYSTEMS TO TRANSFORM OUR WORLD —
ZEROHUNGERCHALLENGE.ORG
ICRISAT

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17 Sustainable Development Goals with emphasis on sustainable and equitable food systems
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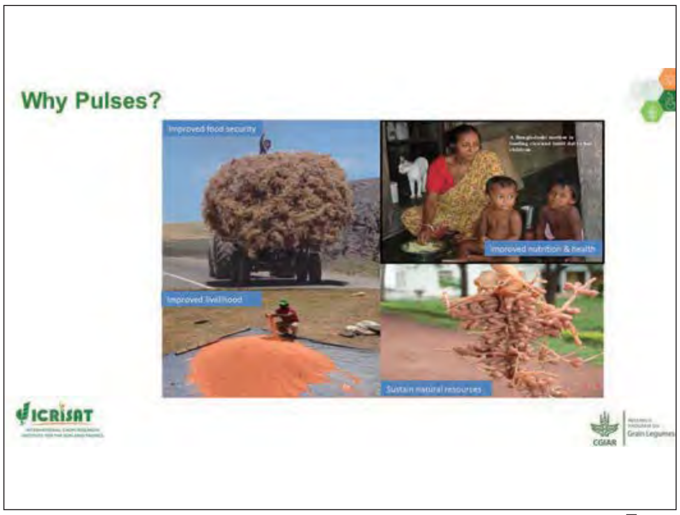
Why Pulses?
Improved food security
Improved nutrition & health
Improved livelihood
Sustain natural resources
ICRISAT

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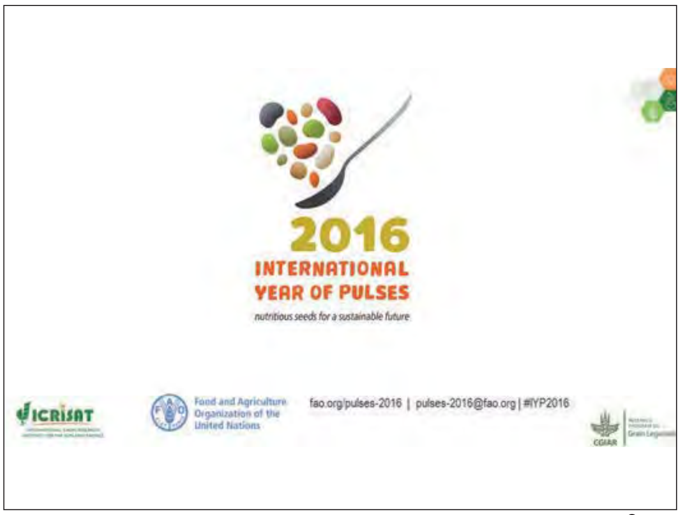
2016
INTERNATIONAL YEAR OF PULSES
nutritious seeds for a sustainable future
ICRISAT
Food and Agriculture Organization of the United Nations
fao.org/pulses-2016 | pulses-2016@fao.org | #IYP2016

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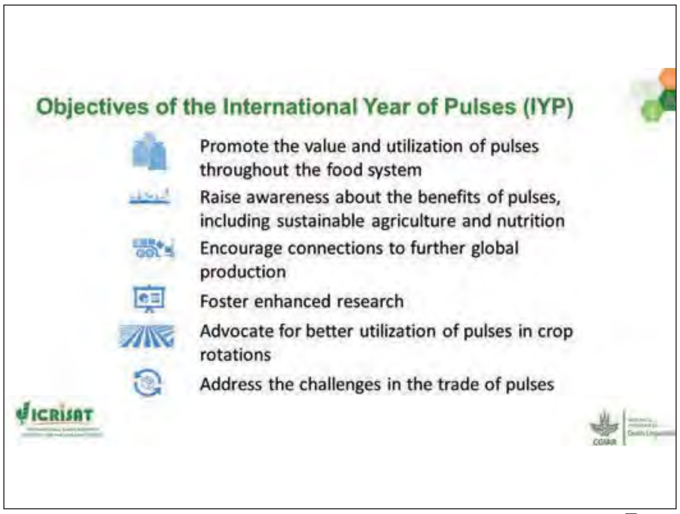
Objectives of the International Year of Pulses (IYP)
Promote the value and utilization of pulses throughout the food system
Raise awareness about the benefits of pulses, including sustainable agriculture and nutrition
Encourage connections to further global production
Foster enhanced research
Advocate for better utilization of pulses in crop rotations
Address the challenges in the trade of pulses
ICRISAT
CGIAR

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Global investment in pulse R,D&E is too low compared with cereal crops: (US $ 175 million per annum in 13 pulse crops)
nature plants
PERSPECTIVE
Neglecting legumes has compromised human health and sustainable food production
Christine H. Foyer, Hon-Ming Lam, Henry T. Nguyen, Kadambot H. M. Siddique, Rajeev Varshney, Timothy D. Colmer, Wallace Cowling, Helen Bramley, Trevor A. Mori, Jonathan M. Hodgson, James W. Cooper, Anthony J. Miller, Karl Kunert, Juan Vorster, Christopher Cullis, Jocelyn A. Ozga, Mark L. Wahlqvist, Yan Liang, Huixia Shou, Kai Shi, Jingquan Yu, Nandor Fodor, Brent N. Kaiser, Fuk-Ling Wong, Babu Valliyodan and Michael J. Considine
ICRISAT
CGIAR

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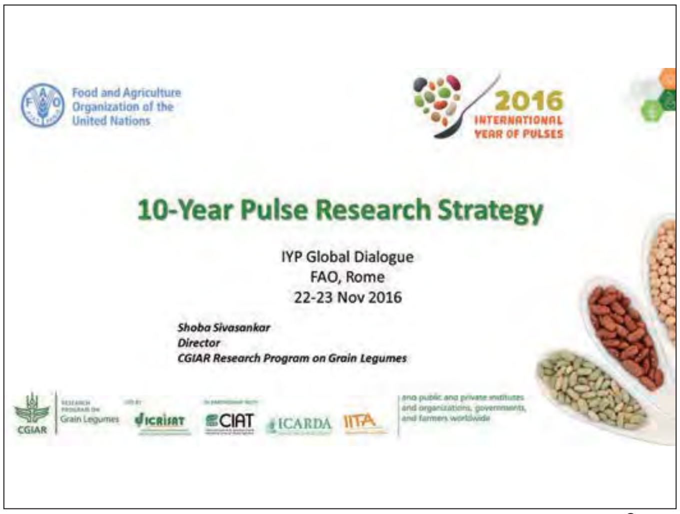
Food and Agriculture Organization of the United Nations
2016 INTERNATIONAL YEAR OF PULSES
10-Year Pulse Research Strategy
IYP Global Dialogue
FAO, Rome
22-23 Nov 2016
Shoba Sivasankar
Director
CGIAR Research Program on Grain Legumes
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Grain Legumes
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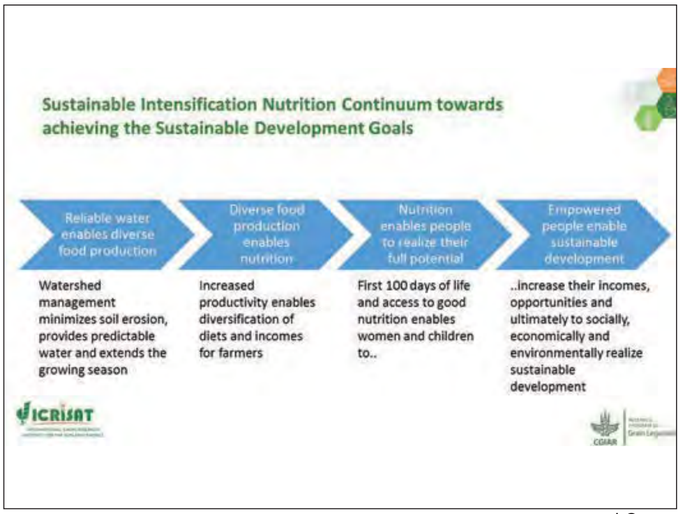
Sustainable Intensification Nutrition Continuum towards achieving the Sustainable Development Goals
Reliable water enables diverse food production
Diverse food production enables nutrition
Nutrition enables people to realize their full potential
Empowered people enable sustainable development
Watershed management minimizes soil erosion, provides predictable water and extends the growing season
Increased productivity enables diversification of diets and incomes for farmers
First 100 days of life and access to good nutrition enables women and children to..
..increase their incomes, opportunities and ultimately to socially, economically and environmentally realize sustainable development
ICRISAT
CGIAR

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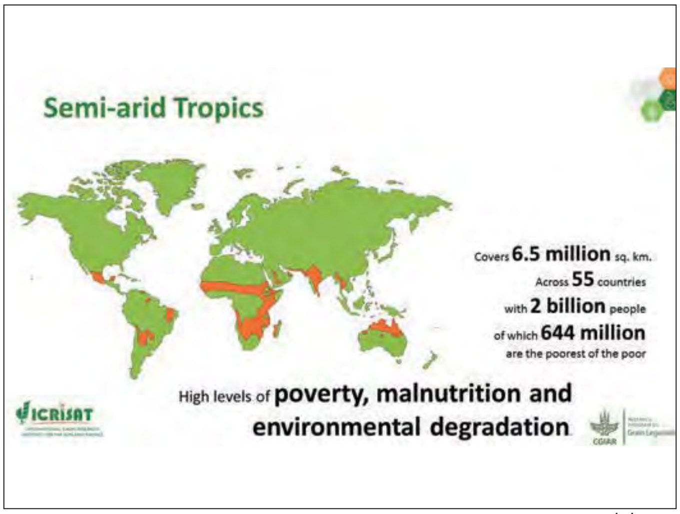
Semi-arid Tropics
Covers 6.5 million sq. km.
Across 55 countries
with 2 billion people
of which 644 million are the poorest of the poor
High levels of poverty, malnutrition and environmental degradation
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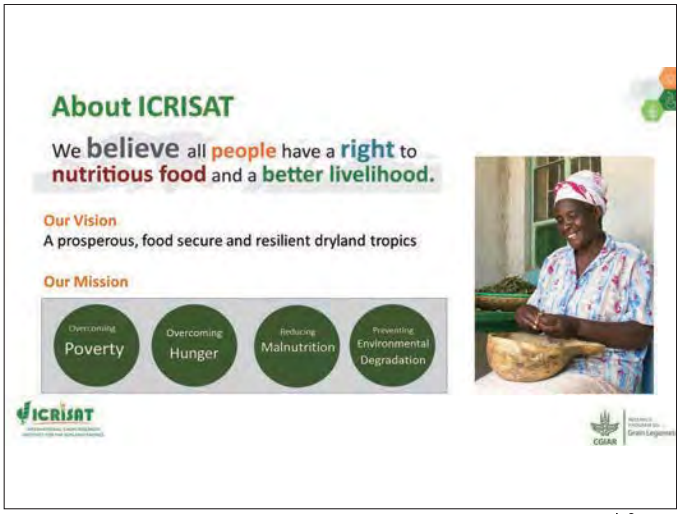
About ICRISAT
We believe all people have a right to nutritious food and a better livelihood.
Our Vision
A prosperous, food secure and resilient dryland tropics
Our Mission
Overcoming Poverty
Overcoming Hunger
Reducing Malnutrition
Preventing Environmental Degradation
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CGIAR

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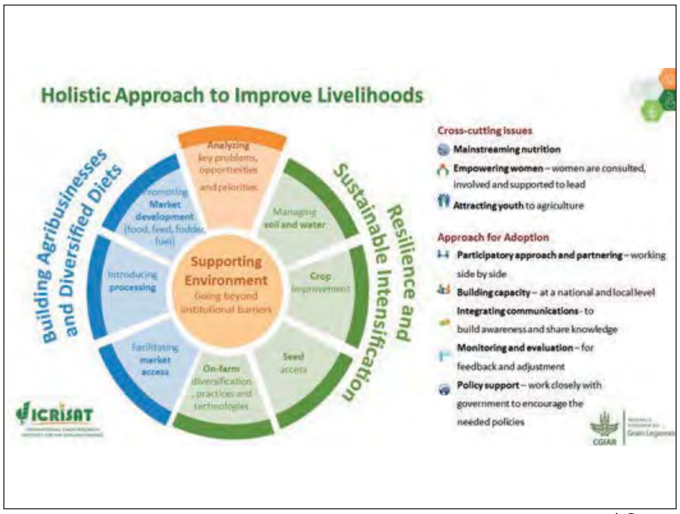

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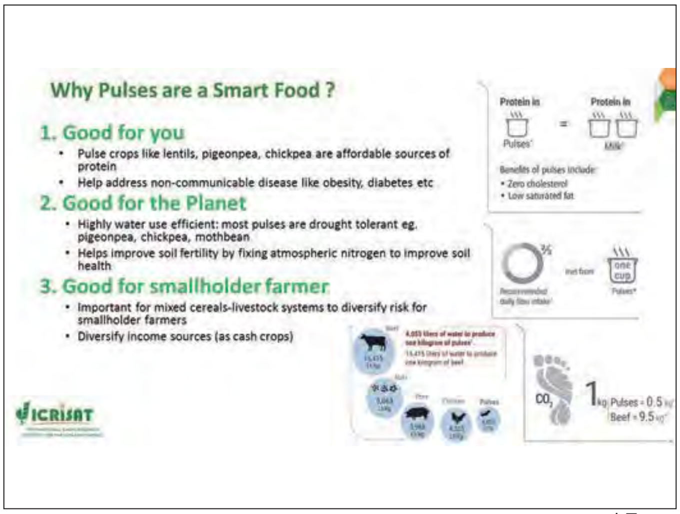

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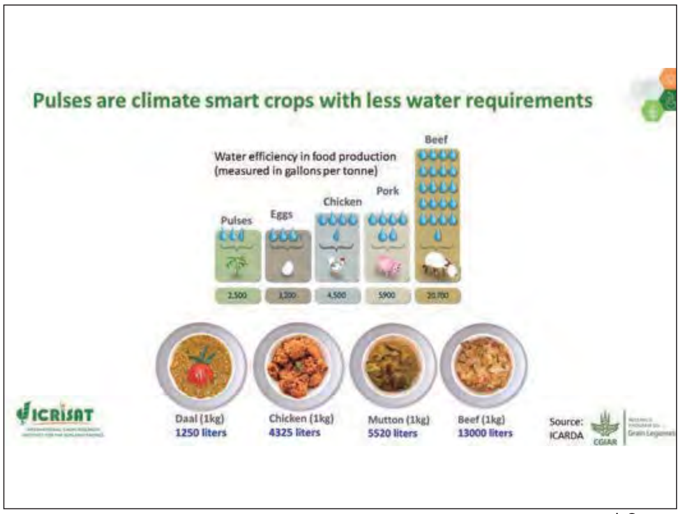

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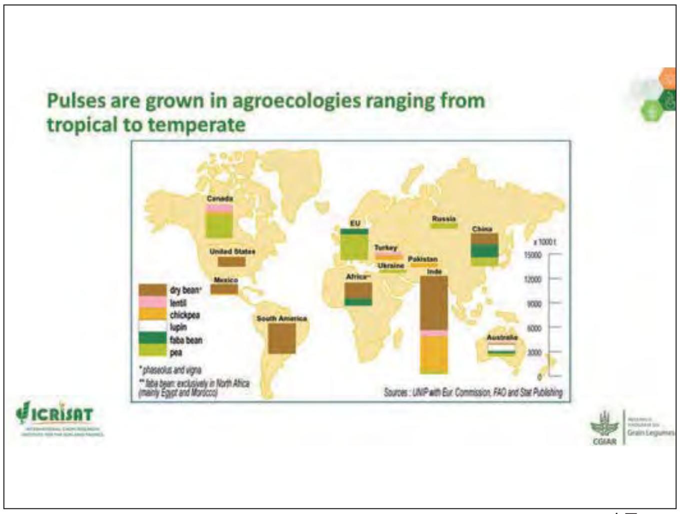

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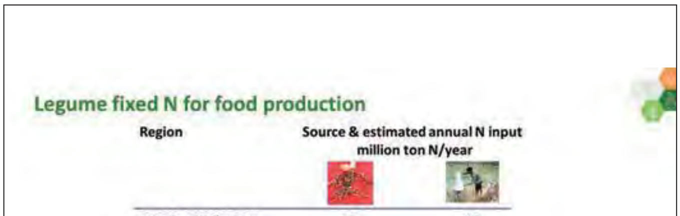

Region	Source & estimated annual N input million ton N/year	
Asia & middle East	19	47
Europe	3	14
North America	8	14
Africa	3	5
South America	10	6
Australia	4	1
Total Global	47	87

value =>US$50 billion

Source: Herridge *et al* (2008) *Plant & Soil* 311:1-18
Peoples *et al* (2009) *Nitrogen Fixation in Crop Production: Agronomy Monograph 52*, pp.349-385

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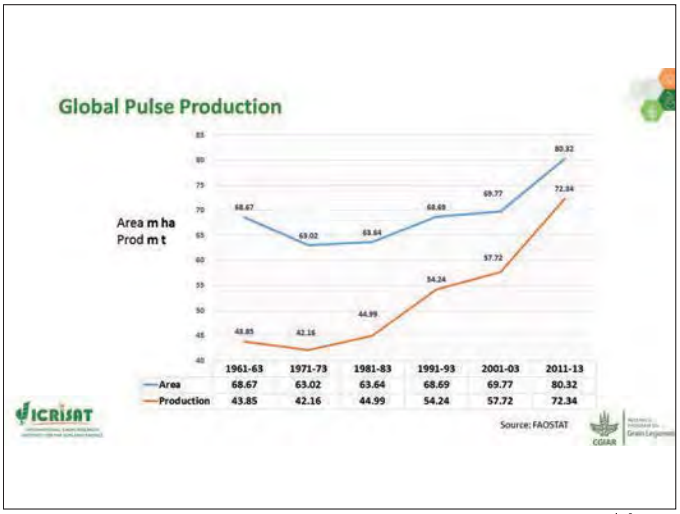

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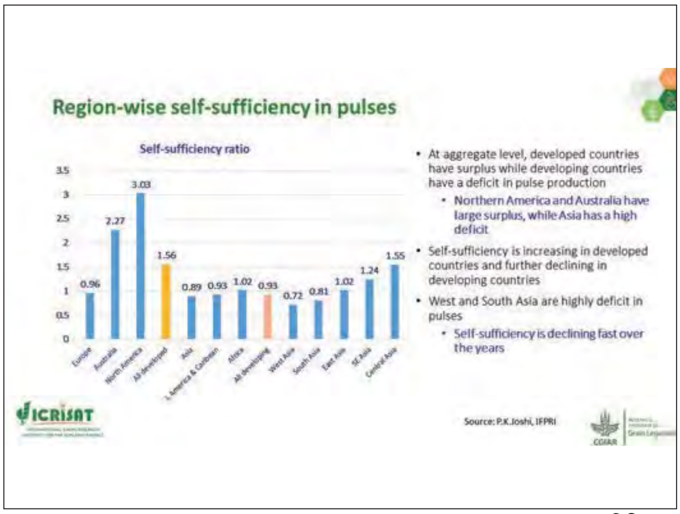

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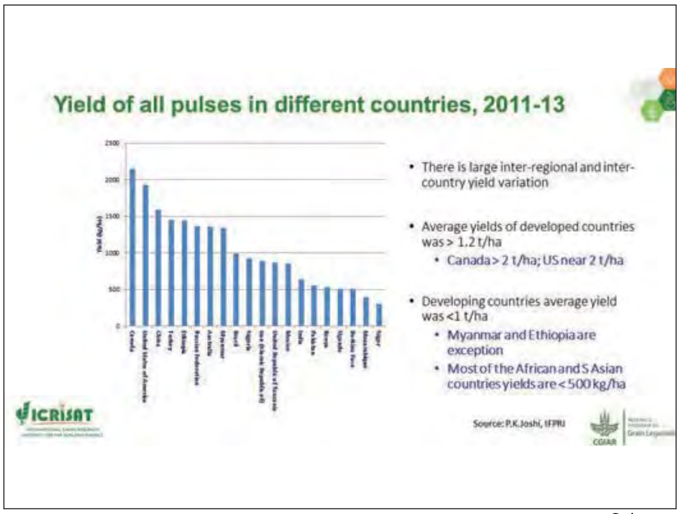

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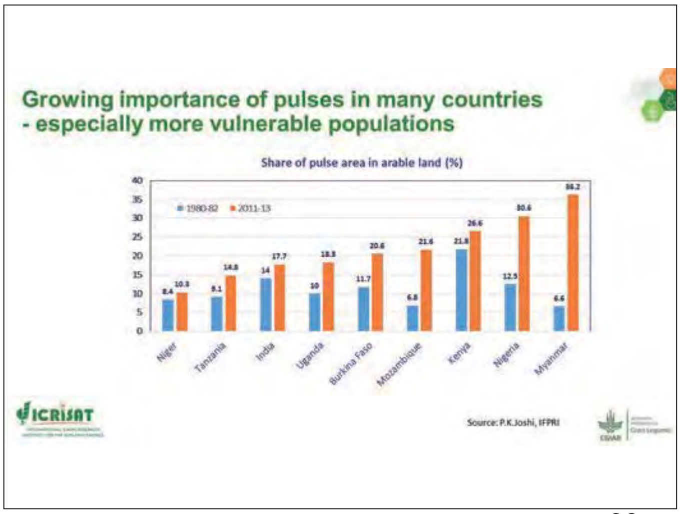

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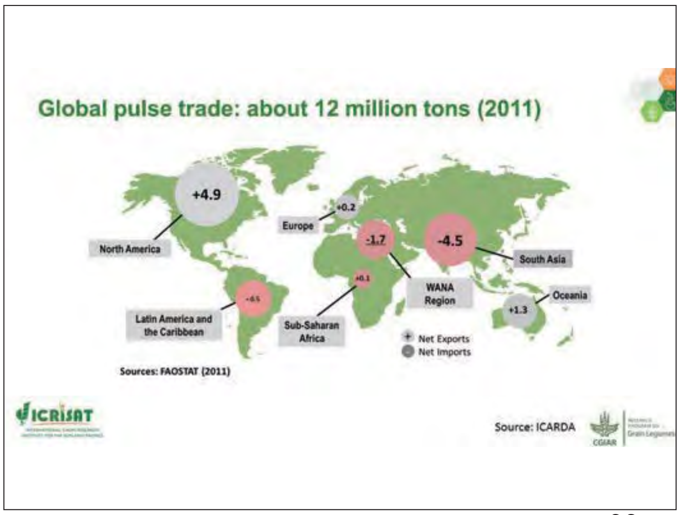

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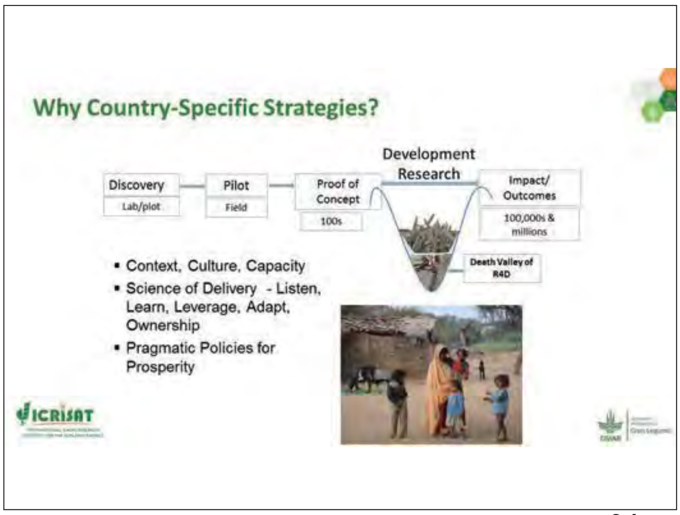

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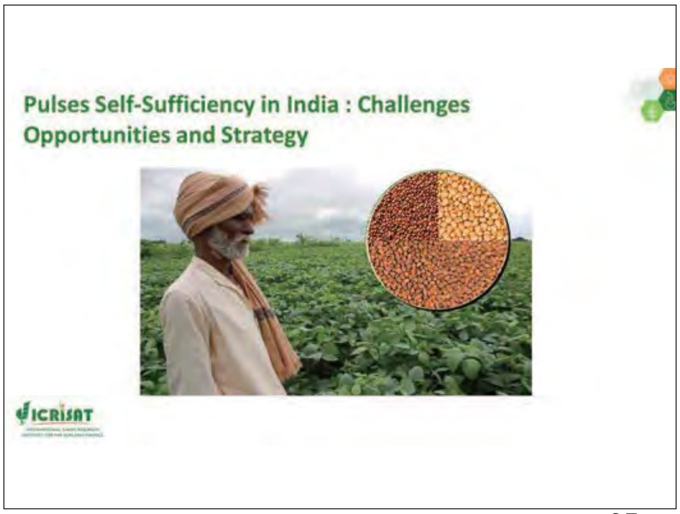

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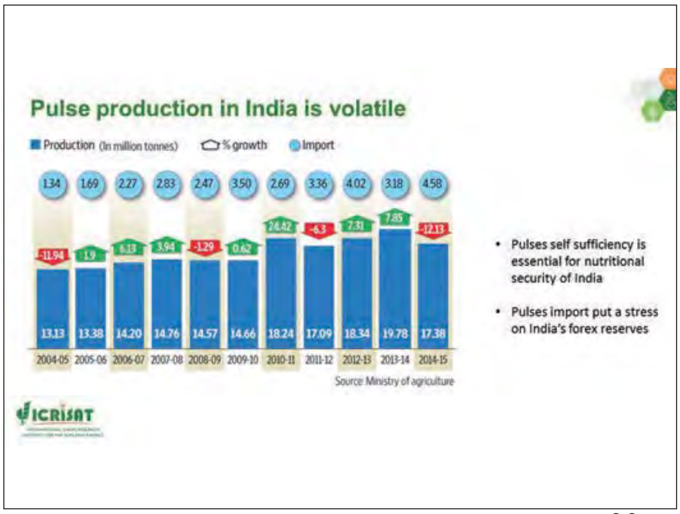

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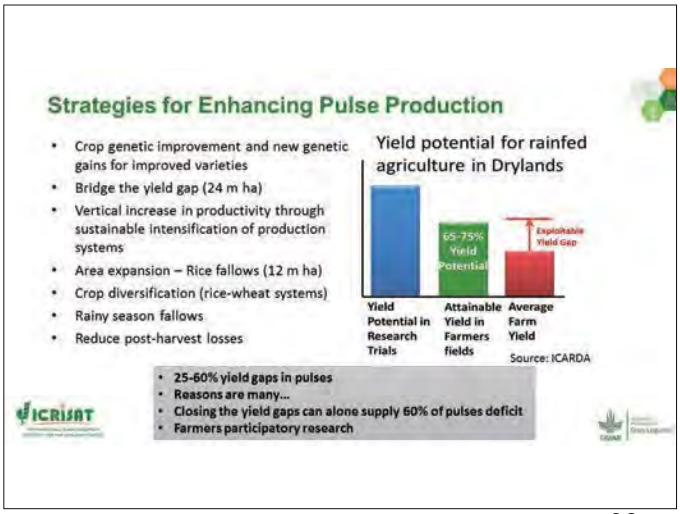

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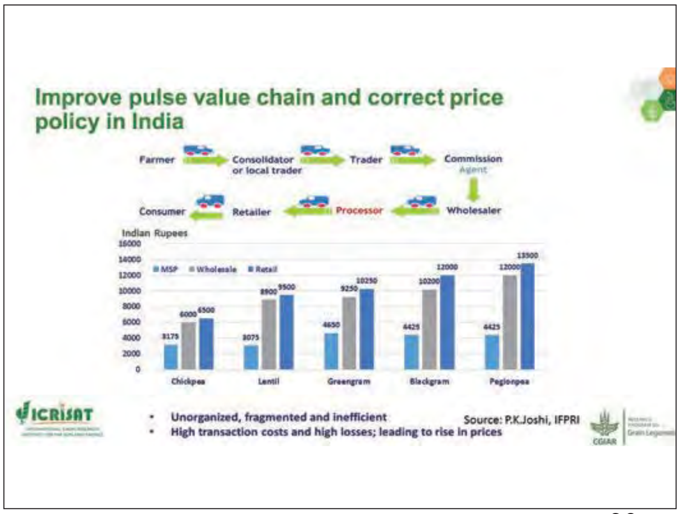

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Research thrust areas….

- Enhanced phosphorus acquisition efficiency (PAE)
- Exploitation of wild species and transgenic for insect resistance
- Protein enhancement and bio-fortification
- Refinement of agronomic practices for crop establishment in rainfed-rice fallows
- Modernization of pulses breeding programs (forward breeding)

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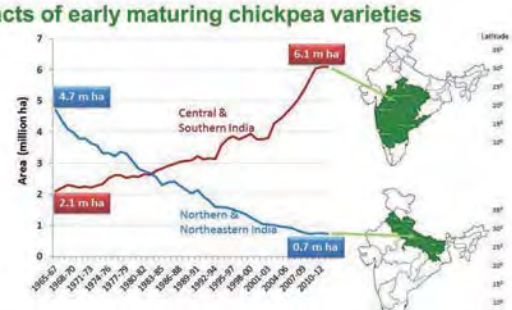
Impacts of early maturing chickpea varieties



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Pigeonpea production ('000 t) trends

ICRISAT

Source: Ganga Rao, ICRISAT

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Pigeon pea growth trends in Africa

Country	In '000 t		% increase		
	2001	2014	Production	Area	Yield
Tanzania	87.1	249.3	186	106	39
Mozambique	31.6	120.9	282	261	6
Malawi	105.8	301.0	184	69	68
Kenya	73.46	274.5	274	68	122
Uganda	80.0	93.6	17	28	-8
Africa	380.6	1047.3	175	96	40

ICRISAT

Source: Ganga Rao, ICRISAT

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Pigeonpea drivers of success

- High yielding, wilt resistant MD varieties
- Sustainable intensification through ICM with women participation
- Regional and international export and participation of large traders
- Innovative seed systems in partnership with local farmers, NGOs and Government
- Value addition and export to regional and international markets
- Very strong participation of partners, donors (BMGF, USAID, Irish Aid etc.,) Governments initiatives -Kilimo Kwanza (Tanzania)

Mrs. E.Mollel of Kikatiti, Tanzania
In front of her old house of 1988 — *In front of her new improved house*

Source: Ganga Rao

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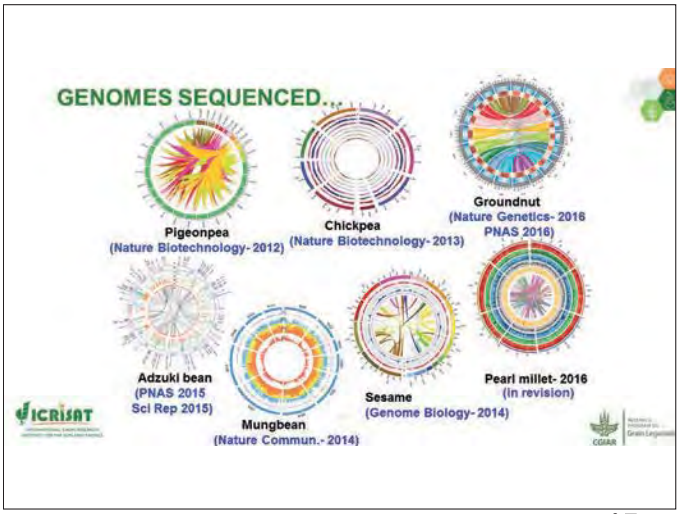

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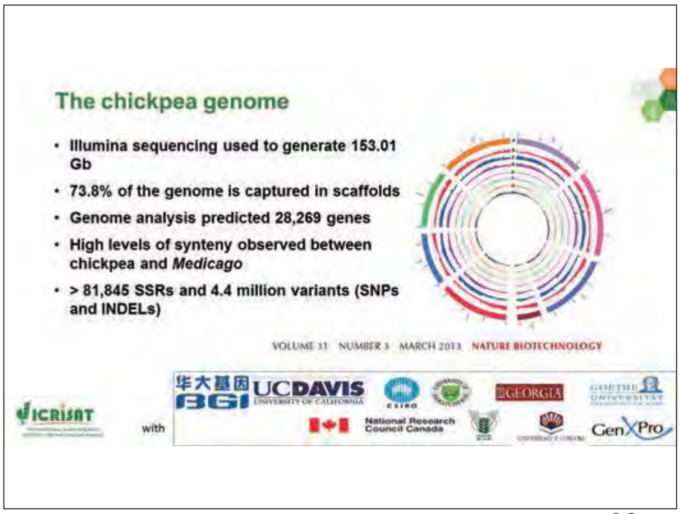

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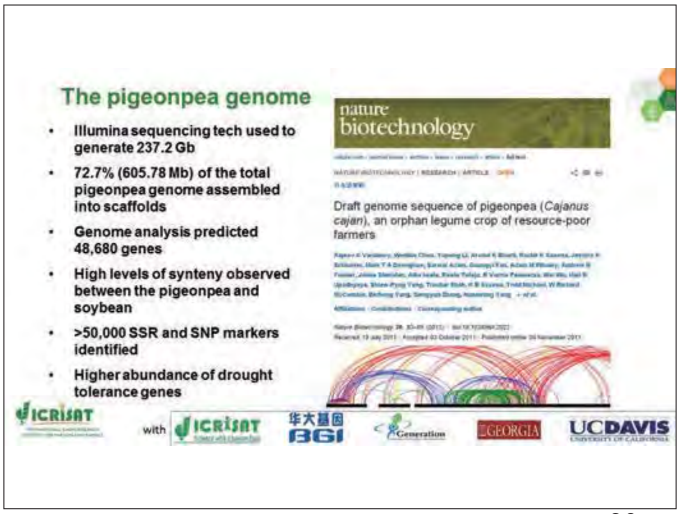

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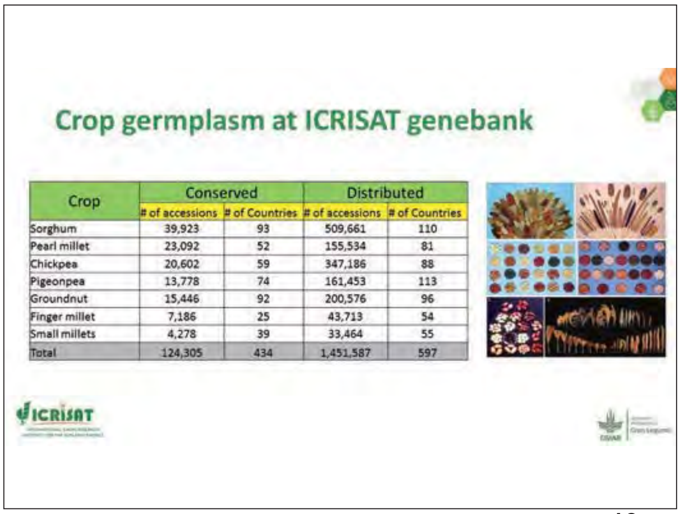

Crop	Conserved		Distributed	
	# of accessions	# of Countries	# of accessions	# of Countries
Sorghum	39,923	93	509,661	110
Pearl millet	23,092	52	155,534	81
Chickpea	20,602	59	347,186	88
Pigeonpea	13,778	74	161,453	113
Groundnut	15,446	92	200,576	96
Finger millet	7,186	25	43,713	54
Small millets	4,278	39	33,464	55
Total	124,305	434	1,451,587	597

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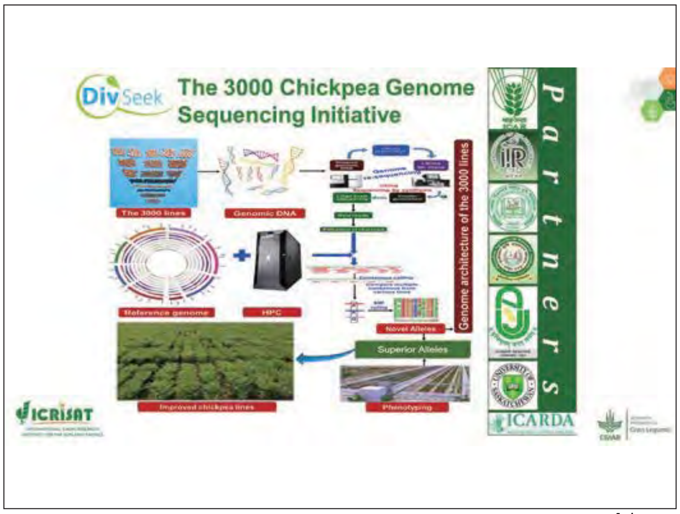

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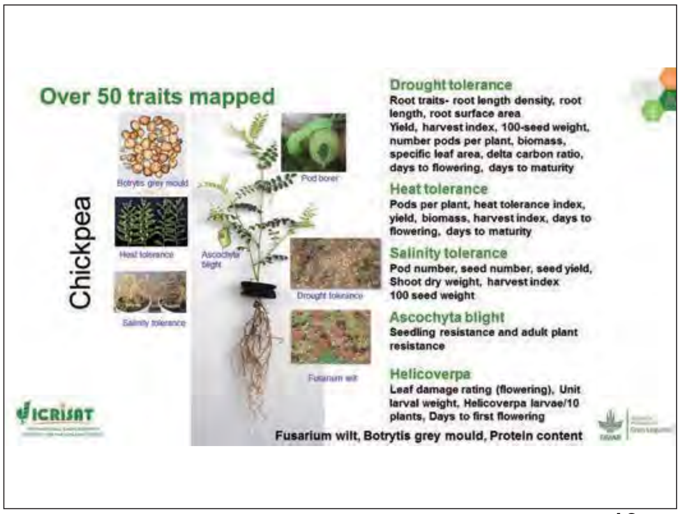

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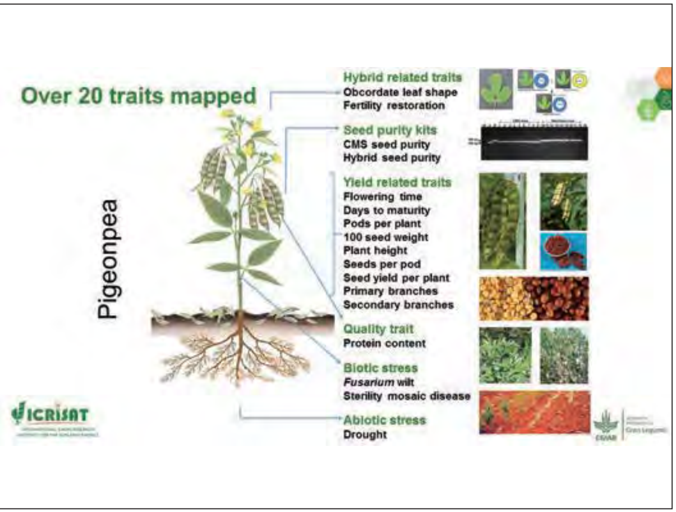

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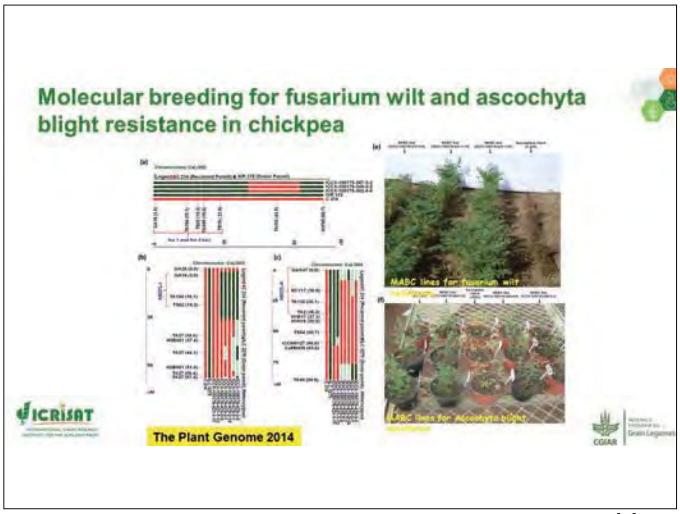

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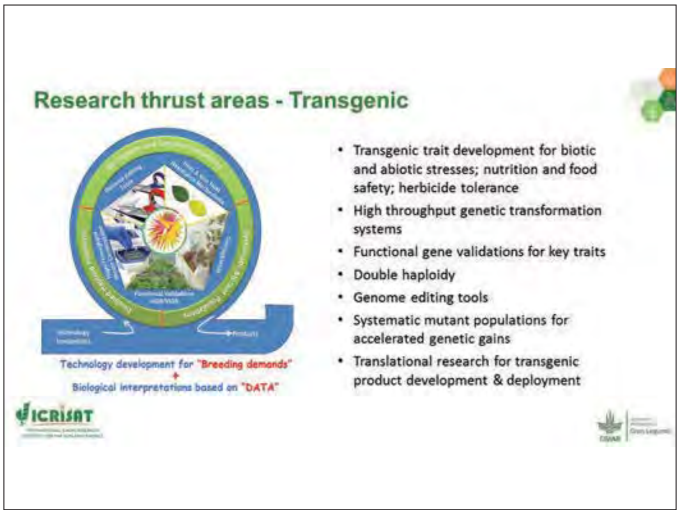

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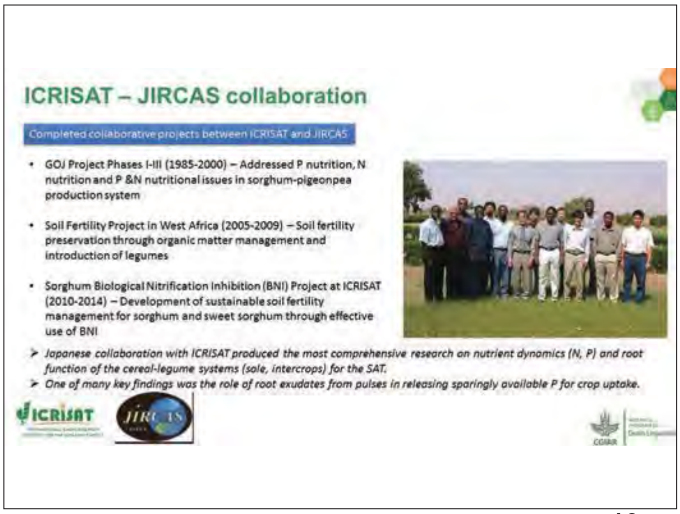

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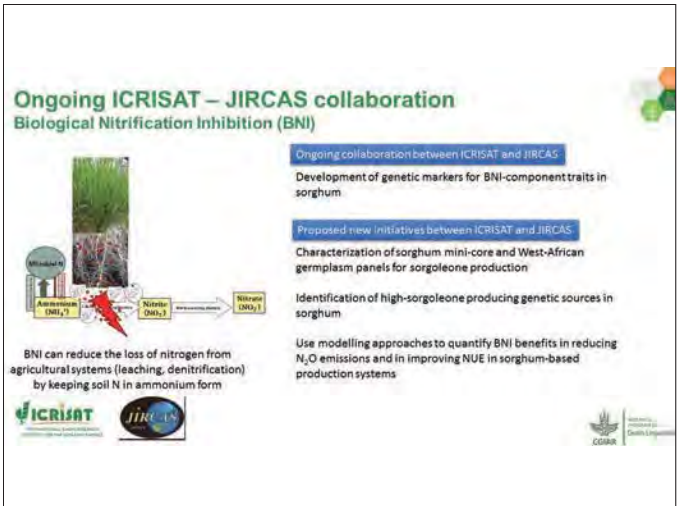

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Onward with urgency to support pulse research that empower farmers and consumers to realize the SDGs – Together!

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Chair Doi
Good morning, ladies and gentlemen. I am Kunihiro Doi, the Director of Research Strategy Office of JIRCAS. It is my pleasure to introduce our keynote speaker today. Before the introduction, I am explaining a little bit about the background of today's symposium.

This year is the International Year of Pulses. It comes to me as a surprise that pulses do not include soybean and groundnuts. In Japan, it is common notion that all beans including soybean and groundnuts belong to the same group. I think my colleagues here, they love Natto and peanuts with alcohol, so they will not accept excluding these two legumes from today's symposium. While we will celebrate this year of pulses, of course, also we should realize the need to promote the importance of the nonpulses legumes.

With this consideration, we decided to change the English title of this symposium from pulses to legumes.

Today, we are honored by the presence of the two prominent scientists who are well known for their expertise in their own field. We are confident that their presentation would provide profound insights into the role of legumes in our lives. Then, I am pleased to introduce our first speaker, Dr. David Bergvinson. Dr. Bergvinson is the Director General of the International Crops Research Institute of the Semi-Arid Tropics, ICRISAT, and International Research for Development Organization and member of the CGIAR Consortium. He joined ICRISAT in January 2015 to lead its strategy development to ensure solid science, demand-driven innovation and strategic partnership that translate science into prosperity for rural families, and he continues what he has done during the former assignment at Bill and Melinda Gates Foundation, to spearhead the advancement of the agricultural development by harnessing digital technology to generate goods and benefits for the poor farmers.

I think I cannot say enough about his scientific career. The title of his presentation is "Potential of legumes: Global needs and challenges." Director General Bergvinson, the floor is yours.

Dr. David Bergvinson
Thank you and good morning. Special acknowledgement of Dr. Masa Iwanaga, President, JIRCAS, thank you for hosting us. Director General Saigo for his insightful comments around partnerships with the private sector and the MAFF perspective, and of course, Dr. Takemoto who is kindly offering this facility to us to have this important dialog around legumes and their role in addressing global needs, especially the Sustainable Development Goals.

Professor Doi, I also am shocked that groundnut and soybean are not considered pulses. So, I won't dwell too much on that because Professor Maeda will give us a very luminary lecture on the definition of pulses and grain legumes more broadly. Mine is really to look at how the pulses or grain legumes will contribute to modern food systems and it will empower us to realize the Sustainable Development Goals in under 14 years, but also highlight the challenges we have ahead of us in realizing that as far as production, trade and consumption of these important commodities.

And then I will highlight in detail two of the grain legumes, chickpea and pigeonpea, which are the largest pulses traded internationally, and how we can unlock biological sciences to realize their full potential, and then some concluding remarks around the interventions at the global, national, and local level that need to be taken to realize this.

In 2012, the Secretary-General, Ban Ki-moon, announced the Zero Hunger Challenge in which we wanted to ensure that we ended hunger, eliminated all forms of malnutrition, and we enabled inclusive sustainable food systems for the entire world. And so framed in five challenges was really this embodiment that last year we moved forward as the Sustainable Development Goals which most of these five challenges are reflected in the 17 Sustainable Development Goals. I would add actually the third goal around good health, especially as we look at the role of legumes in reducing non-communicable diseases like type 2 diabetes. But you can see that the footprint of legumes touches not just Sustainable Development Goals 1 and 2 around poverty and ending hunger, but in many other aspects of our development agenda, including partnerships, the last goal, we often don't talk about goal 17, but I think this symposium is a reflection of that.

So, why pulses? Well, pulses or grain legumes for that matter, they are very important for food security, they are definitely important for improved nutrition and health, for our livelihoods as a diverse source of income, for smallholder farmers particularly in the developing world, and an aspect of grain legumes that's not considered, but critically important, is their contribution to improving soil health by fixing nitrogen and improving the biological health of our soils.

So, as was pointed out, 2016 is the International Year of Pulses, and creating awareness amongst consumers, policymakers, researchers, and of course, farmers themselves of the importance of pulses and sustainable food systems. So, the objectives for the International Year of Pulses or grain legumes is to promote the value in utilization of pulses throughout our food systems, raise awareness of their benefits, especially in the context of sustainable agriculture and nutrition, and encourage the connection to further global production. Grain legumes are very important within a cropping system, and that's often underestimated or undervalued. Enhanced research – the research on grain legumes versus the three main food cereals is very meager compared to the demand. Advocate for better utilization in crops, especially in their rotation and also in trade through the private sector.

So, just to highlight within the global research agenda for pulses, compared to cereals, there is approximately only $175 million per annum for 13 pulses. When we compare this to maize, this is roughly one-fifth the maize global budget for research, public and private sector. So, clearly, for one crop maize, which is a very important crop around the world, these pulses are definitely, if you will, "neglected" in comparison.

So, this year for the International Year of Pulses, a 10-year research strategy is being formulated during this month actually, in November in Rome, to look at what are the different components of research that need to be addressed along the whole continuum of research from basic discovery through to delivery of improved varieties and agronomic practices to realize the full potential of grain legumes over the next decade.

I think another area that we often underappreciate is the role of sustainable water management in the context of sustainable food systems and the role that pulses play or grain legumes play within that. Water is a commodity that we don't value in our current food system, but we need to as there is increased demand for water, which currently consumes about 70% for agriculture, but as we seek increased urbanization, the demand for water is going to grow. And as a result, we need to be thinking about the drops of water per gram of protein produced, and here I think we can make a very strong statement for the importance of grain legumes in diversifying our food system to improved human nutrition, that improve nutrition, especially during the first thousand days of life will lead to increased cognitive ability of future populations, and that in turn will empower society to realize the Sustainable Development Goals.

So, the role of legumes and better use of our water resources for sustainable food systems also needs to be emphasized.

ICRISAT is focused on the semi-arid tropics of Asia and Africa, and this ecology covers roughly 6.5 million square kilometers, including 55 countries, in which 2 billion people of our current 7.3 billion are homed or housed, but it also is a concentration for poverty and malnutrition, and here, grain legumes can play a critical role, both in addressing poverty through structured markets and malnutrition by offering higher value and more nutritious food that restores degraded soils that are common in these ecologies. So, at ICRISAT, we believe that all people have the right to nutritious food and better livelihoods, and grain legumes is a key vehicle for us to realize and address poverty, hunger, malnutrition, and environmental degradation.

For us to really unlock the full potential of grain legumes, we need to take a holistic approach of defining what are the market opportunities for grain legumes, so that's the analysis of the problem, and then looking at how grain legumes contribute to soil and water management so that we have sustainable food systems that allow us to live within the ecological boundaries of our planet, looking at crop improvement, currently we use about 1% of the genetic diversity of our grain legumes. So, clearly, there is a huge opportunity for us to unlock genetic diversity in service of improving nutrition, productivity, and profitability for these crops. We need seed systems that actually deliver these improved varieties into the hands of farmers. This is another area for grain legumes that has been underinvested traditionally.

We need to appreciate how grain legumes fit within a farming system and to ensure farmers have the knowledge to integrate legumes into a mixed farming system that includes cereals, livestock, fish, and agroforestry.

Markets increasingly are going to become important for us to address the issue of poverty, and having structured markets that have grades and standards for our grain legumes, so farmers can actually access the full value of their produce will be very important.

As was mentioned by Director General Saigo, the role of the private sector in processing grain legumes so that more value is captured by farmers locally is very important, and of course, the whole mandate of the International Year of Pulses around creating market opportunities for these commodities is critical as consumers become aware of not just the nutritional benefits of grain legumes but also their important role in sustaining the environment and environmental services that they offer within Agrifood Systems.

So, for research organization like ICRISAT, it's part of the CGIAR, the Consultative Group for International Agricultural Research, we have mobilized a group of research centers that includes CIAT focused on common bean, IITA that's focused on cowpea and soybean, ICARDA that's focused on faba bean and lentils, and ICRISAT that's focused on chickpea, pigeonpea, and groundnuts, to look at not just the discovery of basic science, and you will see the genomics work that we have done through this consortium, but also the science of delivery. As Dr. Norman Borlaug said, "Our research doesn't count until it reaches a farmer's field." So, this is an area where we have an interconnected world that is accelerated our basic science at astonishing rates, and yet, we often underestimate the science of delivery and adoption to make sure that our science is translated to adoption in farmers' fields.

So, as I go through this talk, I want to highlight some of these areas such as demand-driven innovation or participatory approaches that provide rapid feedback for our research agenda to make sure our research is focused on the needs of farmers and of value chain actors to ensure adoption, the anthropology of adoption recognizing that not all farmers are equal or the same or have the same aspirations and that we have to take this into consideration as we design how we communicate our science to a wide range of stakeholders.

The whole area of scaling up technology is becoming very exciting, especially with the use of mobile technology and our ability to offer timely targeted interventions that are personalized to the needs of farmers that would incentivize them to adopt new technologies.

The role of capacity building, and this university is really focused on building capacity and educating the leaders of the future, but we need the same at the local level with farmers, lead farmers, and how do we empower them to serve their communities and empower their fellow farmers to realize their full economic potential and feed into modern food systems.

I think one area in science that we don't do very well in and that is the soft skills of science that allow scientists to engage with policymakers, with farmers, so that we can actually create a movement, an innovation movement and to this end, especially our young career scientists and empowering with the skills to communicate and convince is very important.

And finally what I would call pragmatic policies for prosperity. Quite often in policy dialogs, we overanalyze problems at the expense of acting on implementing urgent solutions, and so I was very encouraged by the comments of Director General Saigo, the urgency of this agenda that we are discussing today, in order to offer sustainable, equitable solutions that will lead to not only social sustainability, economic sustainability, but also environmental sustainability as we deliver on the SDGs.

So, why grain legumes and considering them as a smart food? At ICRISAT, we consider these commodities good for you as consumers because they offer affordable sources of protein, they have low fat and high fiber, which can lead to improved health of the consumer over time, especially addressing non-communicable diseases like obesity and type 2 diabetes. They are good for the planet because they fix atmospheric nitrogen and convert it into a usable form of nitrogen for all crops. They are also very high in the use of water for generating protein and micronutrients, and in so doing they improve soil health by, of course, fixing nitrogen. But they are also good for smallholder farmers because they offer diversified sources of income. In the case of Africa, intercropping of sorghum or maize with pigeonpea offers farmers two sources of income, the cereal crop which is first harvested but after the harvest of the cereal for grain and fodder, pigeonpea then flourishes as an intercrop that offers a second source of income, improves the soil health for smallholder farmers, and in years of drought is a fallback to ensure at least some income is realized on the farm even in drought.

Pulses are also a smart food in that they generally consume less water and are very climate hardy. They are climate smart commodities, especially crops like cowpea, chickpea, pigeonpea, extremely resilient to high temperatures and low water. And so if we look at the water footprint of pulses versus beef, there is a dramatic reduction in the use of liters of water to produce a kilo of commodity that are enriched in protein.

Pulses are grown around the world in different ecologies. As I mentioned, they are particularly important in drier ecologies where there are suited to take on the harsh production environments, and I will show later in the case of India how chickpea is actually shifted from an irrigated system into a rainfed dry production system. But you can see that the grain legumes are grown around the world in different commodities, with India actually being the largest producer but also the largest consumer of grain legumes or pulses in the world.

But the grain legumes represent over a $50 billion market. Now, while this is relatively small compared to the rice or maize or wheat markets, they play a critical role across all continents in providing nutritious food and fixing nitrogen. And so here is the estimated value of legumes that includes the nitrogen input into the soil through nitrogen fixation.

Pulse production as a result of these benefits is on the rise. Productivity has increased faster than area expansion, but still we cannot relax because we are looking at a nitrogen deficit, especially for core segment of society, and so grain legumes are going to actually have to increase both in their area, especially by being cultivated in new ecologies or in rotation with cereal crops, but also in their productivity, and the drive to increase productivity is going to have to be realized by increasing their profitability for smallholder farmers in particular. So, I am going to speak to some of that a little bit later on.

Where we see the increased production? We see most of that in response to market opportunities in the developed world; Australia and Canada, as major export crops to Asian countries that are deficit in the production of pulses, especially South Asia, India in particular.

When we look at the yield of pulses in different countries, we see this response to market opportunities with Canada, United States, and China being the leaders around productivity of pulses, whereas countries in sub-Saharan Africa that don’t have a strong market signal and infrastructure to support its realization show much lower productivity of pulses, under 500 kilos per hectare in the case of Niger, Mozambique, Burkina Faso. So, clearly, there is a tremendous opportunity to increase the productivity of smallholder farmers in sub-Saharan Africa, and this is an area that ICRISAT and the CGIAR partners along with national programs are working in concert to address.

When we see the countries where growth is taking place, we see emerging economies like Myanmar responding to this opportunity as well as Nigeria and Kenya, and so there is clearly a signal and, if you will, optimism that we can respond to these market opportunities in developing countries to markets that are being generated as consumers become increasingly aware and interested in consuming pulses in order for sustainable food systems.

If we see where the global trade imbalance is taking place, you can see that North America, Canada as being a very large exporter, especially of chickpea and lentils. Australia is a major exporter of chickpea as well. But you see where the deficit is being realized in South Asia at 4.5%, especially in the case of India. So, the Prime Minister’s office in India has taken notice and is being very pragmatic in looking at how can India become pulse self-sufficient over the next 5 years, and ICRISAT and the Indian Institute of Pulse Research along with many other partners are coming together to realize that vision.

So, to do this, we really need to take a country-specific approach to unlocking the full potential of grain legumes around the world, because we need to make sure that it’s context-specific, that we understand the culture, as well as the capacity of the whole agri-food value chain for pulses to realize their full potential. And if we do this, we can actually jump over what we call the death valley of research for development of moving from small pilot stage projects into large scale, large impact programs that reach millions of farmers. In order to do this, we have to think about our science in a slightly different way, the science of delivery which we learn by listening to our key stakeholders, adapting our science, and creating ownership of the whole process of achieving pulse self-sufficiency around the planet. And to support this, we need pragmatic policies from governments, especially the willingness to invest in longer term research for development in pulses which have traditionally been underinvested.

So, in the case of India, I mentioned the Prime Minister's office has been taking up this challenge and looking at very targeted strategies to achieve pulse self-sufficiency. One of the things that has really undermined pulse production has been the volatility in prices. Farmers are interested in responding to markets but markets that are predictable. So, in the case of India, there has been predictable rise in wheat markets because of the government's procurement policy for these commodities. And now recently, the Government of India has put in place the Minimum Support Price for the pulses. They have offered a price signal to smallholder farmers to increase their production. And so this year there has been an increase of approximately 2 million hectares in pulse production to respond to that. But still we see price volatility because the infrastructure required to offtake and store that surplus production is not currently in place. And this is where we need to bring the public and the private sectors together to support.

So, the key constraints that we are addressing in pulse production in India, first is the low investment by farmers to increase their productivity because historically there hasn't been a price signal. Secondly, pulses because they are nutritious for us, they are also nutritious to disease and insects, and so protecting legumes biotic stresses is very important, but also they are exposed to harsh production environments, as I mentioned, often grown in rainfed environments that have high temperatures. And so, developing varieties that are climate smart is very important.

Also, they tend to be grown on marginal lands where soil has been degraded. Now, they contribute to the restoration of soils, but the soils in which they are cultivated are often less productive. And increasingly for all of agriculture but specially pulses, labor costs are major consideration, and so we have to think about mechanization as a way to reduce the cost of production for all of our crops but especially grain legumes.

So, in enhancing pulse production, we really need to see how we can close the yield gap, which is significant for many countries. You saw the wide range in productivity from over 2 tonnes in Canada to less than 500 kilos in the case of Niger. We have to close that yield gap through the intervention of not just improved varieties but also improved agronomic practices and the communication of knowledge to realize their full potential.

We also see an opportunity to expand the area of pulses as part of a rotation with cereal systems. And one of the big opportunities in the case of India is in the rice fallows where approximately 12 million hectares can be utilized that's currently only used for open grazing because of the lack of protection for cultivation in these areas after rice.

We also need to look at the diversification of existing crops systems, of rice, wheat, and other commodities, especially in Africa where we are seeing an emerging trend of maize intercropped with legumes, especially pigeonpea and cowpea.

We also have to look at the rainy fallows and how do we better use water harvesting techniques to expand the productivity of pulses, and something that we often don't consider the losses that occur after harvest, and so postharvest losses of legumes is very high.

So, this takes me to this slide around improving value chain efficiency. In our traditional system now, our agricultural value chains are very long and in every node in that value chain, farmers and consumers are losing value. What we can do now with technology, especially mobile phone technology, is actually compress that value chain and now we are using mobile phones to support farmers-producers organizations sell directly to retailers. And so we are taking out four or five nodes in the traditional value chains and compressing that value to the farmer and to the consumer and offering a higher unit price for farmers and a higher quality product at a lower price to consumers. So, this is really the new era of opportunity for unlocking grain legume value chains in both developed and developing countries.

For research for grain legumes, we are really seeing a need for increasing plant productivity by looking at the plant architecture that supports mechanization. We are looking at reduced use of labor requirement such as weeding through herbicide tolerance. I have already mentioned the need for developing varieties that have a tolerance to higher temperature and can produce a bountiful crop with less water.

Hybrid technology is very important. It's what's driven the maize seed sector and a large investment in maize. What does that look like for pulses or grain legumes? ICRISAT with its partners has developed hybrid pigeonpea and these products are now being commercialized in India and being converted and adapted into African markets as well. We are now gaining insights into the molecular level of hybrid technology through cytoplasmic male sterility and looking at how we can convert and adapt this technology to the other grain legumes which will be very important for future seed systems.

And we also need to look at how do we compress the time to a viable harvest as we adapt to climate change and increase the intensification of our farming systems around the planet. So, reduced maturity is a very important research thrust.

Another area is our nonrenewable resources like phosphorous and how do we increase the phosphorus use efficiency of our legume crops. This is especially important for common bean, for example, that its production is very much dependent on phosphorus availability.

As I mentioned, we haven't utilized very much of our genetic diversity, the wealth of genetic diversity we have in our gene banks. We really need to exploit this more as well as to look at artificial diversity that we can create, especially with the new genome editing like CRISPR-Cas9 technology that's available.

Protein enhancement and biofortification are other areas where we have invested but need to invest more in our grain legumes. Refining the agronomic practices that go along with improved varieties is an area that we have underinvested. We tend to work in isolation as agronomists and as breeders and social scientists, and bringing these disciplines together to unlock the full potential, especially in areas that have been underexploited like rice fallows, is going to be critically important for the future.

We have to modernize our breeding programs. This past week at ICRISAT we have actually brought together most of the CGIAR centers and many of our lead national programs like the Indian Council of Agricultural Research to look at how do we use forward breeding tools to accelerate genetic gain in our crop improvement programs globally.

So, one of the successes that illustrate how we can respond to climate change and increase grain legume productivity is chickpea in India. And so from 1970 through to 2010, you can see the red line showing the increase in area of chickpea production in the central zone of India, where we moved from an irrigated system in the north to a largely rainfed system in the central zone that's exposed to high temperature, very harsh production environment. We have basically maintained the productivity as we moved into this harsher transition zone. So, while the productivity per unit hectare has not gone up dramatically for chickpea, chickpea has adapted itself now into a much harsher production environment, and I would submit, has now become a climate smart crop in response to this. And it's been science that's enabled this to make this transition.

Pigeonpea production is another important crop that's responding to market signals, and you can see the volatility on the blue line in the north, largely South Asia or India, but the red line below is showing tremendous encouragement as we see that production of pigeonpea in sub-Saharan Africa increasing steadily and dramatically in response to market opportunities. This is very important because pigeonpea is now being introduced as an intercrop with cereals in sub-Saharan Africa to increase not just profitability but also sustainable productivity through enhancing soil health. And we can see that in Africa, countries like Tanzania, Mozambique have dramatically increased the area of pigeonpea production in response to these market opportunities in Asia. Our challenge, though, is how do we ensure that these crops are consumed also in sub-Saharan Africa where malnutrition is also very acute. So, I think this is a challenge for us as a research community to look at partnerships with the private sector to capture more value addition and convenience of pulses for local consumption in sub-Saharan Africa.

So, some of the drivers of our success in sub-Saharan Africa have been around high yielding, disease-resistant varieties that are part of an integrated crop management system, especially for women who have been the ones benefiting most especially from the early stages by producing seed and sharing seed with other women farmers, especially for pigeonpea. Integrating with large regional traders has been very important, and the role of NGOs and government in providing innovative incentives for those seed systems to really flourish and for the expansion of pigeonpea to be realized. And also, strong participation of donors has been a key driver, especially the Bill and Melinda Gates Foundation and Irish Aid.

So, what does the future look like? I think it looks very bright for pulses, because pulses of now through this genomics revolution have enabled us to sequence all of the grain legumes and to now really unlock their full genetic potential through the use of these genetic maps. And so ICRISAT and its partners have now sequenced and now is in the process of resequencing these crops. In the case of the chickpea genome as well as the pigeonpea genome, this has been enabled through international consortium across the globe, working in concert to unlock the genetic code for these crops. And by so doing we are going to be able to now tap into the wealth of genetic diversity that we have. One case and point is as you are probably aware, the rice community has re-sequenced 3000 rice varieties from around the world, and now ICRISAT and its partners has done the same for chickpea where we have re-sequenced 3000 chickpea accessions both from the gene bank as well as from elite lines from around the planet to now understand the key phenotypic traits that include the physiological basis for drought tolerance, for heat tolerance, for salinity tolerance, for disease resistance such as Ascochyta blight as well as for insect resistance, and to test these 3000 lines in six different production environments, and we have this data now for 2 years, and bringing all of this data together, we can make much more strategic recommendations on unique alleles that can address these major production constraints.

Likewise we have done the same for pigeonpea for 20 different traits, including the hybrid technology, looking at genetic diversity and how we unlock it to increase profitability for smallholder farmers. One early example of this has been Ascochyta blight for chickpea and using molecular markers now to integrate this important production constraint to agronomically elite varieties and accelerating their release into national systems.

Transgenics is another very important area. Apart from the challenges we have with socializing the use of transgenic, I think if we can turn this around and communicate to the general public the nutritional importance of these commodities and the need to use transgenic tools strategically to improve the nutritional value of these commodities is very important, including genome editing, I mentioned CRISPR-Cas9 technology, and we are looking at how we can unlock artificial genetic diversity to improve nutritional quality of grain legumes and increase their profitability for smallholder farmers.

In closing, I would just like to highlight our collaboration that ICRISAT has had with JIRCAS over the years. We have had a very rich collaboration, especially in the area of soil science as we unlock, as I pointed out, the importance of intercropping cereals with grain legumes to improve sustainable food systems, especially as we look at soil nutrition. And so our rich research history of 15 years looking at the interaction of legumes, especially pigeonpea, for increasing the availability of phosphorus and nitrogen in African cropping systems was very important.

Lot of this work was then translated into improving soil health in West Africa through our partnership with JIRCAS, and more recently looking at sorghum biological nitrogen inhibition. Nitrification is a very important process that actually converts ammonium into nitrite, and once it’s in nitrite, it’s subject to leaching and we lose about 70% of our fertilizer because of this process.

And so looking at native alleles in sorghum that impede this conversion of ammonium to nitrite offers us opportunities to genetically engineer and inhibit this process so that more of our nitrogen applied to crops is realized in increased productivity and reduced nitrification or eutrophication of our water waste.

So, in closing, I would like to leave you with a few highlights. The International Year of Pulses 2016 was extremely timely, and I agree with the sponsors it should be broadened to include grain legumes so that soybean and groundnut, two commercially very important commodities are also included. We have used this platform, though, to create awareness among consumers of the critical role pulses or grain legumes play in nutritional security and in making sure that we live within the ecological boundaries of our planet. We need to create increased demand for pulses by ensuring that we dampen price volatility and we put in place the market value chains that allow for their efficient conversion into economic opportunity for smallholder farmers and to affordable consumption for consumers. We need research to focus on profitability for farmers. If we fail to do that, we will fail to realize the full potential of these commodities long-term and to incentivize youth to come back into agriculture, especially pulse production.

At a global level, we need to increase the funding to grain legumes research to make sure that we provide an enabling environment as well as the research required to rise to the challenge of nutritional self-sufficiency around the planet. But to do this, we also need to put in place appropriate grades and standards that are lacking to support global trade. At a national level, we need to be looking at integrated approaches that include genetic improvement of new varieties but also management of those varieties within an integrated farming system and pragmatic policies that allow them to unlock their full potential. If we do this, we will increase domestic production, we will reduce postharvest losses, and we will increase the value of these crops to smallholder farmers and rural communities but also make them more accessible, especially to rural poor consumers who currently do not have good access to nutrition. We have to, in the process, attract the private sector to make appropriate investments along these value chains to make this a reality. And finally, at the local level, we need to look at mechanization to increase the profitability for smallholder farmers, knowledge exchange that allows them to harness innovation and to increase their profitability, and to make sure that value chains are equitable and in service of smallholder farmers to realize their full economic potential, especially for women and youth so that we can deliver on the Sustainable Development Goals.

So, with this, onward with urgency, the agenda is critically important but we need to work in concert to realize this urgent agenda of achieving nutritional security through grain legumes. Thank you very much.

Chair Doi
Thank you Dr. Bergvinson, I am very happy to know that ICRISAT has not forgotten the non-pulses legumes, and I am very impressed that your India project is stressed about the cost of the labor is an important point and our researchers have never forgotten that point. Again, let’s give Dr. Bergvinson a round of applause for his excellent presentation.

THE ACCEPTANCE OF SOYBEAN AND GROUNDNUT INTO SOUTHEAST ASIA -FROM "10,000 YEARS HISTORY OF LEGUMES AND MAN"-

Kazumi Maeda

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ABSTRACT

In the *Leguminosae,* out of about 20,000 species of three sub-families, only some 30 annual and mainly herbaceous species, belonging to the most evolved the Sub-family *Papilionoideae,* grow as food crops throughout the world, and symbiotic nitrogen fixation with root nodule bacteria had been evolved in this Sub-family.

There is "one more" history in the relationship between the legumes and man. That is, gathering peoples know a lot about plants, so, the real "professional botanist" was equipped with all the knowledge necessary to practice agriculture, but did not do so (Harlan 1975). According to Issacs (1987), the native Australian aborigine uses 27 species of 10 genera of the leguminous plants, which account for 10% of all food plants, and of those various parts are eaten, i.e. flower, fruits, seeds, young buds and pith, resins and nectar, and root tubers, etc., in each season. So-called the "founder crops", which were excavated in package at the archaeological sites in the Fertile Crescent in the Near East, contain the cereals, flax and legumes, but roots and tubers are none in the archaeobotanical record due to their perishability, although they had been harvested as the important food crop with cereals and legumes, since the time of incipient agriculture. "Agricultural-Complex", as parallel development of major legume crops with the cereals and root tubers in the ten regions of origins of domestication and secondary-dispersals in the world (Maeda 2015) is shown in Table l.

In the about 10,000 years' history of farming, many legume crops were adopted in the traditional cropping systems, and had been played an important role to maintain the soil fertility. And, legumes are highly nutritive, so, soybean was called a "meat from the soil" and "cow of the field" in China, and mature dried seeds are storable with long viability. They are consumed as dried seeds, green vegetable pods, bean sprouts, and also fermented products. Indigestible fibrous skin and various deleterious substances in some legumes, which are eliminated or reduced by appropriate preparation in cooking and processing, limit consumption. Some toxic substances gave rise the taboo and disease such as the favism and lathyrism. However, the importance of legumes as food and crop had been closely linked with mental belief and ethnic observance in agricultural peoples.

The Silk Road an important trading route from China to Rome, until about the 7-8th Century A.D. There was soybean in its start point, North China, and were chickpea, lentil, peas, and faba bean, domesticated in its west, the Fertile Crescent, respectively. The soybean is said the first legume, of which a written record was made in China, and its technology of cultivation and utilization as food had been completed in about the 15th Century A.D. It is said that a black skin soybean in India and a flat grain soybean in Java, Indonesia, had been introduced from Yunnan, south China, via Laos and Thailand by the road runs at south Himalayan foothill. However, there is no record to refer to the fact on "the Silk-Road was the soybean road", and also, the early history of the acceptance of soybean and other legumes to the Southeast Asia is not clear, before about the 17-18th Century A.D.

As a result of survey and enumeration, the vernacular generic names of the legumes in the Indo-China Peninsula and islands area in Southeast Asia, were classified into three main groups, i.e. "*kacang*-", "*dau*-" and "*kedele*-", except many tribal names in islands and "*sandaek*" in Cambodia, and "*pe*" in Myanmar, as shown in Table 2 and Fig. 1 (Maeda 2015).

The first, "*kancang*"- group names, "*kacang*" means "seed" or "legumes", are distributed widely in Malaysia, Indonesia, and Thailand (Table 2A). And the second, "*dau*"- group names, "*thua*, *tua*, *thwax*, etc.", which are relatives originated from phonetically reading of Chinese character of soybean and legumes, "豆 *dau, dou*", are used restrictedly in Vietnam, Thailand, and Laos (Table 2B). These are common to *"tou, zu"* in Japanese, and "*dou*" in Korea. However, it is noted that the bean sprouts is called "*taoge, toge taugih*" and soybean curd is called "*tauhu*", in Malaysia, Indonesia and the Philippines. These are also similar to in Japanese reading, "豆芽 *touga*" and "豆腐 *toufu*". This suggests that the route and time of acceptance of the Chinese soybean into

Southeast Asia had differed as seeds and the food culture. And the third, "*kedele*"- group names are used remarkably for the soybean in Malay Peninsula and islands area of Indonesia, but not for the groundnut (Table 2C).

Ochse et al. (1931), had not shown the etymology of this "*kedele*" in his list of abundant vernacular vocabulary on farming and foods in Malay-Indonesian languages, including about 100 samples of "*kacang*"-group names. However, as shown in Table 2D-1, it was recognized that chickpea have been called "*kadale, kadala, dalai*" etc., and soybean and groundnut are called,in "*kedele*"- group names, too, by only Dravidian language peoples in South India, with many other tribal names, and "*kon kadala*" by Tamil language peoples in Sri Lanka. For reference, Hindi and other names of major legumes in India are shown in Table 2D-2.

According to Nene (2006), the etymology of "*kedere*" is considered that "*kalaya*", which means peas or roasted chickpea in ancient India, or "*khalva*" (grain) in the documentation of the Vedas *(Rig Veda, Yajur Veda,* etc., ca. 5,500 B.C.). It was considered that the above-mentioned geographic distribution of "*kedele*"- group names suggests not only the contribution of Dravidian language peoples to the acceptance of soybean and groundnut, but also shows a profile of "indianization" and "sinicization" had occurred in the history of Southeast Asian countries, who had not domesticated their own legumes.

KEYWARDS
dua, groundnut, *kacang*, *kedele*, Southeast Asia, soybean, vernacular name of legumes

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Table 1

表１：世界の農耕文化複合における、主なマメ類の穀類およびイモ類との共存的発達　（前田 2015 より作表）

Table１. Agricultural-Complex in the World, viewed from the Parallel Development of Legumes, Cereals and Root Tubers (Maeda, 2015)

地　域 **Regions: Origins and Secondary Dispersals**	マメ類 **Legumes**	穀 類 **Cereals**	イモ類 **Roots and tubers**
東北アジア **Northeast Asia**	ダイズ、アズキ Soybean, Adzuki bean	キビ、アワ、モロコシ Common millet, Foxtail millet, Sorghum	
華南・東南アジア **South China - Southeast Asia**	アズキ（シカクマメ、ナタマメ、ハッショウマメ） Adzuki bean (Winged bean, Sword bean, Velvet bean)	イネ Rice	タロイモ、ヤムイモ Taro, Yam
インド亜大陸 **Indian Subcontinent**	リョクトウ、ケツルアズキ、タケアズキ、ガラスマメ、キマメ、ホースグラム、グアル、モスビーン、ガラスマメ Mung bean, Black gram, Rice bean, Pigeon pea, Horse gram, Guar, Moth bean, Grass pea	イネ、シコクビエ、モロコシ Rice, Finger millet, Sorghum,	
地中海・西南アジア **Mediterranean & Southwest Asia**	ヒヨコマメ、エンドウ、ソラマメ、ヒラマメ、ベッチ、ルーピン Chick pea, Pea, Faba bean, Lentil, Vetches, Lupin	コムギ、オオムギ、エンバク、ライムギ Wheat, Barley, Oat, Rye	
東アフリカ・スーダン-サヘル・セネガンビア・ギニア **East Africa, Sudan-Sahel, Sene-Gambia, Guinea**	ササゲ、フタゴマメ、ゼオカルパマメ、フジマメ Cowpea, Bambara groundnut, Geocarpa bean, Lablab bean	テフ、トウジンビエ、フォニオ、グラベリマイネ、モロコシ Teff, Pearl millet, Fonio, African rice, Sorghum	ヤムイモ、アフリカヤムビーン Yam, African Yam bean
メソアメリカ・アンデス **Meso-America & Andes**	インゲンマメ、ベニバナインゲン、テパリービーン、リママメ、タチナタマメ、ラッカセイ、タルーイ Common bean, Runner bean, Tepary bean, Lima bean, Jack bean, Groundnut, Tarui (Andean lupin)	キノア、トウモロコシ Ouinoa, Corn	サツマイモ、ジャガイモ、キャッサバ、メキシコヤムビーン Sweet potato, Potato, Cassava, Mexican Yam bean

表２：東南アジアとインド諸語におけるマメの呼称例

Tab. 2. Vernacular names of legumes in South-East Asia and India

(*Source*: Ochse et al. 1931/1980, Burkill 1966, van del Maesen et al. 1989, Korisetter et al. 2001, Fuller 2002, 2005, Nene 2006, Krishna 2010；永田 1956, 岩佐 1980, 前田 1986, 2015)

A.「カチャン ***Kacang***」(***katjang, cachang***)系： マレー・インドネシア
Kacang as vernacular-names of legumes in Malay-Indonesia

1．ダイズ **Soybean**

Malay-Peninsula: ***kacang soya, k. bulu riman, k. depoon,*** etc.
Indonesia, Java, Bali, Sunda Is., Thailand: ***k. kadele, k. kedelai, k. djepoon, k. bulu.*** etc.

2．ラッカセイ **Groundnut**

Malaysia: ***kacang tanah, k. china, k. goreng, k. jawa, k. maneela,*** etc.
Indonesia: Java, Bali Is.：***k. tanah, k. tjeena, k. broodool, k. goreng,*** etc.
Borneo: ***k. tjeena,*** etc., Sumatra: ***anee kacang, retak katjang,*** etc.
Celebes: ***kasang, kasan goreng, katjang djawa,*** etc.

3．その他のマメ **Other legumes**

アズキ **Adzuki bean**：***kacang merah;*** ヒヨコマメ **Chickpea**：***k. Arab, k. kuda***
インゲンマメ **Common bean**：***k. buncis, k. pandak;*** ササゲ **Cowpea**：***panjang***
ソラマメ **Fababean**：***k. babi;*** フジマメ **Lablab bean**：***k. kara, k. peda,*** etc.
リョクトウ **Mungbean**：***k. hijau*** ; エンドウ **Pea**：***k. polong***
キマメ **Pigeonpea**：***k. kayu;*** シカクマメ **Winged bean**：***k. belimbing, k. botor***

B. 中国語の「豆」系 (In Chinese character, 豆 ***dau***)
(cf. Japanese: トゥ ***tou***、ズ ***zu***; Korean: ***dou***)

Chickpea	Thailand: ***thua hua chang***
Common bean	Laos: ***thwax falangx***; Thailand: ***thua khaek***, ***thua phum***; Vietnam: ***dau ve***
Cowpea	
a. var. *Unguiculata*（ササゲ）	Laos: ***thwax do***; Thailand: ***tua dam, tua na*** Vietnam: ***dou den, dou trang, dou tua***
b. var. *Sesquipedalis*（ナガササゲ）	Thailand: ***thua fak yaw, tua phnom*** Vietnam: ***dau dua, dau giai ao***
Faba bean	Thailand: ***thua yang***
Groundnut	Thailand: ***tua lisong***; Vietnam: ***dau phong;***
Lablab bean	Thailand: ***tua nang, tua paep***; Vietnam: ***dau van***
Lentil	Thailand: ***thua daeng***
Mung bean	Laos: ***thwax khiew, thuwax ngo***; Thailand: ***thua khieo, thua thong*** Vietnam: ***dau xanh, dau che***
Pea	Vietnam: ***dau hoa lan***
Pigeon pea	Thailand: ***tua re***; Vietnam: ***dau sang, cay dau chiu, dau maetaai*** Laos: ***thwax h'e***
Soybean	Thailand: ***thua lueang, thua phla lueang, tua rae*** Vietnam: ***dau tuong, dau nahn, dau xa***
Sword bean	Thailand: ***tua pra***
Winged bean	Thailand: ***tua pu***

cf. Malay ー Indonesia, Philippines:「豆芽」Bean sprouts: ***taoge, toge, taugih***;「豆腐」Soybean curd: ***toufu***

Table 2

C.「ケデレ ***kedele***」系：マレー-インドネシア

（***kedele*** etc. as vernacular-names of Soybean in Malay-Indonesia; Sumatra, Borneo, Java, Sunda Is., Celebes, Timor-Moluccas)

ダイズ **Soybean** ***kedele, kudele, kadoele, dele, dekeman, dekenan, gadele,*** etc.

D-1. インド-ドラビダ語系のマメの呼称

(Names of legumes in Dravidian languages, India)

Chickpea	Kannada (Karnataka): ***kadale***; Tamil: ***kad(t)alai*** Telegu (Andhra): ***sannagalu, harimandhakam***; Malayalam (Kerala): ***kadala***
Grass pea	Gujarati: ***lang***; Malayalam: ***lakh***;
Groundnut	Bengali: ***mat kalai***; Kannada: ***nila kadale, kadalae kayi***; Malayalam: ***nela kadala***; Tamil: ***ver kadalai, nila kadalai,kadalai kai***
Horse gram	South Dravidian: ***kol***; Sri Lanka (Sinhara): ***kondakadala***
Lentil	Kannada: ***massur, channang***; Tamil: ***misurpurpu***
Mung bean	Kannada: ***udu, uddu***; Tamil: ***uruntu***
Peas	Kannada: ***batgadle***; Tamil: ***patanie***; Telegu: ***patanlu***
Pigeon pea	Tamil: ***kanti***; Telegu: ***kandalu***
Soybean	Bengali: ***garikalai***; Kannada:***kadale***; Malayalam: ***kadala***; Tamil: ***kadalai***

D-2. インド-ヒンディ語ほかのマメの呼称

(Hindi and other names of Indian legumes)

ケツルアズキ **Blackgram**	***urd***
Chick pea	***chana,gram***
Cowpea	***lobia***
Faba bean	***baqla***
ガラスマメ **Grasspea**	***khesari***
Mungbean	***mung***
Groundnut	Hindi, Panjabi, Gujarati: ***mungphalii, vilayatimung*** Marathi (Maharashtra): ***phuimung***; Telegu: ***nila senagalu, vershenagalu***
ホースグラム **Horsegram**	***kulthi***
Lentil	***masur***
Pea	***matar***
Pigeon pea	***tur***
Soybean	***bhat, bhatmas, ramkurthi, soyabeen*** Gujarati: ***soyabin***; Telegu: ***soyachikkudu***; Punjabi: ***soyabean***

＊呼称言語の表音記号は略.

基調講演　Keynote speech
1

東南アジアにおけるダイズとラッカセイの受容
―「マメと人間、1万年の歴史から」―

前田和美
（高知大学　名誉教授）

The Acceptance of Soybean and Groundnut into Southeast Asia
From "10,000 Years History of Legumes and Man"

Kazumi MAEDA
(Prof. Emeritus, Kochi University, Japan)

1

マメの子実の変異
2

Variation of Legume Seeds in Size, Shape, Color and Pattern

インゲンマメ
Common bean (Japan)

Magnification is not equal in species and cvs.

2

マメ科のイモ形成種　―ホドイモとヤムビーン―
3

Tuber crops in Legume spp. – Apios and Yambean-

アメリカホドイモ
（日本栽培種）
Apios grown at Kochi, Japan

クズイモ（ヤムビーン）
ミャンマー, パガン
Yam bean grown at Pagan, Myanmar

3

地下結実のマメ;ラッカセイ(南アメリカ)、バンバラマメとゼオカルパマメ(西アフリカ)
4

Geocarpic legumes; Groundnut (S. America), Bambara groundnut & Geocarpa bean (W. Africa)

ラッカセイと近縁野生種
Groundnut & wild relative, *Arachis monticola*

バンバラマメ
Bambara groundnut

ゼオカルパマメ
Geocarpa bean

4

食べる木本種のマメ
5

Leguminous woody plants for Food

フサマメノキ
Parkia sp.

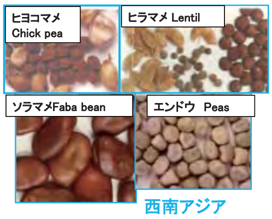
モダマの子実と
その芽出し
Entada sp.

タマリンド (タイ, バンコク)
Tamarind (Bangkok, Thailand)

5

世界の農耕文化を創ったマメ
6

Legumes as "Founder Crop" in the World



Southwest Asia	Chick pea, Lentil Faba bean, Peas
Northeast Asia	Soybean, cv. *Tanbaguro* (Japan) Adzuki bean, cv. *Tanba Dainagon* (Japan)
India & Africa	Black gram, Rice bean Cowpea
Meso-South America	Common bean Scarlet runner bean

6

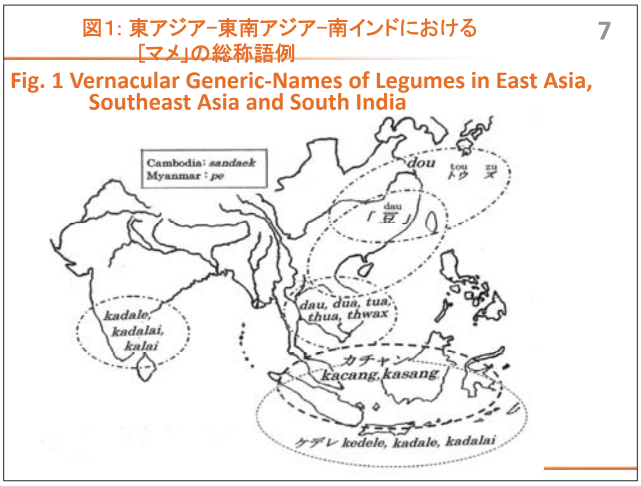


図1: 東アジア−東南アジア−南インドにおける
「マメ」の総称語例
7
Fig. 1 Vernacular Generic-Names of Legumes in East Asia, Southeast Asia and South India
Cambodia: sandaek
Myanmar : pe
dou
tou トウ
zu ズ
dau 「豆」
dau, dua, tua, thua, thwax
kadale, kadalai, kalai
カチャン
kacang, kasang
ケデレ kedele, kadale, kadalai

7

Chair Doi
May I now introduce our next speaker, Dr. Kazumi Maeda. Dr. Maeda is a Professor Emeritus at Kochi University. His expertise is on legumes crop physiology and farming systems in tropical countries. He has an experience working as a visiting scientistat ICRISAT. He wrote a book which describes the relationship between the cultural history of beans and human beings. He is considered as one of the top legume scientists in Japan until now.

The title of his presentation is “The acceptance of soybean and groundnut into Southeast Asia – From 10,000 years’ history of legumes and man.” This is included in his recently published book. Dr. Maeda, floor is yours.

Dr. Kazumi Maeda
Thank you very much for your kind introduction. Ladies and gentlemen, it is my great pleasure to be able to make this keynote speech, and I am very much honored for the opportunity.

Originally, I was requested to give a talk on the domestication, history, and culture of legumes. However, it is too broad for the limited time. Therefore, I would like to focus my keynote speech today on “the acceptance of soybean and groundnut into Southeast Asia -from 10,000 years’ history of legumes and man-”.

What I would like to do first is to show you examples of wide variation in the seeds of leguminous crops. A total of 24 species of widely utilized leguminous crops are shown in Slide 2. As you can see here, “Common bean”, domesticated in the New World, shows a wide variation in seed patterns and colors. It is commonly said that the diverse patterns and colors of seeds are the results of adaptation to obtain camouflage effects to escape from natural enemies. On the other hand, it is also said that these beautiful seeds are the products of a sense of beauty of the Latin American people who domesticated this crop. I myself prefer supporting the latter theory for the beautiful diversity.

In Slide 3, examples of tuber-bearing crops in legume species are shown. On the left is “Apios” or “American potato bean”, *Amerika hodoimo* in Japanese, from Aomori Prefecture, Japan. It is grown with tubers and survives the winter in the form of a tuber under natural conditions in Kochi Prefecture, Japan.

Two photos on the right show a “Yam bean” field in a village in Pagan, Myanmar and its tubers. Please note that “Yam bean”, which belongs to *Leguminosae*, is totally different from the so-called “Yam”, a tuber crop belonging to the *Dioscorea* sp.. I introduced a variety of yam bean that originated in Mexico via the Philippines. It can be well grown in Kochi, Japan, and some farmers there have been able to grow the crop and even sell the tubers to the markets.

Slide 4 shows examples of geocarpic legume species. “Groundnut” is the most well-known geocarpic legume. A wild relative, *Arachis monticola* with the pod of which isthmus elongated is also shown. According to recent research, this *A. monticola* is the most possible ancestor of groundnut. Bambara groundnut and Geocarpa bean were both domesticated in West Africa. Since these 3 legumes grow seeds underground, there were considerations in favor of treating these leguminous crops as tuber crops. It has been recorded that when groundnut was introduced from Latin America to Western Africa, where hunting was the primary work of men and women did most of the hard farming work, men in the region specifically pointed out that groundnut was very easy to grow. This may be a reason why groundnut became very popular there.

As shown in Slide 5, leguminous woody plants are also used as food. These were seeds of leguminous woody plants sold in Bangkok, Thailand, though I did not have the opportunity to taste them.

Here in Slide 6, I listed the major legume crops that played important roles as “founder crop” of agriculture in different regions of the world. In Southwest Asia, “Chick pea”, “Lentil”, “Faba bean” and “Peas” were domesticated. Please look at the photo of lentil. The smaller-sized grain on the left is a local cultivar from India. The large grain on the right is an old Russian cultivar. I consider this comparison as a good example showing selection effectiveness towards bigger seed size.

Regarding India and Africa, “Black gram” and “Rice bean” were domesticated in India, and “Cowpea” has its origin in Africa. Including “Adzuki bean” from Northeast Asia (the photo shown here is the famous Japanese cultivar “Tanba Dainagon”), these 4 species all belong to the genus *Vigna*.

Northeast Asia was also the origin of “Soybean” cultivation. The photo shown here is of a Japanese black soybean cultivar known as “Tanbaguro”, which has a large grain size. “Common bean” and “Scarlet runner bean” are representatives of leguminous crops domesticated in Meso-South America. These two beans in addition to “Tanba Dainagon” Adzuki bean and “Tanbaguro” Soybean are known in Japan as value-added foodstuff for their excellent quality.

Thus far, I have given you a brief introduction on major leguminous crops for food use. Out of more than 20,000 species that belong to *Leguminosae*, only about 30 species of herbaceous plants are cultivated as crops for food use today. However, leguminous plants generally have a special function or ability to perform nitrogen fixation through symbiosis with nitrogen-fixing bacteria. Because of this function, leguminous crops/plants are being adopted in agricultural systems such as mixed cropping and intercropping. They also play important roles in soil fertility management and in conserving traditional agriculture.

Regarding its nutritional value as food, grain legumes are rich in protein, and they supplement cereals for the balanced uptake of essential amino acids in the diet. Recently, grain legumes have been re-acknowledged and are getting more popular as functional food because it is rich in dietary fiber, polyphenolic compounds etc. Therefore, grain legumes are cooked and processed in various ways including fermentation, and served at peoples’ daily table all around the world.

The grains of some leguminous crops have hard or thick seed coats, and some species contain poisonous compounds. Hence, eating habits involving some grain legumes are considered taboo. Generally, however, appropriate preprocessing before cooking solve the problems. As you may know, Lathyrism, a higher incidence of a neuroparalytic disease caused by excessive intake of grass pea, *Lathyrus sativus*, *khesari* in India and Bangladesh. And, Favism, a genetic disorder caused by a hemolytic response to the consumption of faba bean is also well known in Mediterranean area. In ancient Greece and Rome, people believed that evil spirits lived in faba bean, on the other hand the crop was a symbol of procreativity and productivity, and it was also believed that the crop has special powers to expel demons. They used to scatter faba beans at festivals and ceremonies in ancient times, just as we scatter roasted soybean at the traditional end of winter in East Asia. Accordingly, legumes, as valuable crops and foods, offered mental and spiritual sustenance to agricultural people, and this “legume crops belief” still remains with the traditions and customs today.

In regard to the relationship between legume crops and human beings, I have long been emphasizing that there would be another history. I am referring to the way the Australian aborigines and some African tribes, who didn’t choose to get into farming activities and continue to make their living by gathering and hunting up to today, have been utilizing plant species. They have shown an intimate knowledge where and when they could get edible plant species. They also understand how to eliminate and avoid toxic components, and utilize as food sources all parts of the plants such as flowers, fruits, grains, new buds, central part of stems, roots, and resin and nectar for sweetener. What the Australian aborigines call "Bush potato" are enlarged roots of wild *Vigna* sp., for example. It is reported that 27 species from 10 genera of *Leguminosae* plants are utilized as food sources. This accounts for about 10% of edible plant species, thus making *Leguminosae* the most profusely utilized family among plant species as a food source for humans.

Three cereal crops (emmer wheat, einkorn wheat and six-rowed barley), a fiber crop (flax), and 4-5 grain legumes were included in the unearthed articles from the remains of incipient agriculture in Southwest Asia, the area called the Fertile Crescent. These crops are called "founder crops". There were no roots and tubers included in the unearthed articles. The reason why archeobotanical information on roots and tubers was limited is that their tissues were perishable and hence, difficult to preserve and identify. According to the famous classic book entitled "Origin of Cultivated Plants" by A.P. de Candolle (1883), there were many different views and discussions on the origin and diffusion of food crops. In Table 1 in the handout, the origins and centers of secondary diffusion of food crops, where grain legumes, cereals, and roots and tubers existed and developed side-by-side, are summarized.

As per the FAO statistics on crop production, 17 leguminous crops are separated into two groups, “Beans” and “Pulses” with soybean and groundnut grouped as “oil seeds” and not “pulses”. Also in Japan, groundnut (peanuts) is classified as “nuts”. However, from an academic and educational point of view, I would like to propose to treat soybean and groundnut to be classified as “pulses/legumes”.

Now, I am going to focus my talk on the diffusion and acceptance of soybean and groundnut in Southeast Asia, an area where domestication of their own unique legume crop did not occur in its history.

As you know very well, till the time when the oceanic routes became well developed at the end of the 8th century, the Silk Road was a very important trade route by land starting from Luoyang in China via Changan, Dunhuang, Loulan, and Persia towards Rome in Europe. It was recorded that the Silk Road had more than one route, but soybean was cultivated at the starting point of the eastern end, and many leguminous crops were grown in Southwestern Asia as the western end of the road. Therefore, I would call Silk Road as "Soybean Road" or "Legumes Road". Black soybean in Northern India and slightly flat soybean in Java, Indonesia are considered to have been delivered through the route from Yunnan, China, via Laos and Thailand, to the Himalayan area. However, no definitive evidence was recorded on when and how soybean had been dispersed into Southeast Asia. As you know, generic names of crops had been developed based on their vernacular generic name at the place of origin, and modifying words describing the crop's features, such as seed color, shape, and name of the place of origin, were further combined. As a result, the generic name of crops is mostly a so-called compound word. Therefore, if the history of cultivation is longer and spread wider, vernacular generic names of the crop tend to increase more in number through adaptation of and modification by other languages during the dispersion.

If we draw our attention to the Malaysian and Indonesian people, it is said that their ancestor was the Han populations who moved from Chang Jiang, China to Taiwan and further to the south about 5,000 years ago. They used the Austronesian language as common language. Therefore, I surveyed the vernacular generic names of soybean in Southeast Asia to explore the pathways by which the soybean was dispersed. A part of the results is summarized in Table 2 and Figure 1. Here, I would like to provide the gist of the detailed research.

There are many vernacular generic names for leguminous crops in Southeast Asia. Excluding "Sandaek" in Khmer of Cambodia, "Pé" in Tibetan-Burmese in Burma, and diverse vernacular generic names of ethnic minority groups in island areas, the names of leguminous crops in Southeast Asia are mostly classified into 3 groups, i.e., "*kacang*" group, "*dau*" group, and "*kedele*" group. Regarding the *kacang* group, the origin of the word is not clear yet, but since the integration of the Indonesian and Malaysian languages in 1977, the spelling has become common. As shown in Table 2-A, "Soybean" is called *kacang soya* (soya for soy sauce in Japanese) or *kacang depoon* (*depoon* for Japan), which means that the legume is from Japan. Groundnut, a geocarpic legume, is called *kacang tanah*, which means "bean in soil", as it is also commonly called in other languages. Other names for groundnut in this region are *k. china* or *k. goreng,* where the words *china* and *goreng* mean China and oil, respectively. In this group, they call pigeon pea as *k. kayu* (bean on tree), cowpea as *k. panjang* (long bean), adzuki bean as *k. merah* (red bean), and mung bean as *k. hijau* (green bean).

Next is the group of *dou*, *tou* and *tua*, as shown in Table 2-B. These names were considered to have originated from the Chinese character 「豆: *dau*」. These generic names are used in Vietnam, which was mediatized by force of arms to China about 1,000 years ago. In Laos and Thai, they also use these names. In Japan, we also read out this Chinese character as *tou* or *zu*, and as *dou* in Korean.

In Chinese, bean sprout「豆芽」is pronounced as *dou-ya*. The "*Kacang* group" people in Malaysia and Indonesia call bean sprout *taoge*, *toge* or *taugih,* which sound relatively similar to Japanese. In Sarawak, Malaysia, 「豆腐」is called *toufu*, and as *tafu* in Indonesian. This indicates that soybean as a crop and as food, such as bean sprout and bean curd, were dispersed and accepted into Southeast Asia in different times and through different routes. Details have not been researched yet, but overseas Chinese merchants would play important roles in the dispersion and acceptance of soybean and its culture. In addition, groundnut is *Luò-huashēng* in Chinese, and *Lac-hoasin* (or *aulac* for short) in Vietnamese when it is written in Chinese character.

The third group is *kedele* as shown in Table 2-C. Soybean is called *kedele* or its modified variations in the Malaysian peninsula. There is a name *kacang- kedele* which combined *kacang* and *kedele* together. In 1930, J.J. Ochse published a great and famous book; its English edition was titled "Vegetables of the Dutch East Indies" (1980). The book contained a vast amount of vocabulary (more than 7,000 terms) related to agriculture and food in different languages (in Malay, Javanese and in the languages of the island areas in Indonesia). The vernacular generic names of the *kacang* group and *kedele* as soybean were listed in this book; however, the origin of *kedele* was not mentioned at all.

In other reference sources, it was described that peas were called *atar* in one of the Ethiopian tribal languages, and there might be some relation with *matar*, a generic name of peas in Hindi, India. Therefore, I searched the Hindi words for leguminous crops and the results are summarized in Table 2-D-1. Chickpea, already had been spread about 3,000 years ago in India, is called as *kadale*, *kadala*, or *kadalai*, very similar to kedele by Telegu, Tamil, Kannada and Malayalam, which all belong to the Dravidian languages in south Indian states.

Furthermore, although soybean and groundnut had only been introduced relatively recently into India, both names are considered as names in line with *kadele*. Indian names of crops are mostly based on the Sanskrit language and further linguistic verification will be needed, but I have assumed the classification of both *matkalai* for groundnut and *garikalai* for soybean in Bengali language belongs to the Aryan language group, similar to Hindi, to be included into the *kadale* group.

I think it would be very interesting to further study vernacular generic names in the *kadale* group and the *dou* group, with its many modifying words, but I have not touched this area in detail yet. There is a theory that *kadale* originated from the word *kalaya* for roasted chickpea in ancient India. According to the Rigveda, a collective name for the Brahmanic religious scriptures written in the period from 1,200 to 1,000 BC, it is said that the word *khalva* in Sanskrit for "seeds" or "grain legumes" might be the origin of the word *kadale*.

Please look at Slide 7, Figure 1. As you can see, Indochina peninsula covers a wide part of Southeast Asia. Since it is located in the middle of India and China, it is said that Indochina hindered both Chinese and Indian civilizations from spreading into Southeast Asia. As a result, it is said that Sinicization in Southeast Asia was limited only to northern Vietnam, and Indianization also occurred only in island areas but not to the continent area.

Almost one fourth of the Indian population were Dravidians, and they were very active in trades and cultural exchanges with Southeast Asians through the ages. As you can see in this map, the *kadale* group in South India and the *kedele* group in Southeast Asia are spread and linked, while the *dau* group is geographically quite limited. Taking these facts into consideration, Dravidian people in India could play an important role for the dispersion and acceptance of soybean into island areas in Southeast Asia. Also, vernacular generic names indicate that the Sanskrit language was important for Indianization, as it is often said that Chinese characters played essential roles for Sinicization. Furthermore, according to Ochse's literature as cited before, 50 examples of vernacular generic names for soybean in Malaysian and Indonesian languages were counted, but for groundnut, about 100 examples, which account for twice as many as soybean. The point to consider is how we analyze these facts. In ancient times, the journey from the Chinese continent to the south used to be very difficult either by land or by ocean. However, in 13th century, the maritime route had become developed, allowing the Cape of Good Hope to sail via the eastern coast of West Africa to the Indian Ocean and even to Japan. In 1498 May, Vasco da Gama came to the western coast of India, which was only a month later than Columbus' discovery of the "New World". So, we can presume that groundnut might have been dispersed to the island areas of Southeast Asia earlier than soybean, or that groundnut might have spread much quicker than soybean. As the West African people pointed out, people in Southeast Asia may have also recognized that cultivation of groundnut easier than soybean and became more prevalent. Or, it might be for the simple reason that groundnut grew bigger and much tastier grains.

Today, I have presented the history of two important leguminous crops, soybean and groundnut, in agriculture and in the food culture of Southeast Asia from the view point of crop science. To conclude my keynote speech, I would like to share with you the words of Dr. Norman Borlaug in his award lecture titled "The Green Revolution, Peace, and Humanity", for the Nobel Peace Prize in 1970 for his achievement through the Green Revolution. He said, "In my dream I see green, vigorous, high-yielding fields of wheat, rice, maize, sorghums, and millets, which are obtaining, free of expense, 100 kilograms of nitrogen per hectare from nodule-forming, nitrogen-fixing bacteria. These mutant strains of *Rhizobium cerealis* were developed in 1990 by a massive mutation breeding program with strains of *Rhizobium* sp. obtained from roots of legumes and other nodule-bearing plants. This scientific discovery has revolutionized agricultural production for the hundreds of millions of humble farmers throughout the world..." He passed away at 95 years old in 2009, but his dream has not come true yet. At the end of my presentation today, I would like to express my sincere hope that the new green revolution in leguminous crops will come true in the near future through the work of young scientists here and throughout the world. Thank you very much.

Chair Doi
Thank you Dr. Meada for the perspective of origins of names of legumes are deeply connected with their histories. What a romantic phrase Silk Road was soybean road, I am sure I will use that phrase in other occasions.

I think we understand about importance of leagues and both presentations set the baseline of today's symposium. Please join me in giving a big applause to our excellent keynote speakers. Thank you very much.

Session 1

Legumes in agriculture:
Sustainability, environment, and development

Chair:

Satoshi Tobita, JIRCAS

AN OVERVIEW OF LEGUME CULTIVATION IN JAPAN

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ABSTRACT

The volume of legumes produced by Japanese agriculture is small, but in Japanese traditional food culture, their presence is significant. Soybeans and adzuki beans are processed into Japanese traditional foods such as tofu, natto, soy sauce and adzuki bean paste (bean jam). Furthermore, other legumes introduced recently, such as green pea and sugar pea, have already become very popular in Japanese menus. In my lecture, I will explain the present situation of legume cultivation in Japan.

Soybean is the most planted legume in Japan in terms of acreage (141,800 ha). Most soybeans are cultivatedfor dry seeds. To prevent the overproduction of rice, the Japanese government recommends the cultivation of soybean instead of rice. Hence we commonlysee soybeans in Japanese paddy fields. About 20-30 years ago, Japanese farmers usually planted soybeans on a small scale, and seeding and harvesting were performed manually. But recently, mechanization of soybean cultivation became more widespread at production sites, encouraging the cultivation scale of soybean to become larger as well.

Another soybean type is edamame (green soybeans). Edamame, i.e, the boiled young soybean pod, is a very popular snack in Japan, often served as a partner or appetizer to beer. Edamame's planted acreage is only 1/10 of dry seeds, but total production value is almost the same as those of dry soybean seeds. The main production areas of edamame are Kanto and Tohoku (East and Northeastern) regions.

Adzuki bean is the second most important legume in Japan (32,300ha). Most of the adzuki beans are produced in Hokkaido region. Outside Hokkaido, we can find economical cultivation of adzuki beans at some small areas only, such as those in Kyoto and Hyogo prefectures. In other regions, economical cultivation of adzuki bean are few, and they are often planted for personal production and consumption.

The cultivation area of kidney beans is about 9,000 ha, with over 95% of Japanese kidney bean production coming from Hokkaido region. Kidney beans are mainly used for making bean jam and as boiled beans. For vegetable grade (green bean), the planted acreage is about 5,800 ha and the main producing regions are Kanto and Tohoku.

Peanut came to Japan in 18th century. Currently, the total production acreage is about 7,000 ha. It is mainly processed as snacks like roasted pods and beans. The main production area of peanut is Southern Kanto (East) region, especially Chiba prefecture. The scale of peanut cultivation is small, so harvesting and drying operations are still done manually.

Pea and broad beans are mainly used as vegetables. Podded peas and green peas, with a total production acreage of about 3,000 ha, find major usage in Japan. Dry pea production is little and limited mainly to Hokkaido.I It is used for snacks such as bean paste and fried beans. Broad bean, with about 2,000 ha cultivation area, is used like edamame.

About other legumes, there are not enough statistical data. Surely, we can find other legumes, such as cowpea and winged bean, in farmers' fields. However, the production scale is not large and they are cultivated much like those in kitchen gardens. In the Southwest region, cowpeas are often confused with and planted instead of adzuki beans. Winged bean is mainly planted at Okinawa region and used for vegetable dishes. Mung bean is popular as a bean sprout, but most mung beans are imported and there are none or only little cultivation in Japan.

KEYWORDS

beans, legumes, soybean, production, cultivation

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Institute of Crop Science, NARO

An Overview On Legumes Cultivation In Japan

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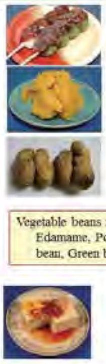
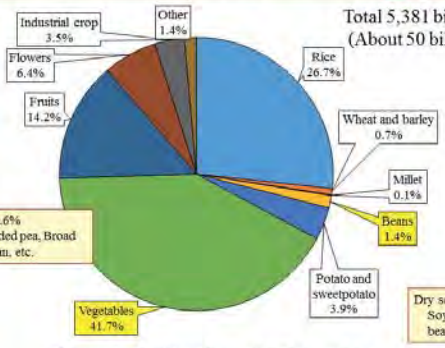
Today's contents

1. Present Situation of Japanese Legumes





Total 5,381 billion yen
(About 50 billion dollars)

(MAFF data)

Vegetable beans : 2.6%
Edamame, Podded pea, Broad bean, Green bean, etc.

Dry seeds
Soybean, Adzuki bean, Peanuts, etc.

Gross agricultural production value

Though total legume production value is only 4%, legume presence is not small. Legumes are becoming indivisible in Japanese diet, such as tofu and soy source.

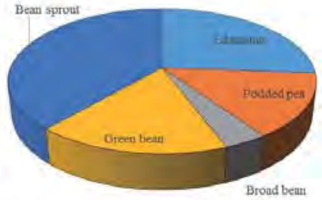
Agricultural production value of legumes

(MAFF data)

Production of dry bean

76.6 billion yen

Production of vegetable bean



137.9 billion yen

(Note)
Most of dry beans are processed to factory products, such as Tofu and Natto.
For example, production vale of tofu and fried tofu is more than 280 billion yen.

Total agricultural production value of legumes is more than 200billion yen. In addition to that, the economical value as the factory product is higher.

Legume position in the field crops

Production of field crops

Item	Year	Planted area (ha)	Yield (kg/10a)	Production (t)	
○Soybean	2015	141,800	171	242,400	
○Azuki bean	2013	32,300	211	68,000	
○Peanut	2015	6,700	184	12,300	
Sweet potato	2015	36,600	2,220	814,200	※Fresh weight
Potato	2014	78,300	3,140	2,456,000	※
Sugarcane	2015	29,600	5,380	1,260,000	※
Sugar beet	2015	58,800	6,680	3,925,000	※
Buck wheat	2015	58,200	60	34,700	
Sesame	2007	216	46	96	
Rapeseed	2015	1,630	194	3,160	
Rice	2017	1,506,000	531	7,989,000	

Circles show crops mainly bred in NICS

(By MAFF data)

Self-sufficiency ratio (%) of dry beans

Item	Domestic production (t)	Import (t)	self-sufficiency ratio(%)	year
Soybean	231,700	2,828,000	7.6	2014
	(231,700)*	(836,000)	(21.7)	2014
Adzuki bean	67,500	28,300	70.5	2013
Common bean	19,100	31,300	37.9	2013
Pea	700	15,200	4.4	2013
Broad bean	100	5,000	2.0	2013

*Characters in the parenthesis is for food grade

(MAFF data)

Because adzuki bean is local bean from the worldwide view point, so the import volume is little.

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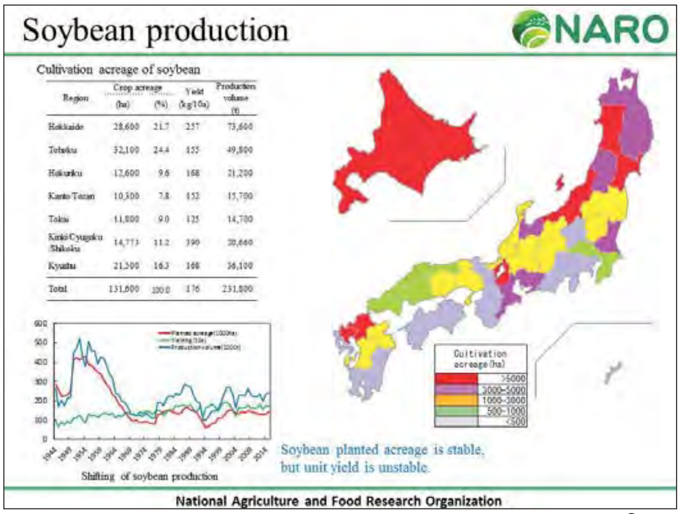

Region	Crop acreage (ha)	Crop acreage (%)	Yield (kg/10a)	Production volume (t)
Hokkaido	28,600	21.7	257	73,600
Tohoku	32,100	24.4	155	49,800
Hokuriku	12,600	9.6	168	21,200
Kanto/Tozan	10,300	7.8	152	15,700
Tokai	11,800	9.0	125	14,700
Kinki/Cyugoku/Shikoku	14,773	11.2	190	20,660
Kyushu	21,500	16.3	168	36,100
Total	131,600	100.0	176	231,800

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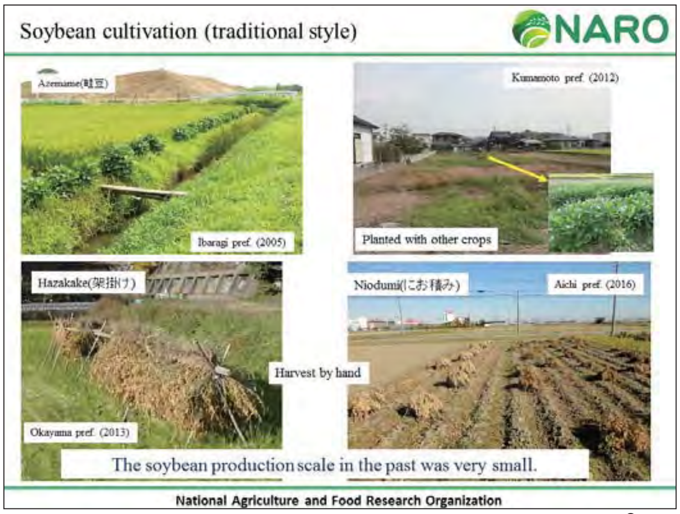

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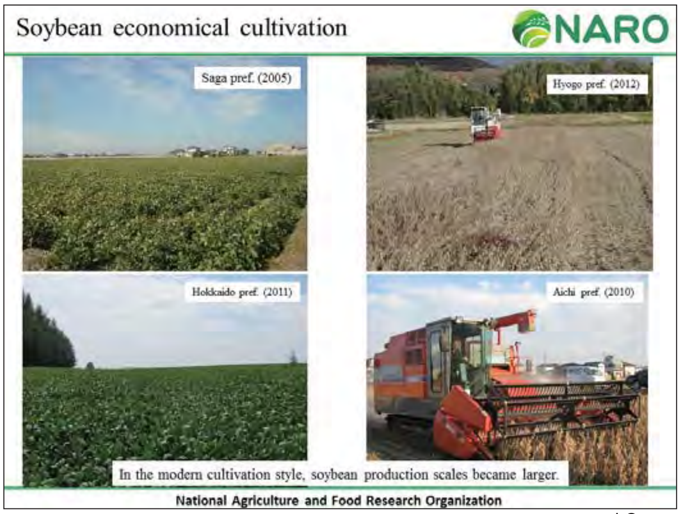

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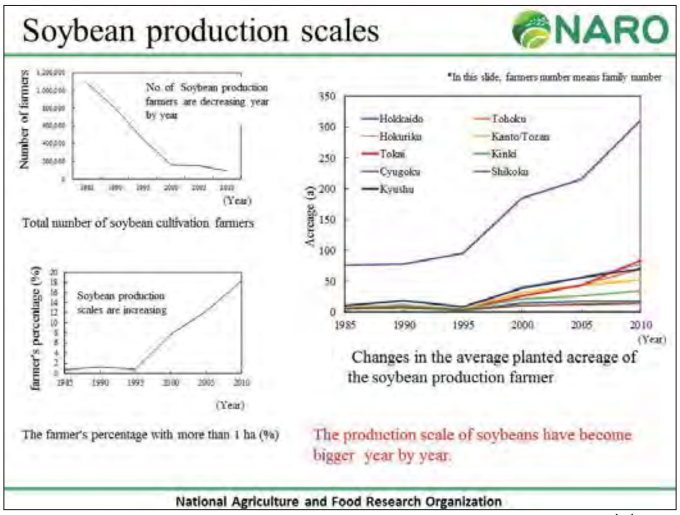

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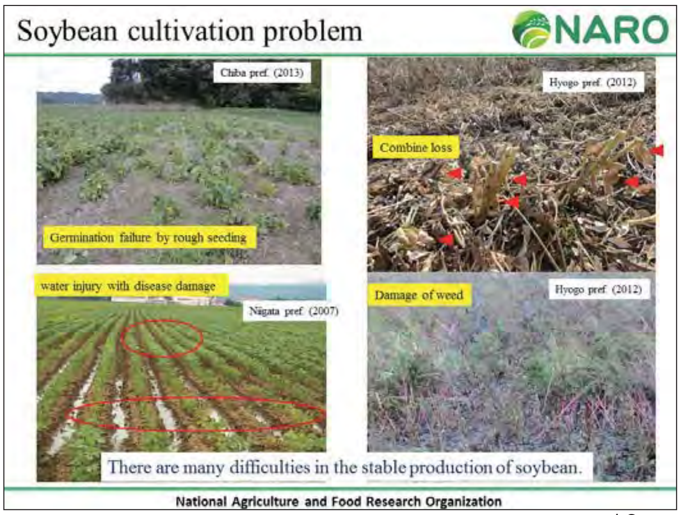

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Adzuki bean production

NARO

Cultivation acreage of Adzuki bean

Region	Crop acreage (ha)	Crop acreage (%)	Yield (kg/10a)	Production volume (t)
Hokkaido	26,300	82.2	274	72,100
Tohoku	1,390	4.3	…	…
Hokuriku	369	1.2	…	…
Kanto/Tozan	1,110	3.5	…	…
Tokai	136	0.4	…	…
Kinki/Cyugoku /Shikoku	2,256	7.1	…	…
Kyushu	438	1.4	…	…
Total	32,000	100.0	240	76,800

Most of the adzuki beans are produced in Hokkaido region.

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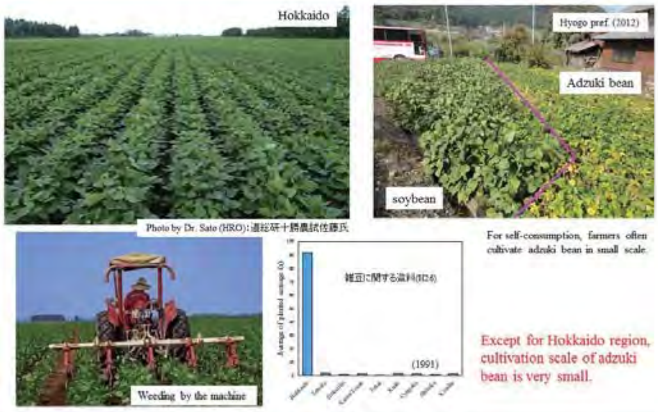
Cultivation of Adzuki bean

NARO



For self-consumption, farmers often cultivate adzuki bean in small scale.

Except for Hokkaido region, cultivation scale of adzuki bean is very small.

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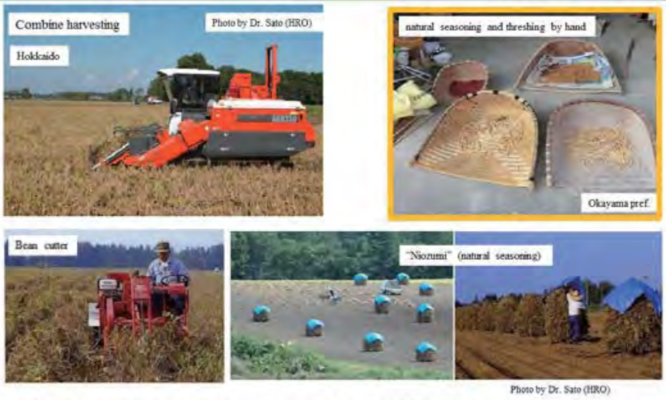
Adzuki bean harvesting

NARO



In Hokkaido, combine harvesting become popular. But man hand harvest still remain in the other region.

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Common bean production

NARO

Cultivation acreage of Common bean (*Phaseolus vulgaris*)

Region	Crop acreage (ha)	Crop acreage (%)	Yield (kg/10a)	Production volume (t)
Hokkaido	8,540	92.2	231	19,700
Tohoku	119	1.3	…	…
Hokuriku	87	0.9	…	…
Kanto/Tozan	484	5.2	…	…
Tokai	4	0.0	…	…
Kinki/Cyugoku /Shikoku	22	0.2	…	…
Kyushu	1	0.0	…	…
Total	9,260	100.0	221	20,500

Common beans are mainly produced at Hokkaido.

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Common bean cultivation

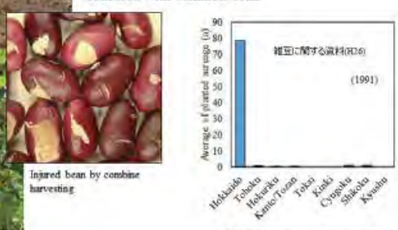
NARO

Except for Hokkaido region, cultivation scale of common bean is very small. The production situation of common bean is same as adzuki beans.

Non-climbing type common bean can be harvested by harvester.

Runner bean (Phaseolus coccineus) is often confused with common bean.

Climbing (vine) type



Injured bean by combine harvesting

Cultivation scale is very small.

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Peanut production

NARO

Cultivation acreage of Peanut

Region	Crop acreage (ha)	Crop acreage (%)	Yield (kg/10a)	Production volume (t)
Hokkaido	-	-	…	…
Tohoku	8	0.1	…	…
Hokuriku	30	0.4	…	…
Kanto/Tozan	6,370	93.1	…	…
Tokai	104	1.5	…	…
Kinki/Cyugoku /Shikoku	39	0.6	…	…
Kyushu	281	4.1	…	…
Total	6,840	100.0	235	16,100

MAFF Stat

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Production of other beans

NARO

Crop	Planted acreage (ha)	Yield (kg/10a)	Production volume (t)	Main production area
Pea	536	222	1,189	Hokkaido, Yamaguchi
Cowpea	90	56	50	Okinawa, Okayama, Gunma
Broad bean	81	(231)	5	Kagawa, Okayama, Ehime
(remarks)				
Soybean	142,100	161	229,200	Hokkaido, Tohoku, Kyushu
Adzukibean	32,287	(169)	53,636	Hokkaido, Kinki
Peanut	9,765	(241)	22,856	Chiba,Ibaraki

*The newest statistical data of these beans are 10 years ago (MAFF, 2006)
**The parenthesis shows the average of some prefecture which correct data was obtained


Mung bean (green gram)

Mung bean is used for bean sprout, but there are few production in Japan.

Cowpea shapes is similar to adzuki bean, and farmers often plant cowpea as adzuki bean. Cultivars, such as "Kuroadzuki" and "Tenko adzuki", are cowpea.

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Snap peas (young pea pods)

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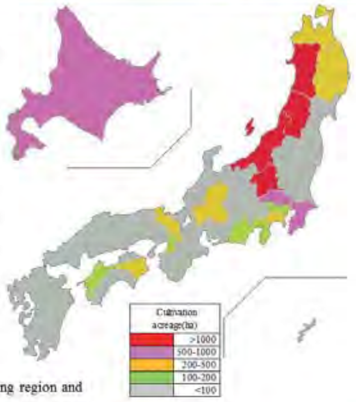
Production of Edamame (green soybean)

NARO

Edamame (エダマメ)

Region	Crop acreage (ha)	Crop acreage (%)	Yield (kg/10a)	Production volume (t)
Hokkaido	854	8.5	587	5,010
Tohoku	3,155	31.6	405	12,773
Hokuriku	1,570	15.7	384	6,030
Kanto/Tozan	3,167	31.7	710	22,490
Tokai	488	4.9	561	2,740
Kinki/Chugoku/Shikoku	757	7.6	578	4,375
Kyushu	-	-	-	-
Japan	9,991 (12,500)	100	536	53,418 (67,000)



Edamame is mainly cultivated near big consuming region and often sold with a branch.

National Agriculture and Food Research Organization

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Edamame harvesting

NARO

Recently, machine harvesting is coming popular in edamame production. Sorting process after harvesting is important for economical value.

National Agriculture and Food Research Organization

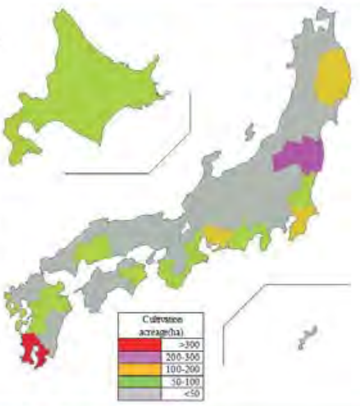
22

Production of Snap peas (podded pea)

NARO

Snap peas, podded pea（さやえんどう）

Region	Crop acreage (ha)	Crop acreage (%)	Yield (kg/10a)	Production volume (t)
Hokkaido	95	5.5	650	618
Tohoku	380	21.9	377	1,434
Hokuriku	-	-	-	-
Kanto/Tozan	208	12.0	567	1,176
Tokai	308	17.7	861	2,653
Kinki/Chugoku/Shikoku	244	14.0	840	2,050
Kyushu	502	28.9	916	4,598
Japan	1,737 (3,020)	100.0	666	20,500 (20,100)



National Agriculture and Food Research Organization

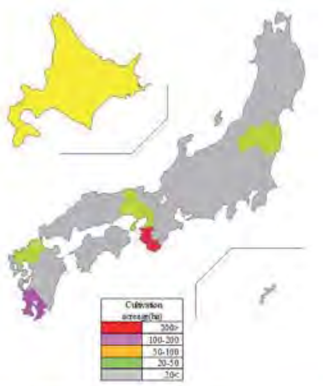
23

Production of Green pea

NARO

Green pea（グリーンピース）

Region	Crop acreage (ha)	Crop acreage (%)	Yield (kg/10a)	Production volume (t)
Hokkaido	51	8.7	532	272
Tohoku	36	6.1	414	149
Hokuriku	- -	-	-	-
Kanto/Tozan	- -	-	-	-
Tokai	- -	-	-	-
Kinki/Chugoku/Shikoku	315	53.6	960	3,025
Kyushu	186	31.6	905	1,683
Japan	588 (859)	100.0	780	5,129 (6,700)



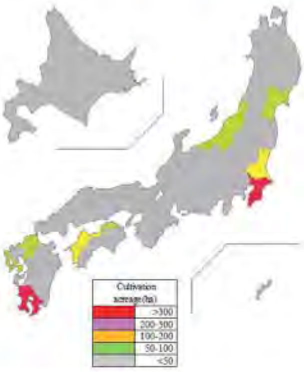
National Agriculture and Food Research Organization

24

Production of Broad bean (vegetable)

Broad bean(そらまめ)

Region	Crop acreage (ha)	Crop acreage (%)	Yield (kg/10a)	Production volume (t)
Hokkaido	-	-	-	-
Tohoku	106	7.2	633	671
Hokuriku	61	4.1	800	488
Kanto/Tozan	540	36.6	796	4,300
Tokai	-	-	-	-
Kinki/Chugoku/Shikoku	247	16.7	693	1,711
Kyushu	521	35.3	1,277	6,652
Japan	1,475 (2,070)	100	860	13,822 (17,800)



National Agriculture and Food Research Organization

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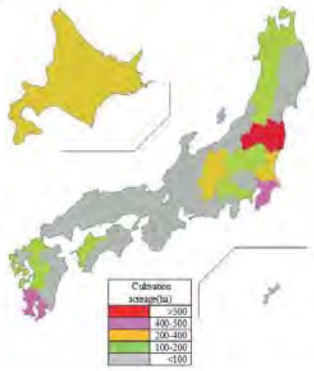
Production of Kidney beans (Green beans)

Kidney beans, Green beans (さやいんげん)

Region	Crop acreage (ha)	Crop acreage (%)	Yield (kg/10a)	Production volume (t)
Hokkaido	353	9.8	892	3,150
Tohoku	946	26.2	681	6,442
Hokuriku	-	-	-	-
Kanto/Tozan	1,168	32.3	1,000	11,683
Tokai	-	-	-	-
Kinki/Chugoku/Shikoku	177	4.9	828	1,466
Kyushu	771	21.4	757	5,833
Okinawa	196	5.4	1,120	2,200
Japan	3,611 (5,820)	100.0	704	30,744 (41,000)



National Agriculture and Food Research Organization

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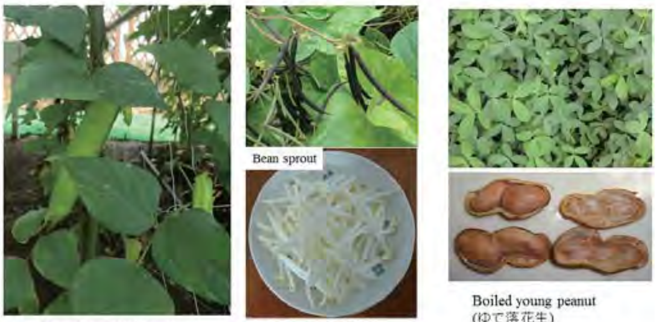
Other vegetable beans



Bean sprout

Winged bean(シカクマメ)　Mung bean (緑豆)　Boiled young peanut (ゆで落花生)

Winged bean is mainly planted at Okinawa region and kitchen garden. Mung bean is popular as bean sprout, but there is no economical production in Japan. Boiled young peanut is cultivated as local specialty products.

National Agriculture and Food Research Organization

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Soybean cultivars

Planted acreage of leading cultivars

Rank	Name	Planted acreage (ha)
1	Fukuyutaka	34,507
2	Yukihomare	12,794
3	Enrei	11,831
4	Ryuho	9,600
5	Tachinagaha	7,485
6	Miyagishirome	4,439
7	Satonohohoemi	4,176
8	Ousu	4,064
9	Sachiyutaka	3,334
10	Toyomusume	3,325
11	Yukishizuka	2,947
12	Tanbakuro	2,861
13	Tanrei	2,610
14	Iwaikuro	2,177
15	Suzumaru	1,940
16	Ootsuru	1,559
17	Nakasennari	1,513
18	Kotoyutaka	1,483
19	Nanbushirome	1,472
20	Natto-syoryu	1,324
	Total	131,600

MAFF (2014)

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Adzuki bean cultivars

Leading cultivars of Adzuki bean

Category	Name	Planted acreage (ha)	Production volume (t)
Dainagon type	Akane dainagon	1,631	2,927
	Hokuto dainagon	426	734
	Kyoto dainagon	477	305
	Tanba dainagon	445	388
	Benidainagon	398	306
	Iwate dainagon	238	183
	Toyomi dainagon	328	686
	other	4,279	3,159
Standard type	Erimosyouzu	15,847	28,948
	Sahorosyouzu	1,035	655
	Kitanootome	6,852	13,442
	Syumari	3,105	5,632
	Tyunagon	504	427
	Syonagon	71	59
	Shiroazuki	200	140
	other	5,418	4,886
Total		32,287	53,636

*)Adzuki bean cultivars are categorized to two types, Dainagon and Standard. Dainagon type is the adzuki bean cultivars in which seed coat do not rupture after boiling.

MAFF(2007)

Except for Hokkaido and Kinki region, native varieties are major.

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Common bean cultivars

Leading cultivars of common bean

Category	Name	Planted acreage (ha)		Production volume (t)
Tebo type	Hime tebou	993		2,530
	Yuki tebou	2,136		5,771
	other	21		39
Kintoki type	Taisyo kintoki	4,175		9,655
	Fukujiro kintoki	446		1,155
	Hokkai kintoki	403		956
	Fukumasari	3,492		8,895
	other	64		139
Uzura type	Fukuryuuchunaga	150	**	337
	Fuku uzura	299	*	692
	other	7		11
Oofuku type	Oofuku	111	*	276
	Toyaoofuku	186	*	385
Toramame type	Kairyotoramame	95	*	220
	Fukutoramame	123	*	262
Runner bean (*Phaseolus coccineus*)	Ooshirohana	415	*	983
	Murasakihanamame	59	*	153
	Hanamame	1	*	1
	Benibana ingen	71	*	63
	other	72		141
Other	Kuwanokimame	2	*	6
	other	761		834
Total		14,082		33,505

* Vine-type
** Semivine-type

MAFF(2007)

Common bean

Photo by Dr. Sato (HRO)

Taisho kintoki	Yuki tebo	Fukura kintoki	Fuku uzura
Fuku toramame	Toyaoofuku	Benishiberi	Panda mame
Kurimame	Kaigaramame	Shirohanamame	Murasakihanamame

Blue character shows Runner bean

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Adzuki bean and Common bean in Hokkaido

Leading cultivars of Adzuki bean

Category	Name	Planted acreage (ha)
Dainagon type	Akane dainagon	369
	Hokuto dainagon	7
	Homare dainagon	296
	Toyomi dainagon	1,946
	other	4
Standard type	Erimosyouzu	9,470
	Sahorosyouzu	266
	Kitanootome	5,025
	Syumari	1,120
	Kitaroman	6,853
	Kitahotaru	29
	Kitaasuka	344
	other	473
Total		26,200

*)Adzuki bean cultivars are categorized to two types, Dainagon and Standard. Dainagon type is the adzuki bean cultivars in which seed coat do not rupture after boiling.

雑豆に関する資料(2014)

Leading cultivars of common bean

Category	Name	Planted acreage (ha)	
Tebo type	Hime tebou	145	
	Yuki tebou	1,685	
	Kinu tebou	251	
	other	19	
Kintoki type	Taisyo kintoki	2,534	
	Fukujiro kintoki	110	
	Hokkai kintoki	154	
	Fukumasari	1,929	
	Fukujyu kintoki	180	
	Fukura kintoki	643	
	other	19	
Uzura type	Fukuryuuchunaga	21	**
	Fuku uzura	148	*
	other		
Oofuku type	Oofuku	48	*
	Toyaoofuku	58	*
Toramame type	Kairyotoramame	17	*
	Fukutoramame	112	*
Runner bean (*Phaseolus coccineus*)	Ooshirohana	117	*
	Murasakihanamame	116	*
	other	3	
Total		8,380	

* Vine-type
** Semivine-type

雑豆に関する資料(2011)

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Legume Major Cultivars in Japan

Item	Japanese name	NO. of registered cultivars**	Example of cultivars
Soybean	大豆、枝豆	217	Fukuyutaka, Enrei, Yukihomare, Tachinagaha, (Tanbakuro)*, Ryuho, Hiden, Okuharawase, Sapporomidori, Sayamusume
Adzuki bean	小豆	23	Akanedainagon, Erimosyouzu, Kitanootome, Syumari, (Tanbadainagon)
Common bean	インゲンマメ、さやいんげん	54	Taisyokintoki, Fukumasari, Yukitebou, Oofuku
Runner bean	ベニバナインゲン	3	Murasakimame, Ooshirohana, Hitachiooguro
Peanut	落花生	9	Chibahandachi, Nakateyutaka, Kairyouhandachi, Oomasari
Pea	エンドウ、さやえんどう、グリーンピース	77	Toyomidori, (Kinusaya endou), (Snap endou)
Broad bean	ソラマメ	23	Ryousaissun, Kawachiissun, Nintokuissun, Ainosora
Winged bean	シカクマメ	6	Urizun, Chikushimidori, Wakasama

*Name in the parenthesis is general name including some cultivars.
** The number of the registered cultivars were counted at MAFF HP. There are many conventional cultivars and patent broken cultivars.

We have not enough cultivars data except for Soybean and adzuki bean. So, number of registered cultivars and cultivar names are pick up from MAFF HP

(pagehttp://www.hinsyu.maff.go.jp/vips/CMM/apCMM110.aspx?MOSS=1).

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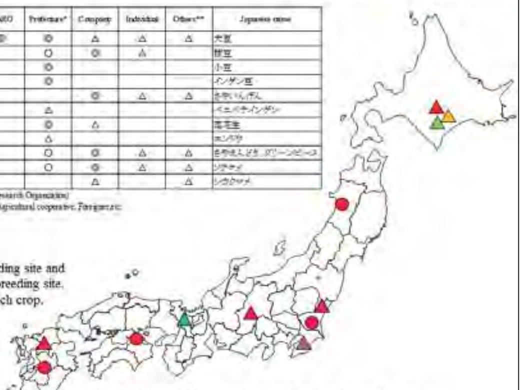
Legume Breeding Organization

Item	Type	NARO	Prefecture*	Company	Individual	Others**	Japanese name
Soybean	seed	◎	◎	△	△	△	大豆
	vegetable		○	◎	△		枝豆
Adzuki bean	seed		◎				小豆
Common bean	seed		◎				インゲン豆
	vegetable			◎	△	△	さやいんげん
Runner bean	seed		△				ベニバナインゲン
Peanut	seed		◎	△			落花生
Pea	seed		△				エンドウ
	vegetable		○	◎	△	△	さやえんどう、グリーンピース
Broad bean	vegetable		○	◎	△	△	ソラマメ
Winged bean	vegetable			△		△	シカクマメ

* "Prefecture" contains HRO (Hokkaido Research Organization)
** "Others" contains University, JIRCAS, Agricultural cooperative, Foreigners etc
◎: Main breeder organization
○: Small breeding organization
△: Not systematic



Circles show NARO's breeding site and triangles show prefectural breeding site. The colors correspond to each crop.

Soybean
Adzuki bean
Peanut
Common bean

This map shows major breeding station and some prefecture have other small-scale breeding laboratory.

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Chair Tobita
Good morning. Welcome to Session 1. My name is Satoshi Tobita, Program Director of JIRCAS, in charge of the Environment and Natural Resource Management Program.

This session is titled 'Legumes in agriculture: Sustainability, environment, and development.' It covers a range of research from agronomy to development. In this session, we will have three presentations. The first presentation is about the situation of legumes cultivation in Japan. Second, we will see the legumes in cropping systems in sub-Saharan Africa in some projects. And third lecture is about agriculture development projects and their impacts in Central America.

I cordially ask all speakers to finish your presentation within 15 minutes. Now, I will call Dr. Makita Hajika as the first presenter. Dr. Hajika is Director of Field Crop Research Division of the Institute of Crop Science, NARO. His expertise is soybean breeding, but today, he may speak also about other legumes in several aspects. I know him as technical advisor to new activities for promoting soybean in Africa. Okay, Dr. Hajika, the floor is yours.

Dr. Makita Hajika
Thank you Chairman. I am Hajika. I am a soybean breeder, but today, I have to talk about not only soybean but also the other legumes. So, some part of other legumes, I have some mistake or so, please allow me. These are today's contents. There are two types of legume usage. One is grain usage and second is vegetable usage. So, I will talk two types of legumes. First, I want to introduce to you the present situation of Japan's legumes. This chart shows gross agricultural production value. We can see legumes at beans and vegetable categories. Though total legume production value is only 4% of Japanese agricultural production value, but the presence of the legumes is not so small in Japanese food life. For example, soybean is very important food material like miso or tofu and adzuki bean is very popular in Japanese sweets. In addition to that, podded pea and green beans are popular at green salad.

Total production value of legumes is more than 200 billion yen. Grain bean is 76 billion yen and vegetable one is two times or so. But in addition to that, the economical value of the factory products is larger. For example, production value of tofu and fried tofu is more than 280 billion yen. So, grain bean is important for processing legumes.

This is the legume position in the field crops. Compared to the rice, the legume production area is not so big, but compared to the other field crops, bean production area is not so little.

This table shows the self-sufficiency ratio of dry beans. Except for adzuki beans, self-sufficiency ratio is not so high, especially pea, broad bean and cowpea are low. In addition to that, probably about lentil, pigeonpea and chickpea, there is no economical production.

From this slide, I talk about the dry legume production, grain legumes. Soybean has correct data, so I can make easily such slide. This table is cultivation acreage of soybean. Major soybean production area is Hokkaido, Tohoku, and Kyushu, but you can see there is not so small production acreage at the other areas. Because Japanese agriculture has one big problem, overproduction of rice. So, instead of rice, Japanese government encourage to produce the soybean at the paddy field. And you can see this small chart. This one is the production chart. Red line is the planted area and blue line is the production volume and green one is unit yield. In these 10 to 20 years, production area is flat, not changing, but the production volume is very unstable. So, it's a very big problem of Japanese soybean production.

This slide shows traditional style of Japanese soybean cultivation. In ancient, you could see the soybean near the ridge of the paddy field or soybean with other crops in the small sizes. In such cases, many farmers seeding and harvested by hand and like that system many man hand labor is needed. But nowadays, in such small production is not so much, very rare. Modern production style is like this. Soybean production scale began larger, not only Hokkaido area but also the other areas, machine seeding and harvesting is standard style.

This is a chart of the production scale. Total number of soybean cultivation of farmers decreasing year by year, but the farmers percentage with more than 1 hectare is increasing rapidly. This is the average of the planted acreage, not only Hokkaido but also the other regions increasing, especially at the Tokai areas, the scale of the soybean production is bigger and bigger year by year. Several slides before, I said soybean production is unstable. There are some causes. One cause is weather disaster or pest damage, but there are other problems.

One big problem is rough management, for example rough seeding, rough harvesting or failure of weed control and humidity control. Accumulation of the small labor misses are big causes of the raw yield or after yield.

Adzuki bean production is mainly conducted at Hokkaido areas. Except for Hokkaido areas, there is not so many economical productions. In Hokkaido, adzuki bean cultivation is similar to soybean. The scale is very big and machine seeding and harvesting is popular. But the other areas like this photo, adzuki bean cultivation is very small size and sometimes farmers only produce for self-consumption like this. This one is a small field and you can see adzuki bean with soybeans. Adzuki bean harvesting in such cases, farmers seeding by hand and harvested by hand and threshed by hand. In small scale adzuki bean production is all hand made. So, it’s only for their self-consumption. In Hokkaido, combine harvesting is becoming standard style. Before style is bean cutter, harvesting, and natural seeding style.

Common bean production situation is similar to adzuki beans. Most of the common bean are produced at Hokkaido areas. Except for Hokkaido areas, cultivation scale of common bean is very small and it is the same as the situation of adzuki bean. There are two types of common bean. One type is non-climbing type. This is a dwarf type that we can easily use the machine for harvesting, but climbing type or running type common bean, we need bean pole and it is difficult to machinization. Compared to the adzuki bean, common bean has a larger seed, so injured bean by combine harvesting is becoming problem.

Now, the peanut production. We can see peanut at the south Kanto areas, especially at Chiba Prefecture. Most of the peanut production is at Chiba Prefecture.

In the works of peanut cultivation, many man hand labors still remain. For example, mulching is machine, but seeding is by hand and harvesting is by hand. Of course, some harvester was developing but it’s not popular. Natural seeding process like this one is very important process for good quality, especially for good taste. So, this process cannot move to the machine harvesting. It’s one big problem for the production of peanut cultivation.

About the other beans, there is not so many data for other bean production. This is 10 years ago data. But the situation is not different probably. Compared to soybean or adzuki bean, the production area is very small. In addition to that, cowpea seed shape is a similar to adzuki bean, so some farmers cultivate cowpea as adzuki bean. For example, cultivar such as Tenko adzuki or Kuroadzuki are cowpea.

From this slide, I will talk about vegetable legumes in Japan. Vegetable legumes, there is not so much official data. Sorry, I have not so much time, so I have to talk in a few words. Edamame production area is near big cities like Osaka or Tokyo, but recently, highway network is elongating to the north Tohoku areas and the other production areas are increasing. Edamame harvesting in ancient, man hand harvesting was major, but recently, many harvesters introduced to the cultivation field. In addition to that, Edamame sorting machine is very important for keeping the quality.

For snap peas, podded pea, the production of the podded pea spreads from north to south. Such spreading production area is very convenient to provide all season.

Green pea has very small planting areas. We have about 7000 tonnes production, but we imported two times of this production as frozen green peas. This is broad bean production. Grain broad bean is very rare in Japan, but for vegetable, young broad bean is very popular in Japan at spring season.

That’s green beans. Green beans production is similar to the green pea. For the other vegetable beans, mung bean is used for the bean sprout in Japan, but the production of the mung bean is not so much. Most of the mung bean imported from China, Myanmar and Thailand. Winged bean is mainly planted at Okinawa region and small size kitchen garden or so. Boiled young peanut is cultivated as local specialty products.

Lastly, I want to talk about the cultivars. Soybean cultivars have correct data. This chart shows a major cultivar and its planted areas. Most of these cultivars are bred by the public breeding station, but conventional cultivars such as Miyagishirome or Tanbakyro still remain as the local cultivars.

For adzuki bean cultivars, I have no new data. So, this is the old data, but you can see in Hokkaido areas, new cultivars planted. For the other areas, conventional cultivars, local cultivars still remain.

Common bean cultivars' situation is the same. This table includes the runner beans. Runner beans taste is similar to the common bean, so sometimes they are confused.

This is the newest data, but I can get only Hokkaido data. This one is the new one. Adzuki bean cultivar is two types, Dainagon type is adzuki bean cultivar in which seed coat does not rupture after boiling. Standard type adzuki bean is mainly produced. About the other legume cultivar, I cannot get correct data, so I picked up the number of listed cultivars from the MAFF home page. Of course, two or three times of these number of cultivars exist, but which cultivar is major I don't know surely. This example of cultivar name I picked up from the old data, books, website, the other private data or so.

This slide is the last slide. I introduce Legume Breeding Organization in Japan. This table is breeding site of legumes. You can see most of the grain beans are bred at the public breeding organization and vegetable legumes are bred as private company or individuals, and this map shows major breeding stations. Of course, in addition to this breeding organization, some prefectures have other small scale breeding laboratory and private companies have their own breeding stations. Thank you.

Chair Tobita
Thank you very much Dr. Hajika for reviewing the legumes cultivation in Japan. Because of time, we can have only very, very quick question, one question from the audience. No? Okay. Thank you very much Dr. Hajika. Please give him a big hand. Thank you very much.

LEGUME-BASED CROPPING SYSTEMS FOR IMPROVING SOIL ENVIRONMENTS IN SUB-SAHARAN AFRICA

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Robert Abaidoo

ABSTRACT

Soils in Africa are less resilient for crop production. The soils range from stony and shallow with poor life-sustaining capabilities to deeply weathered soils with inherently poor fertility status. The soils are situated in five major agro-ecological zones depending on the length of the growing period. The agro-ecological zones are humid, semi humid, semi arid, arid and highlands. The dominant soils in these agro-ecological zones are Ferralsols and Acrisols in the humid zones; Ferralsols and Lixisols in sub-humid zones; Lixisols, Arenosols and Nitosols in semi-arid zones and Lithosols in the arid zones. Among these major soils, Ferralsols, Acrisols and Arenosols are laden with severe fertility constraints. Ferralsols have extremely low nutrient retention, low water holding capacity, high P fixation and deficiencies in magnesium, calcium, potassium and molybdenum. Acrisols also have high P fixation, low nutrient retention capacity, as well as boron and magnesium deficiencies. In addition, the structure is weak and internal drainage is poor. Arenosols have low water-holding capacity, low nutrient content, low nutrient-retention capacity, and chronic deficiencies in nitrogen, potassium, sulfur, zinc, manganese, copper and iron. Furthermore, Arenosols are weakly structured and prone to soil compaction. In contrast, Nitosols have good structure and high nutrient retention. Grain legumes such as cowpeas, soybeans, groundnuts and common beans are commonly grown as mono crop, intercrop or in rotation with other crops in the sub-humid and semi-arid zones. The grain legumes have contributed in diverse ways to the restoration and maintenance of soil fertility. Nitrogen is the most limiting nutrient element in the soils of sub-saharan Africa. The contribution of grain legumes to biological nitrogen fixation varied widely depending on the crop, variety and the management practices adopted. Large number of on-farm trials carried out by N2Africa in West, East and Southern Africa showed that the amounts of N fixed were 12 - 266 kg N $ha^{-1}$by cowpea, 3 - 166 kg N ha^{-1} by soybean, 10 - 124 kg N ha^{-1} by groundnut and 5 - 31 kg N ha^{-1} by common bean. These studies also identified the choice of variety and application of P fertilizers as the key determinants for enhanced biological nitrogen fixation. The choice of an improved variety of cowpea increased N-fixed by 120 kg ha^{-1}in one study, while the application of 30 kg P ha^{-1} increased the N-fixed by 58 kg ha^{-1} in another study. Nutrient mining is a widespread soil fertility challenge in Africa. Over the last three decades, nutrient depletion has been estimated at an average of 660 kg N ha^{-1}, 75 kg P ha^{-1} and 450 kg K ha^{-1} in 37 African countries. Studies conducted by the International Institute of Tropical Agriculture in 52 farms in northern Nigeria showed that retention of cowpea haulm at a rate of 100 kg/ha could reverse N mining within 2 to 54 years and P mining within 2 to 10 years of continuous practice. Undoubtedly, grain legumes are endowed with enormous potentials which, when harness appropriately could propel the attainment of the much needed green revolution in Africa.

KEYWORDS

Biological nitrogen fixation, soil types, grain legumes, nitrogen and phosphorus mining

LEGUME-BASED CROPPING SYSTEMS FOR IMPROVING SOIL ENVIRONMENTS IN SUB-SAHARAN AFRICA

Robert Clement Abaidoo and
Andrews Opoku

1

Outline

- Introduction
- Major soil types in Africa
- Fertility constraints of major soils
- Contributions of legume interventions
  - Case study 1: N2Africa Project
  - Case study 2: Gatsby Crop-livestock project
- Concluding remarks

2

Introduction

African Soils

- Africa Continent covers over 3 million ha and has wide range of soils and climatic conditions.
- Among the major soils in Africa, Ferralsols, Acrisols and Arenosols have severe fertility constraints.
- In contrast, Nitosols have good structure and limited fertility constraints.

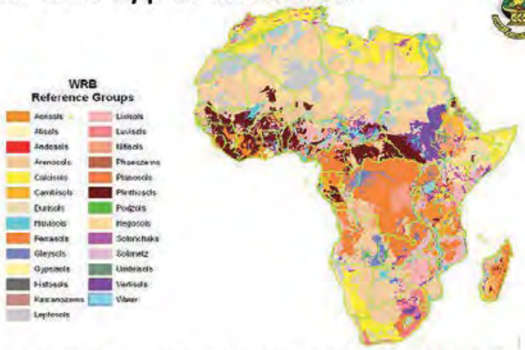
3

African soils....

- Inherently poor in fertility because they are old and lack volcanic rejuvenation, for example.
- There is decline in soil nutrient stocks due to soil erosion, loss of vegetation and poor land management.
- Soils in Africa are less resilient for crop production.

4

Major soil types in Africa



- **Ferralsols, Lixisols and Acrisols are dominant soils in the humid and sub-humid zones**
- **Lixisols, Arenosols and Nitosols are dominant soil in semi-arid zones**
- **Small holder farms predominant**

5

Fertility constraints of major soils

1) Ferralsols

(L. *ferrum*, iron and *alum*, aluminium)

Source: NRCS, 2016

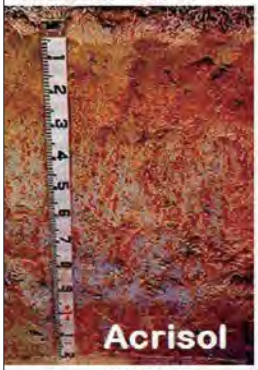
General description:
Red and yellow tropical soils with a high content of sesquioxides.

Soil Fertility limitation:
1) Extremely low nutrient retention,
2) Low water holding capacity
3) High phosphorus fixation
4) Deficiencies in magnesium, calcium, potassium and molybdenum.
5) Prone to erosion

6

Fertility constraints of major soils

2) Acrisols
(from L. *acris*,= very acid)



Source: ISRIC, 2016

General description:

Strongly weathered acid soils with low base saturation

Soil Fertility limitation:

1) Al and Mn toxicities,
2) High phosphorus fixation,
3) Low nutrient retention capacity,
4) Boron and magnesium deficiencies

7

Fertility constraints of major soils

3) Arenosols
(from L. Arena = sand)

Source: ISRIC, 2016

General description:

Sandy soils developed from weathering of quartz-rich rocks

Soil Fertility limitation:

1. Low water and nutrient holding capacity
2. Weak structure

8

Fertility constraints of major soils

4) Lixisol
(L. *lixivia = washed-out substances)*

Source: ISRIC, 2016

General description:

Consists of strongly weathered soils in which clay has been washed down from the surface soil

Soil Fertility limitation:

1. Low nutrient holding capacity.
2. Prone to slaking and erosion in sloping land.

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Fertility constraints of major soils

5) Nitisol
(from L. *nitidus* =shiny)

Source: ISRIC, 2016

General description: *deep, red, well-drained tropical soils with* shiny ped faces.

Soil Fertility limitation:

1) Mn toxicities,
2) high P fixation

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Contributions of legume interventions to soil fertility improvement

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Contributions of legume interventions to soil fertility improvement

Two case studies would be used to illustrate the impact of legume interventions on soil fertility restoration.

Case study 1: N2Africa - Putting nitrogen fixation to work for smallholder farmers in Africa

Case study 2: Gatsby Crop – livestock project

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Case study 1: N2Africa - Putting nitrogen fixation to work for smallholder farmers in Africa

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Case study 1: N2Africa .....

Justification

- Nitrogen is the nutrient element most limiting to plant growth.
- Average fertilizer consumption is still low (ca. 8 kg ha^{-1}) (Sanginga and Woomer, 2009).
- Grain legumes offer an economically attractive and ecological sound means of reducing external N inputs through biological nitrogen fixation (Bohlool et al., 1992).

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Case study 1: N2Africa .....

Yet the average yields of some economically important grain legumes in **Africa are very low**

Grain yields of major grain legumes in Africa

Region	Grain yield (t/ha)						
	Beans	Cowpea	Groundnut	Bambara groundnut	Chickpea	Pigeon pea	Soybean
Africa	0.92	0.94	0.91	0.68	0.81	1.01	1.47
Yield potential	5.00	4.00	3.50	4.00	5.50	5.00	5.00

Source: FAOSTAT (2008)

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Case study 1: N2Africa .....

Why are the grain yields so low?

➢ Successful BNF by legumes in the field depends on

$$(G_L \times G_R) \times E \times M$$

Where:
G_L = Legume genotype
G_R = Rhizobium strain

E = Environment
- climate (temperature x rainfall x daylength, etc) - to encompass length of growing season etc
- soils (nutrient limitations, acidity and toxicities)

M = Management (crop and soil)

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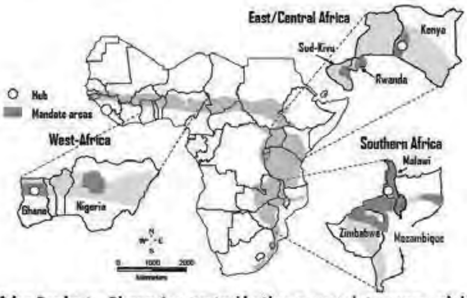
Case study 1: N2Africa .....

Geographical focus of the project



N2fixAfrica Project – Phase 1operated in three mandate areas, eight target countries through three sub-regional hubs

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Mobilizing the best varieties

➢ Varieties of grain legumes with high potential for BNF and yield were selected from existing breeding programs and evaluated on farmers fields.

➢ In total, 301 varietal tests were conducted across the project
- ➢ Nine best soybean varieties,
- ➢ Six best bean varieties
- ➢ Six best cowpea varieties
- ➢ Seven best groundnut varieties

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Harnessing Rhizobia and Advancing Legume Inoculants

Need-to-Inoculate tests

- Estimation of soil rhizobia populations
- Soils with fewer native rhizobia (<50) rhizobia per g soil) are more likely to respond to inoculation
- Populations range from zero to several thousands depending on legume crop

19

Collecting African rhizobia and identifying elite strains

•Bioprospection


Uprooting of a leguminous plant

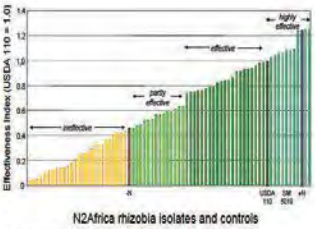

Isolation of rhizobia in the laboratory

20

Evaluating for strain effectiveness under range of controlled and field conditions

Screen house evaluation


Symbiotic effectiveness assay of African rhizobia strains



Effectiveness of 80 isolates nodulating soyabean,

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Case study 1: N2Africa .....

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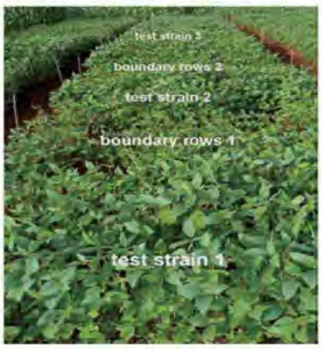
Demonstrating the winning technologies

Field evaluation



Candidate elite strains emerging from N2Africa bio-prospecting and effectiveness evaluation, were:

- ***Climbing bean: NAK 67***
- ***Common bean: NAK 45, NAK 104, NAZ 18, NAZ 23***
- ***Soyabean: NAC 19, NAC 73, NAK 84, NAK 128, NAN 109, NAN 177, NAZ 21, NAZ 25***

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The Phosphorus story..........

Basic layout of BNF technology demonstrations

Table Number of demonstrations, in the eight N2Africa countries.

	Number of on-farm demonstrations[1]
Ghana	1167
Nigeria	347
DR Congo	78
Rwanda	104
Kenya	355
Malawi	753
Mozambique	812
Zimbabwe	1257
Total	4873

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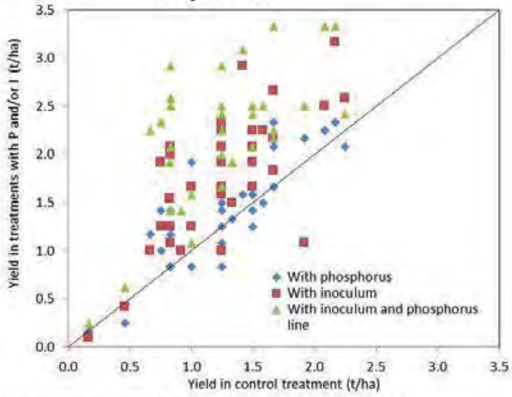
Response to P and inoculation with soybean



N$_2$Africa demonstration trial results in Mushomo, Sud Kivu, DRC 2010

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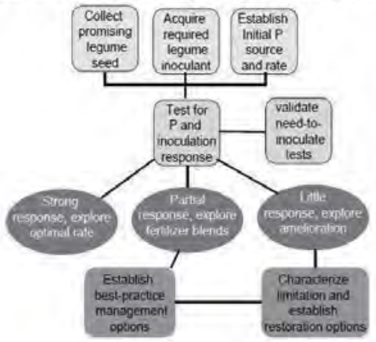
Adhere to the concepts and process

- A stepwise approach for developing best-practice management options will lead to improved legume production



Proven and flexible best-fit management practices are required to realize the potential of improved varieties.

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Case study 1: N2Africa .....

Key outputs

Table summary of the seasonal impacts achieved through BNF technology dissemination over four years by the N2Africa Project

parameter	baseline	after 4 years	change	increase
farmer yield (kg grain ha^{-1})	1,001	1,147	+ 146	15%
legume area (ha farm^{-1})	0.18	0.35	+ 0.17	94%
legume harvest (kg farm^{-1})	179	397	+ 218	122%
crop value ($/ farm^{-1} season^{-1})	154	378	+ 224	145%
BNF (kg N farm^{-1})	10	28	+ 17	169%

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Case study 2: Gatsby Crop – livestock project

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Case Study 2: Gatsby Project - The use of cowpea haulm to reverse N and P mining in the dry savannas of Nigeria

Justification

- Nutrient mining is a widespread soil fertility challenge in Africa.
- Nutrient depletion has been estimated at an average of 660 kg N ha^{-1}, 75 kg P ha^{-1} and 450 kg K ha^{-1} in 37 African countries (Bationo et al., 2006).
- Incorporation of grain legume residues can supply as much as 140 kg N ha^{-1} depending on the legume variety (Giller, 2001).
- The retention of cowpea haulm on the farm after harvest could reverse nutrient mining in the savannas of Nigeria.

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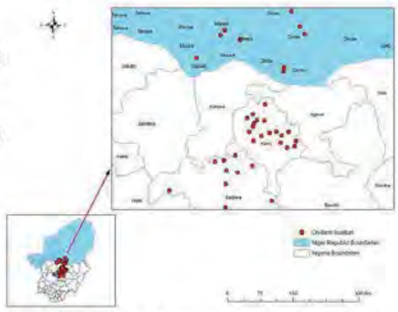
Case Study 2: Gatsby Project.......

Geographical focus of the project

Northern Guinea Savannah (Kaya) : 32 farms

Sudan Savannah (Bichi): 20 farms



Gatsby legume cropping system project sites in Nigeria and Niger Republic

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Case Study 2: Gatsby Project…….

Legume interventions

1) Northern Guinea Savannah: Maize-double cowpea strip cropping (cereal: legume, 2:4)

2) Sudan Savannah: Cereals (sorghum, millet and maize) - cowpea strip cropping [cereal: legume, 2:4]

3) Sole cropping (rotation)

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Quantification of farmer managed flows

- Structured questionnaire for data on:

  Manure (IN 2), allocation of Crop products and Crop residue

Calculations

Nutrient flow	Equation
IN1, IN2, OUT1, OUT2	Amt of material (kgha^{-1})×(nutrient conc (%))
BNF (IN4)	$[\{(N_G \times Y_G) + (N_H \times Y_H)\} \times 0.6]$
Partial balance	**IN1+IN2+IN4 - OUT1- OUT2**

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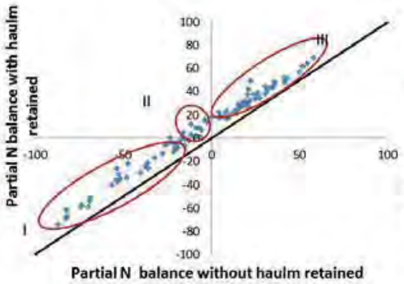
Case Study 2: Gatsby Project…….

Key findings



Three farm groups were identified:

Group 1: farms having –ve partial N balances with or without haulm retention.

Group 2: farms having -ve partial N balances without haulms retention but +ve balance with haulm retention

Group 3: farms having +ve partial N balances with or without haulm retention.

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Case Study 2: Gatsby Project…….

Time frame for reversing negative N balances

	Season 1		Season 2	
	Bichi	Kaya	Bichi	Kaya
Intercept	2.6756	66.44378	18.004	56.321
Coefficient	-0.013	-0.15476	-0.016	-0.022
Amount of Haulm (kg/ha)	**Projections (years)**			
100	1.4	51.0	16.4	54.2
200	0.1	35.5	14.7	52.0
300	0.0	20.0	13.1	49.8
400	0.0	4.5	11.4	47.6
500	0.0	0.0	9.8	45.5
1000	0.0	0.0	1.6	34.6
2000	0.0	0.0	0.0	12.9
3000	0.0	0.0	0.0	0.0

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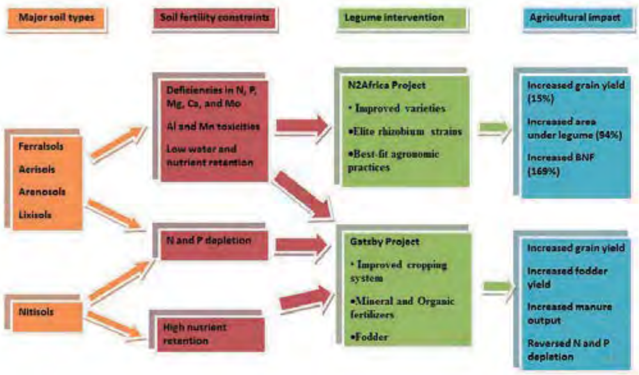
Contributions of legume interventions to soil fertility improvement-Summary



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Concluding remarks

- By disseminating best-fit BNF technologies directly to 253,299 household in eight African countries, N2Africa increased grain yield by 78-272 kg ha^{-1}, BNF by 7-41kg N ha^{-1} and average household income by US$ 355.
- By extending best-fit legume cropping systems to farmer, the Gatsby Project showed that the use of cowpea haulm alone could reverse N and P mining.
- Certainly, grain legumes have enormous potentials which, when harness appropriately could propel the much needed green revolution in Africa.

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Chair Tobita
Next, let me call the second speaker, Dr. Robert Abaidoo. I have known him for more than 10 years when he was working for IITA, Ibadan, Nigeria, as a soil microbiologist. He is currently working for Kwame Nkrumah University of Science and Technology, Kumasi, Ghana as Dean of the School of Graduate Studies. Today, he will speak about the research results, impacts, and lessons from two projects implemented for more efficient utilization of legumes in agriculture systems of sub-Saharan Africa. Okay, Robert, the floor is yours.

Dr. Robert Abaidoo
Okay. Thank you very much Satoshi. Let me also thank the organizers for having me here today. And I think from yesterday I have been quite excited about research in and around legumes.

Today, as he said, I will speak to you on legume-based cropping systems for improving soil environments in sub-Saharan Africa. Briefly, we will talk about the major soil types and their fertility constraints and how legumes can be introduced to intervene in these soil-related problems. I will do this by sharing with you two case studies, one from the N2Africa Project and another one from the Gatsby Crop-Livestock Project. Then, we will share some concluding remarks.

Now, Africa, the continent covers over 3 million hectares including water, with a wide range of soils and climatic conditions. Among these are the Ferralsols, the Acrisols, the and Arenosols which have severe fertility constraints. In contrast, we have the Nitosols that have some good structure and limited fertility constraints. This makes the soils in Africa inherently poor in fertility because they are also old and as suspected we have lack of volcanic rejuvenation. There is therefore decline of soil nutrient stocks due to soil erosion, loss of vegetation, and poor land management. And consequently, as you may expect, the soils in Africa are less resilient in crop production.

Now, we will share with you again here that we have several types from the Acrisols to the Vertisols. But, of course, the predominant ones are the ones we want to pick on today, the Ferralsols, Lixisols, and the Acrisols that are dominant in the humid and sub-humid zones. The Lixisols and the Arenosols and the Nitosols are also dominant soil in semi-arid zones. Why are we picking on these soils? We are picking on them because these are the areas where you have the smallholder farming activities occurring.

I would like to share with you some nice pictures of the profiles. I would like to say that these nice profiles have shadows, and the shadows are largely in respect of their soil fertility constraints. The Ferralsols, for example, are extremely low in nutrient retention, they are low in water holding capacity, they have high phosphorus fixation, and they are deficient in magnesium, calcium, potassium, and molybdenum. And they are also prone to erosion.

The Acrisols are very acid soils, which means that they have high aluminum and manganese toxicity, also high phosphorus fixation, low nutrient retention capacity, they lack boron and magnesium.

We have the Arenosols that are sandy soils, which come from old quartz-rich rocks, which are also low in water and nutrient holding capacity and also have a weak structure.

Lixisols are the ones that are strongly weathered soils in which clay has been washed downwards, which means that the top soils are very poor in clay and as such we expect low nutrient holding capacity and they are also prone to slaking and erosion when they occur on sloping lands.

Here, we have the deep, red Nitisols; deep, red, well-drained soils with shiny ped faces. But of course, they are also limited by the fact that they have high manganese toxicity and also high phosphorous fixation. Now, since these are the predominant soils in the areas where we have smallholder entities, how will we support the livelihood of such smallholder entities? By way of cropping these soils.

Now, as I said, we will use two case studies. The N2Africa is putting nitrogen fixation to work for smallholder farmers in Africa, and the case study 2 is Gatsby Crop-Livestock Project.

Now, why legumes? Briefly, it has been said, this one, by David how wonderful these crops are and how we can use them for environmental sustainability. Because they make natural use of the nitrogen, and by so doing, if they develop high roots systems, they obviously will leave high amount of organic matter in the soils. For the N2Africa, we believe that nitrogen is the most limiting nutrient, and as you might know, in Africa, there is the lowest use rate, about 8 kilograms per hectare, and we also know that the grain legumes will offer an economically attractive and ecological sound means of reducing external N inputs. But of course, we have a precarious situation in Africa where the use of these grain legumes as compared to the huge potential, I can easily estimate it to be less than 25% of this potential. From beans to soybean, they are all very low yielding in these farmer fields. Why it is so? It is so because, probably I am not able to exploit fully the benefits of biological nitrogen fixation by these legumes – why? Because we have probably emphasized too much on breeding. Why? Because probably we do not understand very much the soil environment that support this group.

In this equation, we will say that the variety is very important, the type of Rhizobium is extremely important, the environment that covers the climate, temperature, rainfall, and day length, and also length of growing season become very important and the soils, the natural and nutrient limitations, the acidity and toxicities also influence upon growth. Now, when you have all these conditions, how do you put a management in place to offset some of these limitations? This is what N2Africa tried to do in that project.

Now, the Phase 1 actually spread around eight countries, two in West Africa, three in South and East and Central Africa, and three in Southern Africa.

Now, how was it perceived? First and foremost, looking at the equation, we tried to mobilize the best varieties. So having tested over 300 varietal types, we could identify nine best soybean varieties, six best of bean varieties, six best of cowpea varieties, and seven best of groundnut varieties.

We also stepped into looking at the need-to-inoculate. At this point, let me say that we introduced rhizobia into the soil to enhance the BNF capacity of these legumes. Then, if we have high population of rhizobia in the soil, then your reintroduction of inoculants may be minimized, so you need to establish whether or not you have to introduce new strains into the soil. Normally, when you have population from 0 to 50, you expect some responses to inoculation. In the N2Africa project across the countries, you could observe from zero to several thousands depending on the legume and the soil environment, and whether or not the soil environment has been grown to legumes has explanation inoculation trials in the past.

Now, we exploited the phenomenon of looking at the natural population where did bioprospect looking for strains that have already adapted to the soils in this country, trying to isolate this rhizobia from them and trying to establish how effective these are by comparing them with a standard strain USDA110 here. So, you find that the number of isolations that made - we find those that are really ineffective, those that are partially effective, those that are effective in relation to USDA110, those that are highly effective which meant that you can still have strains that are better than those are already in circulation.

How do you measure effectiveness? Depending on where you are the grain pods are the ones that have made sectioning of the rhizobium inoculation to maximize the – for the synthesis and accumulates more chlorophyll.

On the front, you will be excited to see that these ones are the ones that are dealing with ineffective nodulation or nodules that did not store and these ones are the ones that’s encountering effective rhizobia for high productivity.

Now, having done this, we tried to share the winning technologies with farmers through series of evaluations. As you go up here, you have many strains being tested, and at the moment, we have many of the strains that are kept in the countries. NAK is N2Africa Kenya and these are the nomenclature given them and they are stored in the urban countries.

Now, the phosphorus story. In order to search information of all P fixing, in which case it’s important that we introduce some amount of P into the food when growing these legumes and from several trials and demonstrations, which encompass the good varieties, the rhizobia strains and P addition, you will find that anywhere you have P addition plus inoculation, that is by way of these cones, you will find that they are far, far higher than when you have only phosphorus and only inoculate addition. At this point, it is important to stress that growing legumes would need to supply with additional phosphorus in this soil that’s actually P fixed.

By summary, we are saying that when you do the collection, legume genotypes, you acquire the inoculant and you establish the P initial sources, you can either come by a strong response, a partial response, or little response. This two point-of-need to further diagnosis, to establish that you need to optimize whatever is resistant.

From these activities, N2Africa could increase the farmer yield by 15%, legume yield by 94%, and BNF by close to 170%.

I will take the second one very quickly. It is also on the same premise that as we have the grains back home, we deprive the soil of its inherent stocks. And therefore there is a need to retain some of the produce, especially the nonconsumable parts like the haulms. Now, this project took place in Nigeria and part of Niger where farmers were exposed to improved cropping systems. Here you have soybean and maize if it’s in the Northern Guinea Savannah and sorghum or millets if it’s in the Sudan Savannah. And also the one crop that is below.

Now, by interviewing farmers and knowing how much of the haulms they take home and how much of it is fed into the animals and how much of the animal manure is brought back to the soil, we could do a simple partial analysis where you estimate all your inputs that is inorganic fertilizer, organic fertilizer, BNF that is other position. When you subtract the output that is the grain and output that is the haulm, you will find that you may come by three groups of farmers. The lower group are the ones that will still have a negative balance, that is you are taking more from the soil than left behind, whether they apply the haulms or not. You have a second group that will retain some positive if we don’t apply the haulms, and we have a third group that will be positive whether you apply the haulms or not. And these so that the inherent soil cartridges are very important in establishing whether or not we have a positive balance or a negative balance.

Now, the interesting point is that we tried to look at how many years will we need to repair or reverse the negative balance, in this case, with respect to nitrogen. You could find here that when you apply only 100 kilograms per hectare of the haulms, you will take for example in Bichi where there was very little negative balance, about 1.4 years, whereas in Kaya where you have huge negative balance, you need more than 50 years to reverse this. Now, coming down here, we know that there is recommendation for applying haulm at the rate of 2000 or 3000 kilogram per hectare, in which case in areas where you have literal negative balance, that will easily be corrected. And even in where you have a high negative balance, we are able to use a huge amount of 3000 kilogram per hectare, you may have that correction done over a year.

In summary, I want to say that these are the major soils we spoke about and the deficiencies we also spoke about and the legume intervention by N2Africa and by Gatsby Project. You will find that I have said there is increase of 15% up to about an increase of about 170% of BNF. Now, in the Gatsby Project, you will find that there is increased grain use, there is increased fodder use, there is increased manure output, and you can reverse nitrogen and P depletion.

So, we can say that by disseminating the best-fit BNF technologies to over 300,000 households in eight African countries, N2Africa made a substantial increase in grain yield, in BNF, and also household income by about US$ 300.

Again, by extending best-fit legume cropping systems to the farmer, the Gatsby Project showed that the use of cowpea haulm alone could reverse N and P mining, which certainly means that grain legumes have enormous potentials which when harnessed appropriately could propel the much needed green revolution in Africa. Thank you so much for your attention.

Chair Tobita
Okay. Thank you Robert. We have learned the soil health is in danger in sub-Saharan Africa and legumes can alleviate it through their power. It is clearly shown from your presentation about the two projects. Thank you very much. We can have several questions and comments from the floor. Anybody? Yes.

Male Questioner
My question is about the strains, nitrogen fixing strains. You have successfully screened the very effective strains. Have you ever made a comparison between those effective strains with other strains already found in the United States or so? Which is more effective is my interest.

Dr. Robert Abaidoo
Okay. Thank you very much. As I said, these effective strains have been compared with the existing soybean strain USDA110. So, as long as they perform better than USDA110 under these conditions, we can safely call

them very effective strains. Now, the question that has not been addressed so far is how competitive are these strains with the indigenous strains? Now, when you obtain the strain, for example, from this pot in this room, then you need to apply some others, it is likely possible to go into encounter competition from those or the other strains. And we also know that for the legumes that are dealing with groundnuts, the cowpea, the promiscuous soybeans are difficult to deal with because of the high populations on indigenous rhizobia, that always interfere as a successful nodulation by the introduced rhizobia. So, it would be interesting to find how these locally identified strains would compete, and we believe that because they have come from the same environment, they will not have so much difficulty. But that has to be established. So, a direct answer to your question simply is that, yes USDA110 when it comes to soybean is what has been recommended worldwide. Now, we have strains from Brazil that are supposed to do rather well on groundnut and cowpea, and these strains that we have isolated are also comparable with that. Now, we need to do a molecular titration to establish whether or not these are already introduced strain or it could be really indigenous strains from this environment.

Male Questioner
I need to discuss more but time is limited. I will discuss with you later.

Chair Tobita
Okay. Thank you. Another, yes.

Male Questioner
Okay, thank you very much for your presentation, especially about the N2Africa that I often receive some reports monthly. If you succeed to have very efficient rhizobia, I know that you work with farmers, my concern is how do you – is it easy or hard to get the farmers master the technique of inoculation? Do you perform seminars or – I am interested in how you transfer the technology to the main users. How they do the inoculation technique or…?

Dr. Robert Abaidoo
If I got it right, you ask how we will disseminate the technology, is that correct?

Male Questioner
Yes, exactly.

Dr. Robert Abaidoo
Okay. Now, as I said, the N2Africa Project has dissemination integral to its implementation. So, as long as we are disseminating imported inoculum, it shouldn't be too difficult disseminating these ones that we have isolated, provided they perform better than your imported rhizobia. Three is challenge as to how the smallholder farmers handle this inoculum, and by education, we think that they will overcome the initial problem that they have with inoculum handling. In many cases, because this contains life materials, poor handling needs to be addressed before they apply it. So, it's important that the farmers get educated in how to handle these organisms safely.

Male Questioner
Thank you very much.

Chair Tobita
Okay. Time is up. Thank you very much Dr. Robert. Yes, please give a big hand.

Questioner

IMPACT PATHWAYS OF LEGUMES: INCREASING BEAN PRODUCTIVITY AND NUTRITIONAL QUALITY OF FAMILY DIETS IN THE WESTERN HIGHLANDS OF GUATEMALA

Gretchen Neisler, Ph.D.

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GRETCHEN NEISLER is the Director of the Center for Global Connections in Food, Agriculture and Natural Resources (CGC), a boundary-spanning global organization located in the College of Agriculture and Natural Resources at Michigan State University. The CGC provides leadership support to the Legumes Innovation Lab. Dr. Neisler holds a B.S. in Animal Science, an M.S. in Agriculture Extension Education, and a PhD from MSU in Higher Education Administration. Her international portfolio includes work across the Middle East, East Africa, West Africa, and Southeast Asia, building sustainable partnerships within and for academic institutions. Her expertise is in organizational development, conducting translatable research in agriculture, communicating the impact of agriculture science, and learning from our development failures.

ABSTRACT

Despite the fact that the *three sisters of agriculture* (maize, beans, and squash) were domesticated in the Americas and provide a wholesome diet when augmented weekly with animal foods, and despite efforts to increase agricultural production, the indigenous Mayan population of the western highlands of Guatemala remains one of the most undernourished in the world (UNICEF 2013). Government and donor-led efforts have been reporting on the consequences of malnutrition in the Guatemalan population, particularly children of Mayan families located in municipalities with the highest stunting rates. Locally and internationally, this situation has been portrayed as a national shame since many consider that the country is rich enough to have prevented this situation (*The Economist*, 2009). Government-funded hunger and malnutrition relief projects are working in a state of emergency to improve the situation in priority municipalities. Másfrijol is part of the Legume Innovation Lab's unique approaches focused on improving the nutrition of the entire family by promoting a greater consumption of beans.

The Feed the Future Innovation Lab for Collaborative Research on Grain Legumes, branded as the "Legume Innovation Lab (LIL), began in 1980 as the Bean/Cowpea Collaborative Research Support Program (CRSP) (1980–2007). The program supports ten multi-disciplinary collaborative research and institutional capacity strengthening subcontracted projects working in 13 Feed the Future countries in Africa and Central America and the Caribbean involving scientists at 10 US universities, 3 USDA/ARS research centers, and 23 developing country national agriculture research systems and universities. Much of the LIL research portfolio is geared toward producing new technologies, mainly new grain legume varieties. Six of the ten projects are focused on advancing legume productivity; five of these are focused on plant breeding and genetic improvements, while research of the sixth (SO1.B1) focuses on integrated pest management technologies and overcoming other production constraints.

Másfrijol is a new approach within the LIL that situates nutrition education as a major component. The program provides intensive measures to promote dry bean consumption through consumer (particularly women's) training and education. The training is intended to move under-five children's diets from mainly maize consumption toward more diversity and foods with higher nutrient density such as beans. The output from Másfrijol is educated consumers that have a solid platform in which they can make household decisions for the family. The outcome of this approach is comprehensive and sustainable change in production and dietary decisions among a population of people that has otherwise been ignored.

Global development project impact pathways are complex. As a result of this complexity, the pathway from research outputs to impacts must consider several conditions, most of which are beyond the scope of a pure research project. The Másfrijol project made a conscious decision to institutionalize impact assessment focused on improving project outcomes and by connecting with local stakeholders in every aspect of the programming. This approach integrated a culture of impact assessment and generated an awareness among stakeholders about the obstacles that they were facing and ways in which they could overcome them to obtain sustainable change. The project team and its stakeholders were able to visualize how the research fits into development change and to understand constraints to realization of the change needed as indicated by the research.

KEYWORDS

Guatemala, impact assessment, stakeholders, Másfrijol

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IMPACT PATHWAYS OF LEGUMES:
INCREASING BEAN PRODUCTIVITY AND NUTRITIONAL QUALITY OF FAMILY DIETS IN THE WESTERN HIGHLANDS OF GUATEMALA

Gretchen Neisler, PhD.
Director, Center for Global Connections in Food, Agriculture, Natural Resources

1

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The disequilibrium of food, natural resources, and ecological and economic security

- Per capita consumption of animal proteins is 496 calories compared to an average of 1331 in most of the developed countries.
- 13% of the population in Latin America is undernourished.
- Diet variability is due to cultural, environmental and socioeconomic factors.

2

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Photo courtesy of USAID

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MASFRIJOL AT A GLANCE

Project Objective	Indicative Activity	Expected Results
Increase bean productivity in highland systems	Participatory community needs assessments	200 communities (depending on population densities)
	Almacenes Comunitarios	*75 Almacenes*
	Farmers with access to improved bean seed varieties	25,000 households with access to improved bean seed varieties improving productivity
Enhance nutritional quality of diets		
	Improved technologies for household bean grain storage (PICS bag)	20,000 households with access to PICS technology
	Nutrition education and promotion of nutritious bean-based dishes	12,000 households with access to nutrition education consuming more beans
Total beneficiary households		25,000

6

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The Success Story of Nutrition and Agriculture Education

Patrocinio Garcia, 66
Sows beans after a failed maize crop

7

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MASFRIJOL and Michigan State University wishes to thank:

USAID FROM THE AMERICAN PEOPLE

FEED THE FUTURE

8

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Questions?

9

Chair Tobita
Okay, I will call Dr. Gretchen Neisler, the third speaker of this session. Dr. Neisler is the Director of the Center of Global Connections in Food, Agriculture, and Natural Resources located in Michigan State University. She is specialized in education and her expertise is in organizational development. So, today, she will speak about the complexity of impact pathways in global development project with showing an experience in western highlands of Guatemala. Okay, Gretchen, floor is yours.

Dr. Gretchen Neisler
Good morning everyone. It's always a terrible realization when you realize you are the one that's standing in between in you and lunch. This discussion of food and nutrition education in Latin America will attempt to highlight factual challenges we all know the region to be facing and Michigan State University's attempt to critically dissect these challenges and empower consumer decision making. Since Malthus' first debated food and population, basic data on nutrition problems in Latin America, the demographic impact, food production, and the possible future prospects look relatively the same. But what if a new approach, a shifting paradigm, an attention to culture and education changed this trajectory?

All developed countries have per capita caloric availabilities of over 3000 calories a day, compared to an average of 2465 for Latin American as a whole. Only Barbados and Argentina have 3000 calories per day. The daily average per capita protein consumption of 65.7 grams in Latin America is above the 54 gram per day recommended by the Food and Agriculture Organization and WHO.

In Latin America, the average daily per capita consumption from animal protein is 496 calories, compared with the 1331 in the US. The nutrition status of different Latin American countries varies, with minimal caloric intakes of 1880 calories per day to 2170 in some Central American and Caribbean countries. Haiti, the Dominican Republic, Honduras, Ecuador, and Bolivia have frank protein deficits. Within countries, there may be large food gaps between regions, rural and urban populations, and social classes. The FAO estimated that 41 million Latin Americans representing 13% of the population are undernourished. 38% of Guatemalans, Hondurans, and Haitians, 30% of Ecuadoreans, and 23% of Peruvians are believed to be inadequately nourished. The quality of the diet varies widely between the countries and regions because of a multitude of cultural, environmental, and socioeconomic factors.

In general, the diet is heavy in carbohydrates and light on protein. Undernutrition has a characteristic mortality pattern with deaths concentrated in those under 5 years of age and with physical and mental effects that may persist throughout the lifespan. The Latin American population was increasing at 2.3%/year in 1983, representing 9 million new consumers each year. Food production increased by 3.9% a year between 1971 and 1980, but in at least a third of the countries, the rate of increase in food production was exceeded by the population growth rate. The relationship between population and food is complex and is affected by multiple and changing environmental, economic, and social factors directly related to the international economic system. Latin America must augment its food production capacity and focus on basic nutrition education of its population if the issues of malnutrition are to be eradicated.

The Mayan population in Guatemala's western highlands is one of the most undernourished in the world, with children there suffering high rates of stunting. A well-established indicator of early childhood malnutrition, stunting can affect cognitive development and productivity as well as increase the likelihood for heart disease, diabetes, kidney damage and anemia into adulthood.

Despite the fact that the three sisters of agriculture, maize, beans and squash, were domesticated in the Americas and provide a wholesome diet when augmented weekly with animal foods and despite efforts to increase agricultural production, the indigenous population of Guatemala remains one of the most undernourished in the world. Government and donor-led efforts have been reporting on the consequences of malnutrition in the Guatemalan population, particularly children of Mayan families located in municipalities with the highest stunting rates. In 2009, The Economist reported that locally and internationally, this situation has been portrayed as a national shame since many consider that the country is rich enough to have prevented this situation. Government-funded hunger and malnutrition relief projects are working in a state of emergency to improve the situation in priority municipalities.

Beans, a nutrient-dense food with a high percentage of protein, may seem a likely answer to remedy Guatemala's malnutrition problem, but the solution isn't quite that straightforward. As we all know, farmers don't grow enough beans to meet nutritional needs of the people. Limited access to farmland and elevations greater than 2500 meters above sea level make bean production difficult.

While the three sisters of agriculture are more easily grown in the highlands, they're eaten in disproportionate amounts for proper nutrition. The ratio of maize to bean consumption is 97:3 for most households. A diet this high in corn does not provide the necessary protein and other nutrients to promote healthy growth and development.

To achieve a high-quality protein, equivalent to that of meat, the recommended corn-to-bean consumption ratio should be 70:30, according to Sharon Hoerr, a nutritionist and professor emerita from the Michigan State University. Professor Hoerr goes on to state that a high-quality protein contains the nine essential amino acids that humans must get from food for proper nutrition, health and growth. Beans and maize both contain incomplete proteins; if combined during the same day, however, they form an excellent high-quality protein. Critical problems also lie in the population's limited understanding of the nutritional value of beans, which are often dismissed in favor of processed foods. Consequently, beans are not always consumed when they're available. Instead, farm families frequently sell their beans to purchase less nutritional foods.

Enter Másfrijol. In 2013, Michigan State University, through the support of the Legume Innovation Lab, realized that improving nutrition in the western highlands required the following goals: Increasing bean yields, increasing bean consumption, improving nutrition education, especially about the long-term health benefits of proper nutrition.

The Feed the Future Innovation Lab for Collaborative Research on Grain Legumes, branded as the Legume Innovation Lab, began in 1980 as the Bean/Cowpea Collaborative Research Support Program. The program supports 10 multi-disciplinary collaborative research and institutional capacity strengthening subcontracted projects working in 13 Feed the Future countries in Africa and Central America. Feed the Future is a demarcation of the United States Agency for International Development.

The project involves scientists at 10 US universities, 3 USDA/ARS research centers, and 23 developing country national agriculture research systems and universities. Much of the Legume Innovation Lab research portfolio is geared toward producing new technologies, mainly grain legume varieties; six of the ten projects are focused on advancing legume productivity. Five of these are focused on plant breeding and genetic improvements while research of the sixth focused on integrated pest management technologies and overcoming other production constraints.

Másfrijol is a new approach within the Legume Innovation Lab that situates nutrition education as a major component. The program provides intensive measures to promote dry bean consumption through consumer, particularly women's, training and education. The training is intended to move under-five children's diets from mainly maize consumption toward more diversity and foods with higher nutrient density such as beans. The output from Másfrijol is educated consumers that have a solid platform in which they can make household decisions for the family. The outcome of this approach is comprehensive and sustainable change in production and dietary decisions among a population of people that has otherwise been ignored.

[Audio]

Male Speaker
We are along with mountain range of the Cuchumatanes altitude close to 1600 meters above sea level.

Male Speaker
These are the highlands of Guatemala, and while they are absolutely breathtakingly gorgeous, it's also one of the poorest, least nourished areas in the world.

Male Speaker
It is special for me because I believe that with all the wealth we have in natural resources, it is embarrassing to have very scary malnutrition statistics. We can feed ourselves. With the technology that we are bringing, we can not just have a diverse diet but sufficient for kids not to go through that.

Male Speaker
We are looking here at least 15 to 18 pods per plant. This is an excellent pod formation. This is what we are talking about when we discuss technologies that can help farmers produce more yield per acre.

Male Speaker
This is beautiful. Look at this crop. I see a very intelligent use of this plot to maximize what they can get per square meter and this area here is going to be at least 1.5 quart and I can tell you just by the strength of it and based on our experience, this is a plot that will yield circa 200 pounds per quart. We are talking enough beans for a good four or five months. For a family to have access to protein that is grown in their own soil is very importa.t

Male Speaker
And so the hope is that kids like this little guy down here will be growing up eating beans and understanding their importance and all of that.

Male Speaker
Absolutely. Our deal, our contract with USAID is to focus on families with children of 5 years and under. We found a lot the importance of the 1000 days of life, the first 1000 days which start from conception through your second birthday. If they don't take enough protein, we know that they will be limited in expanding their full potential, both intellectually and physically. So, they are the main focus of Másfrijol.

Male Speaker
Do you know you are the main focus of Másfrijol?

Child
What?

Male Speaker
Do you know you are the main focus of Másfrijol? C or no?

Child
Yes.

Male Speaker
I think we got a "Si" out of him.

Male Speaker
I think we did.

Male Speaker
That's good. We will take it.

Dr. Gretchen Neisler
Másfrijol began its work by providing 15,000 smallholder farmers each with 5 pounds of high-quality seed of improved, disease-resistant bean varieties adapted to the unique agroecology of the region. These altitude-appropriate varieties were developed by the Institute of Agricultural Science and Technology or ICTA to improve bean yields in the inhospitable, high-altitude elevations of the region.

Through its collaboration with the Guatemalan Ministry of Agriculture, the project also provides farmers training on soil preparation, seed germination and safe bean storage postharvest. The training helps farmers improve their integrated crop management, enabling them to grow more beans on their land and safely store the increased yields long-term. As a result, beans can last up to 6 months after harvest.

By relying on the expertise of established public and private sector agencies and organizations in the region, Másfrijol has been able to extend its impact to reach in greater numbers of farmers and even the most remote areas of the highlands. The partnerships have effectively linked the agriculture and nutrition education activities to ensure that farming families are not only growing more beans but eating the beans they've grown.

To support these lessons and facilitate technology adoption, Másfrijol's training team has developed technical guides and videos that focus on key training messages. Key messages are limited to three to five per topic, so farmers and families can remember to put them into practice at home. We don't want to overwhelm them with too much information but build on the knowledge they have and then lead them to new skills for growing and consuming more beans.

For example, in our training on seed storage, one of 15 training modules offered through Másfrijol, we make sure participants understand exactly how to use special plastic bags to store and preserve their grain for up to 6 to 12 months, and that optimal seed humidity for bean storage is less than 14%. The science behind these principles is interesting, but the farmers don't need to understand such details to use the bags, so training doesn't emphasize them. We focus on practical skills that can be easily applied. Many farmers who had become used to inferior seed quality and assumed that beans were difficult and risky to produce have reported twofold bean yield increases. And most are saving beans for family consumption and the next planting season instead of selling them.

Nutrition Education: Within months of the improved seed distribution and crop management education, Másfrijol, working with the Government of Ministry and Health began establishing nutrition education programs to increase the understanding of the link between regular consumption of beans with maize and improved health.

With its partners, Másfrijol has developed culture-sensitive educational materials that accommodate the literacy and language barriers of the target populations, including a coloring book for children focused on making healthy food choices.

Three years after its formation, Másfrijol reports that families consume more beans at family meals, at least three times a week. Infants and children younger than 5 are being fed more beans on a daily basis instead of a predominantly maize-based diet. Families are learning to measure how many pounds of beans they need per week to meet their food requirements. Although there is more work to do and more people to reach, Másfrijol is succeeding in its project goals. Families are growing and eating more beans and sharing them with neighbors. Másfrijol teams have empowered communities to manage improved varieties on a sustainable basis and implement technologies and practices to grow and consume more beans in the future. Thank you very much.

Chair Tobita
Okay. Thank you very much for introducing Másfrijol, more bean project. The key of success was the education to promote legumes production and consumption. It's almost time but I would like to have one quick question or comment. Yes, please.

Male Questioner
Constraints to produce bean in your country in the field condition…

Dr. Gretchen Neisler
I missed the first part of your question, can you repeat it please?

Male Questioner
What is the constraints, difficulties to produce bean in your country in the field?

Dr. Gretchen Neisler
So, early on before the varieties were established, probably the largest challenge was the altitude which we were trying to grow the beans, and it was also in the preparation of the soils as we were providing those cultivars. I should also say related to your question that through the course of the project, 90 different varieties have now been introduced in the western highlands of Guatemala, 45 of them have been small red beans, and when we went back to do the impact assessment on our sort of mid-term of the project, what we realized is that 67% of the land that was being dedicated to bean growth was now these new small red bean cultivars, which then meant an addition of $350 million injected into the agricultural economy of Guatemala.

Chair Tobita
It's clear? Okay, Thank you very much Dr. Gretchen. Okay, now I close the session with thanking to all speakers for a kind contribution. So, please give a big hand to the valuable speakers. Thank you very much.

Session 2

Legumes all over the world:
Use of the diversity for improvement

Chair:

Kazuo Nakashima, JIRCAS

IMPORTANCE OF PULSES RESEARCH IN INDIA: CHICKPEA AND PIGEONPEA

Girish Prasad Dixit

Indian Council of Agricultural Research (ICAR)
- Indian Institute of Pulses Research,
Kanpur 208 024, India

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GIRISH PRASAD DIXIT is presently working as Project Coordinator (Chickpea) at Indian Institute of Pulses Research, Kanpur, India with the responsibility to coordinate the Indian chickpea research programme. He obtained M.Sc. and Ph.D. degrees in Genetics and Plant Breeding from Banaras Hindu University (BHU), Varanasi, India and has been working on the genetic improvement of pulse crops at Indian Institute of Pulses Research, Kanpur, India for the last 25 years. He has developed about 10 high yielding varieties of pulse crops which are very popular in India.

ABSTRACT

Pulses constitute an important dietary constituent for humans and animals because of their richness with proteins and other essential minerals, vitamins and dietary fibres. In India, over a dozen pulse crops are grown in one or the other part of the country, however, the most important pulse crops grown are chickpea and pigeonpea. India has been a leader in production as well as consumption of pulses in the world. The area under pulses cultivation in the country is currently estimated at about 22-23 million hectares while the realized productivity is less than 1 ton per hectare. As a result of rising demand of vegetarian food due to ever-increasing population and diversification of food habits, demand of pulses is increasing at a fast pace. This will be further challenged by changing climate which may manifest itself in the form of shifting rainfall pattern, untimely and erratic rains, extreme temperatures, *etc*. which may also change the cultivation pattern of pulses. Post-harvest losses still remain a matter of great concern. Accordingly, pulses researchers have to remain prepared with a wide range of pulse genotypes which may adapt themselves across changing climates. For developing such genotypes, wild relatives which are rich reservoir of useful alien genes can play an important role. Further improvement in pulses productivity is needed through conservation and diversification of agriculture so as to increase the productivity of the system and improve soil health.

Since pulses are largely cultivated in India under rain-fed and monsoon dependent areas where soil moisture is the critical factor determining the productivity, the production trends keeps fluctuating every year depending upon rainfall. The major constraints that limit the realization of potential yield of pulses include biotic and abiotic stresses prevalent in the pulses-growing areas besides socio-economic factors. Among abiotic stresses, drought and high temperature at terminal stage, cold as well as sudden drop in temperature coupled with fog during the reproductive phase and salinity/alkalinity throughout the crop period inflict major yield losses and instability in production. All these stresses make pulse crops less productive with unstable performance in one or the other way. Thus, there is a strong need to formulate strategic plan to achieve the goal focusing on broadening the genetic base of pulses for breaking yield barriers, hybrid development in pigeonpea, transgenics in chickpea and pigeonpea, high yielding varieties with tolerance to biotic and abiotic stresses, bio-intensification of pulse-based cropping systems and resource conservation, development of micro-irrigation techniques, mechanization and minimizing post harvest yield loss, climate risk management and efficient extension models for dissemination of pulse-based technologies for farmers to make the pulse cultivation productive and remunerative.

KEYWORDS

Chickpea, Pigeonpea, Pulses, Varieties, Yield

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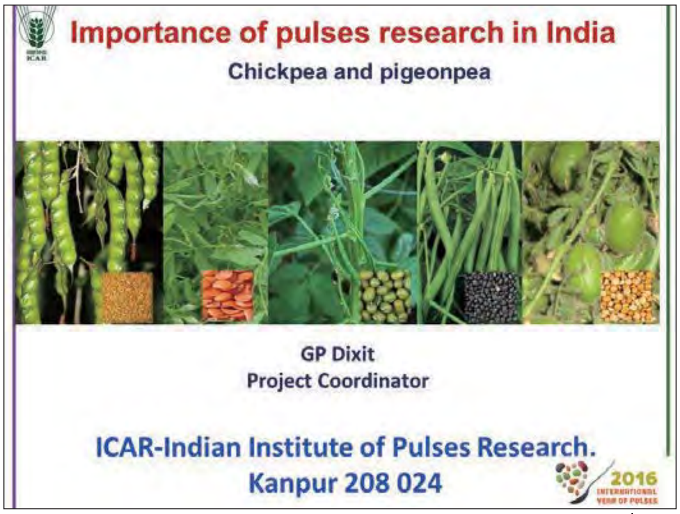

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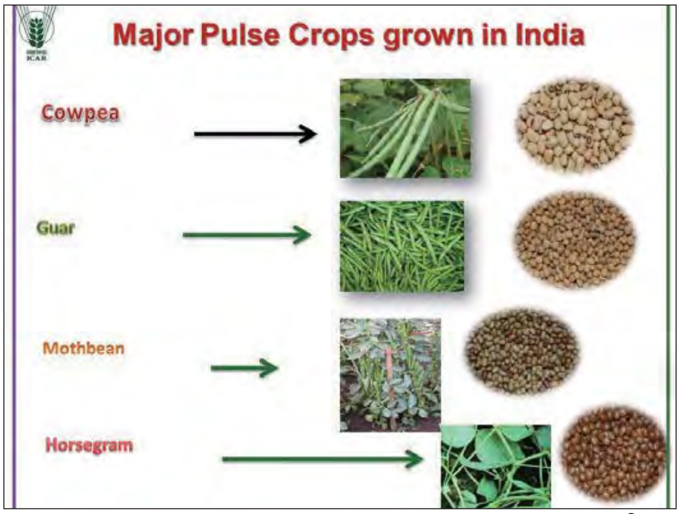

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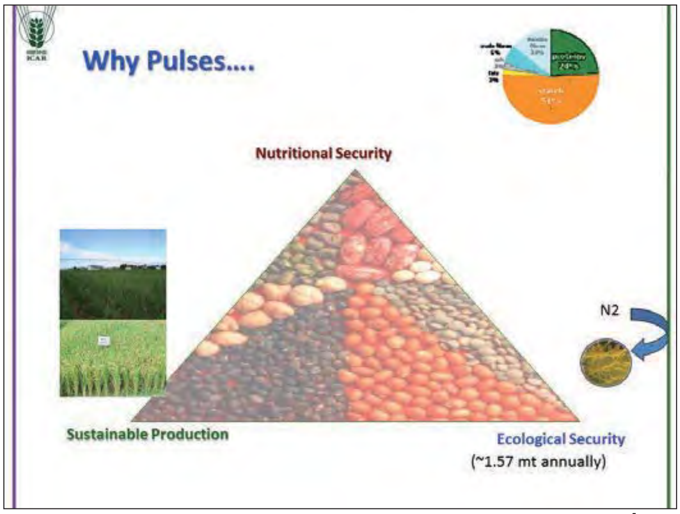

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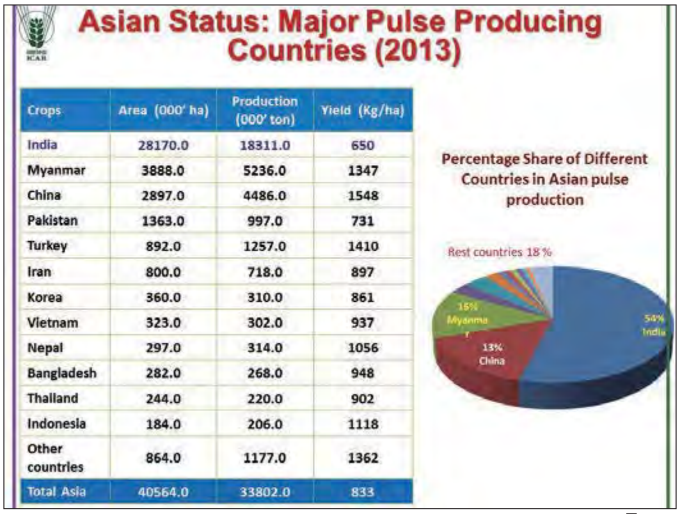

Crops	Area (000' ha)	Production (000' ton)	Yield (Kg/ha)
India	28170.0	18311.0	650
Myanmar	3888.0	5236.0	1347
China	2897.0	4486.0	1548
Pakistan	1363.0	997.0	731
Turkey	892.0	1257.0	1410
Iran	800.0	718.0	897
Korea	360.0	310.0	861
Vietnam	323.0	302.0	937
Nepal	297.0	314.0	1056
Bangladesh	282.0	268.0	948
Thailand	244.0	220.0	902
Indonesia	184.0	206.0	1118
Other countries	864.0	1177.0	1362
Total Asia	40564.0	33802.0	833

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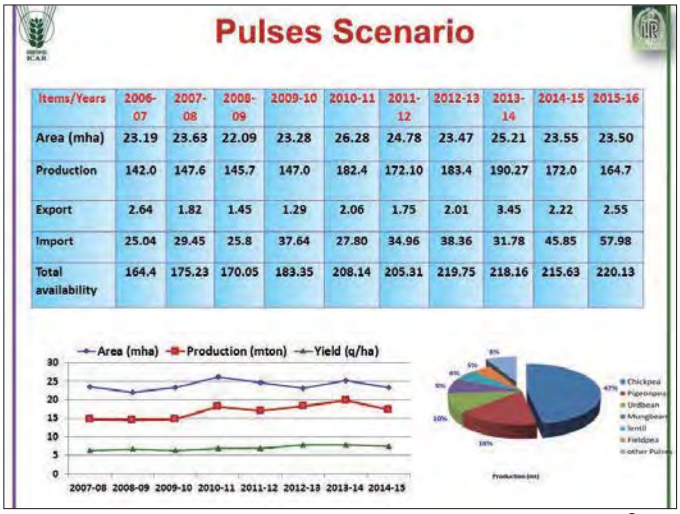

Items/Years	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
Area (mha)	23.19	23.63	22.09	23.28	26.28	24.78	23.47	25.21	23.55	23.50
Production	142.0	147.6	145.7	147.0	182.4	172.10	183.4	190.27	172.0	164.7
Export	2.64	1.82	1.45	1.29	2.06	1.75	2.01	3.45	2.22	2.55
Import	25.04	29.45	25.8	37.64	27.80	34.96	38.36	31.78	45.85	57.98
Total availability	164.4	175.23	170.05	183.35	208.14	205.31	219.75	218.16	215.63	220.13

6

Issues Affecting Pulses Production

- Low profitability and low productivity as compared to cereals
- Mostly grown in rainfed areas, hence wide fluctuations in production from year to year
- Poor price realization
- Poor seed chain
- Vulnerable to biotic and abiotic stresses

7

Focus

Improving yield potential

- Pre-breeding – utilization of wild relatives & primitive landraces
- Restructuring existing plant types
- Nutrient and water use efficient type

Maximizing the Realization of yield potential

- Appropriate agronomic management (in terms of cropping sequence, planting density, water management, biological nitrogen fixation, resource use efficiency)
- Reducing Yield losses (biotic & abiotic stresses)
- Reducing cost of production (mechanization and herbicide resist.)

8

Major Research Achievements

- Reduction in crop duration in chickpea from 135 to 100 days
- Seed size of *Kabuli* chickpea increased from 35 to 55 g per 100 seed weight
- High input responsive, wilt resistant varieties developed in chickpea
- Heat tolerant and drought tolerant varieties for rainfed area
- Early maturing varieties developed in pigeonpea which fit in multiple cropping
- Hybrid pigeonpea
- Machine harvestable varieties

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High yielding varieties of pulses

Chickpea	89
Pigeonpea	36
Mungbean	60
Urdbean	44
Lentil	22
Fieldpea	26
Rajmash	4
Others	38
Total	319

10

Chickpea Varieties

Varieties	Special feature
JG 14, JAKI 9218, RVG 202, RVG 203, Rajas, Pusa 547, JG 11, JG 16, Subhra	Short duration
MNK 1, PKV Kabuli 4-1, Phule G 0517 (Kripa)	Extra Large seeded Kabuli
JG 14 , RVG 202, RVG 203	Heat tolerant
RSG 888, Vijay	Drought tolerant
GNG 1581, JG 16, Digvijay, Gujarat Gram 2, BG 391, BGD 78, Ujjawal, GLK 26155, HK 05-169	Wilt resistant
PBG 5, GNG 469, Himachal chana 1	*Ascochyta* blight tolerant
NBeG 47, GBM 2, HC 5	Machine Harvestable

Most popular variety of the decade: JG 11, Vijay, JG 16, GNG 1581, JG 130

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Genetic Resources

Accessions	Number
Germplasm acc.	14310
Landraces	198
Wild sps. Acc.	126
Total acc.	14634

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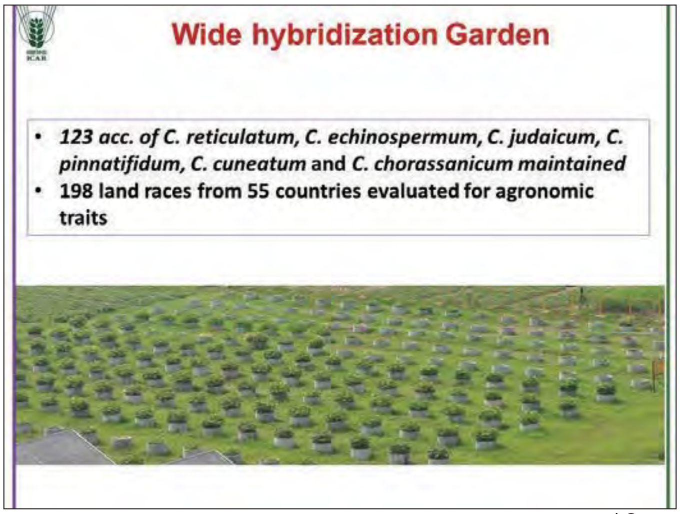

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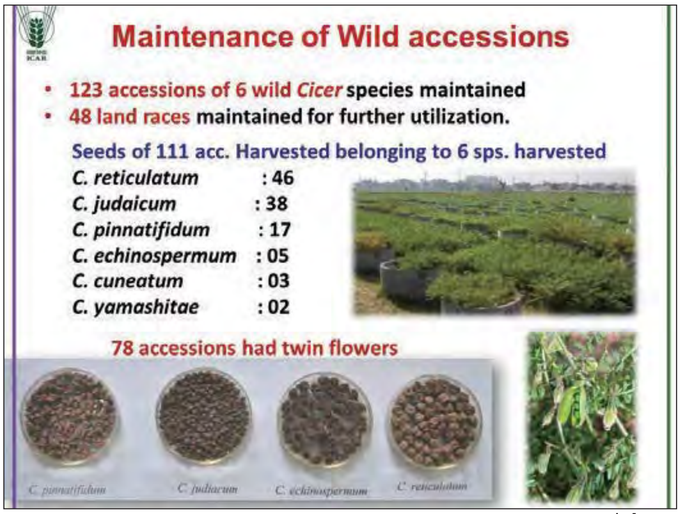

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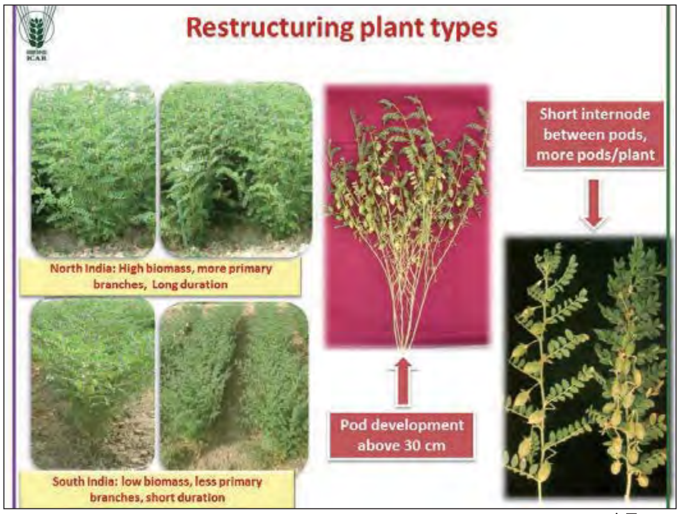

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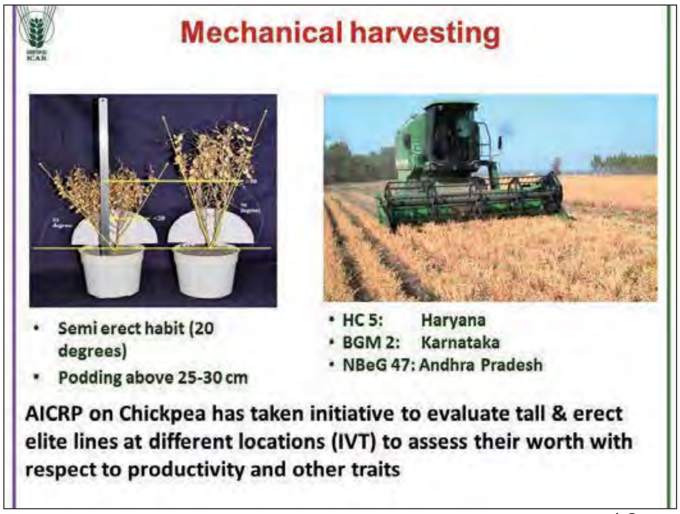

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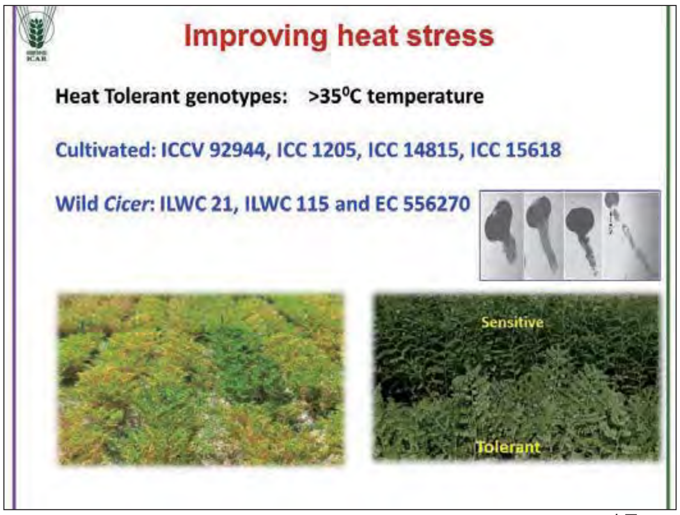

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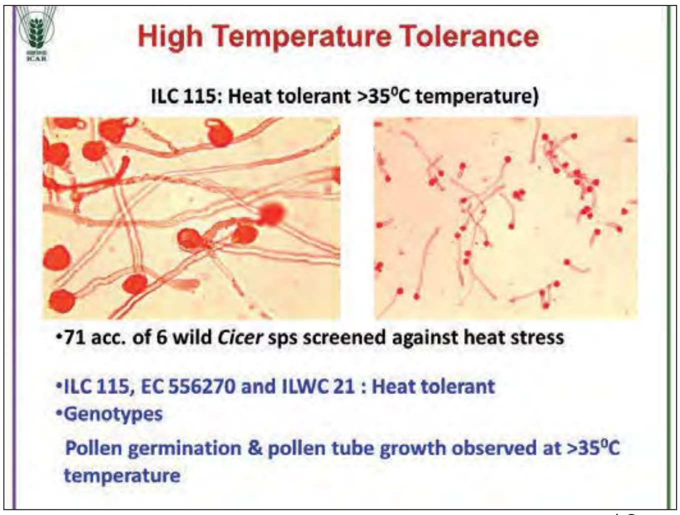

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Herbicide Tolerance in chickpea

Genetic variation is present in chickpea germplasm
Will reduce cost of cultivation and human drudgery
Herbicides: Metribuzin and Imazethapyr

Herbicide tolerant:
ICC 1161, ICC 1205, ICC 13816, IPC 2008-29, IPC 2006-134, ICC 1710, ICC 2629, IPC 2010-56 & IPC 2010-173


19

Varieties with enhanced phosphorus use efficiency

Since phosphorus (P) fertilizers are becoming very expansive or even many times not available for pulses, there will be need to develop varieties with enhanced 'P' use efficiency.

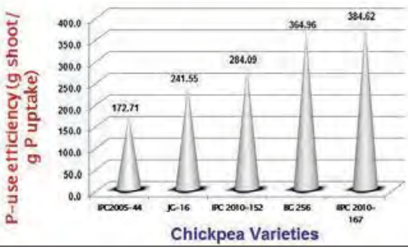
20

P-use Efficiency in chickpea

Reduction in plant biomass due to low P availability in soil varied from 10 to 80% among the genotypes.

Better P use efficiency was observed in BG 256, IPC 2010-167

Presence of genetic variations for P use efficiency observed.



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Rapid Generation advancement

IIPR Off-Season Nursery, UAS Campus, Dharwad

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Pigeonpea Varieties

Varieties	Special feature
Maruthi, Asha, BDN 2, BSMR 736, MA 6 , Vipula,	Wilt resistant
Bahar, BSMR 736, Asha, Sharad, Pusa 9 , IPA 203	Sterility Mosaic Disease
Asha, BSMR 736, BSMR 853, Rajeev Lochan, BDN 711	Wilt and SMD
JKM 189	Drought tolerant
GTH-1	Hybrid
BRG 4	Suitable for both timely and delayed sowings

Most popular variety of the decade →

UPAS 120	Early
Bahar	Late
Narendra Arhar 1	Late
Asha (ICPL 87119)	1993
Maruthi (ICPL 8863)	1985



23

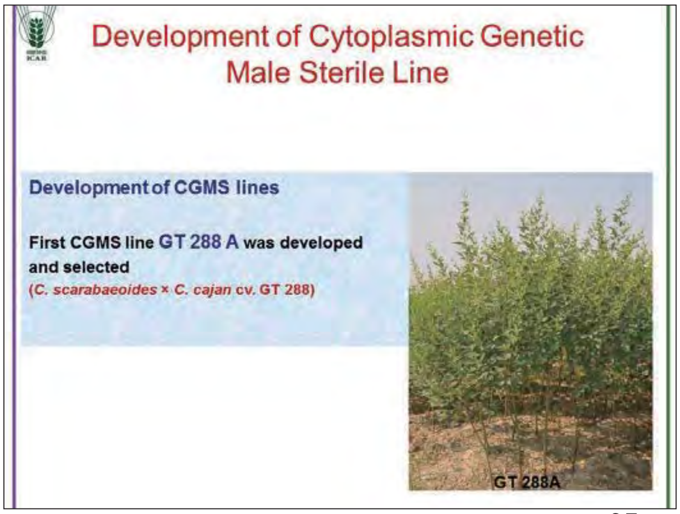
Priority Research Areas for Enhancing Pigeonpea Productivity

Development of hybrids in pigeonpea

- ✓ To introgress CMS and fertility restoring genes into disease resistant and locally adapted lines
- ✓ Study of stability of CMS and fertility restoration systems,
- ✓ Genetic enhancement of parental lines and selection of right combination of parents i.e. parents which are most diverse and possess good combining ability.

Sterile Fertile

24



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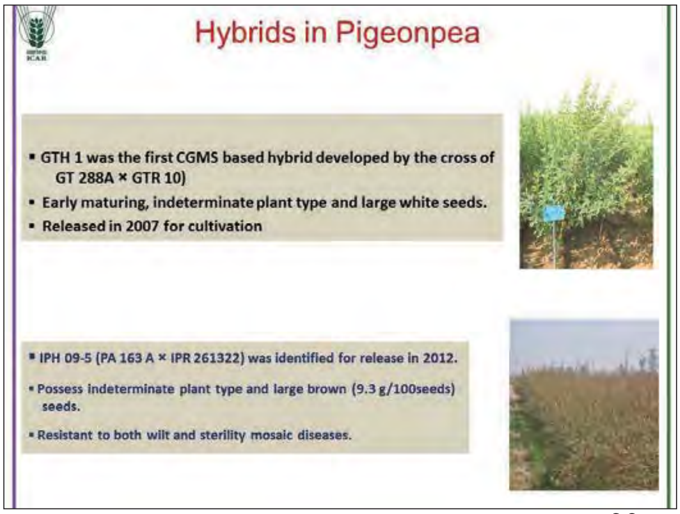

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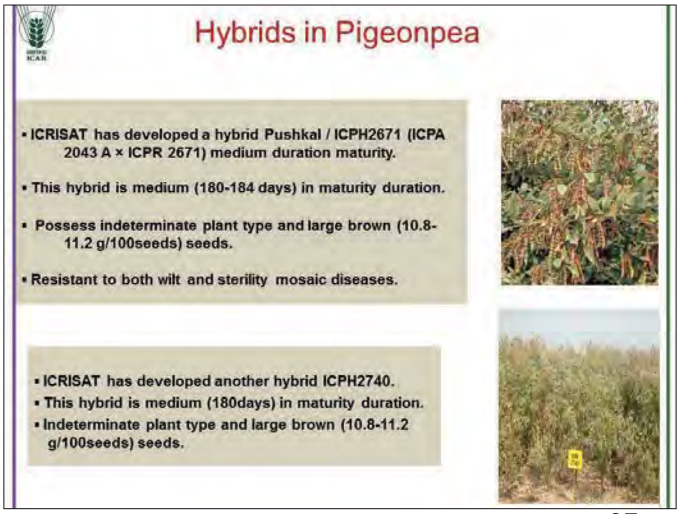

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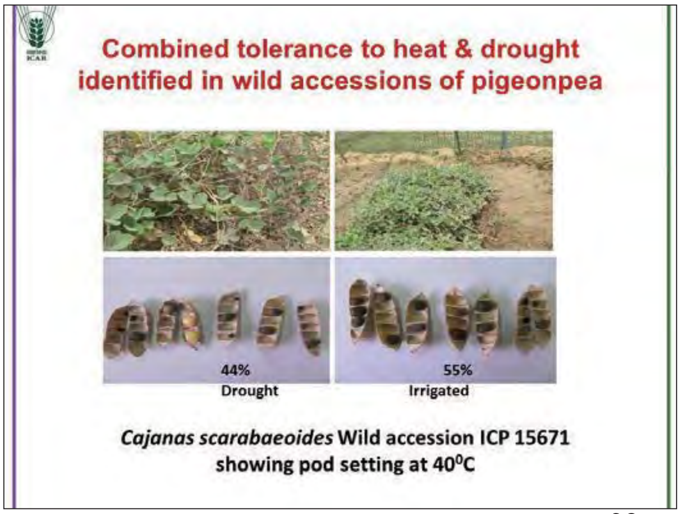

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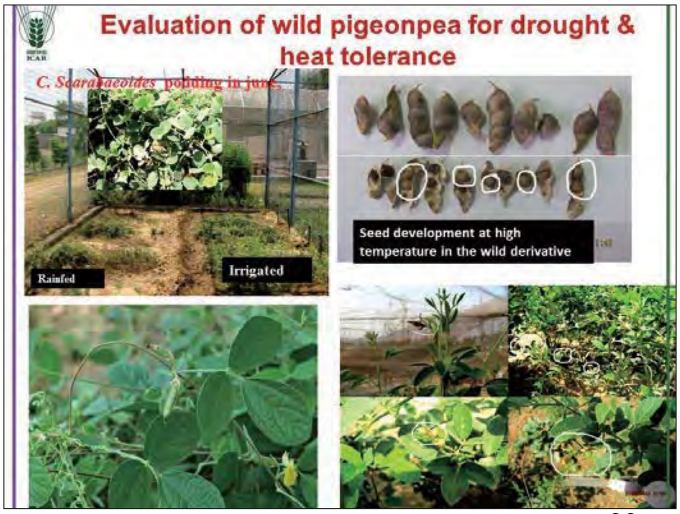

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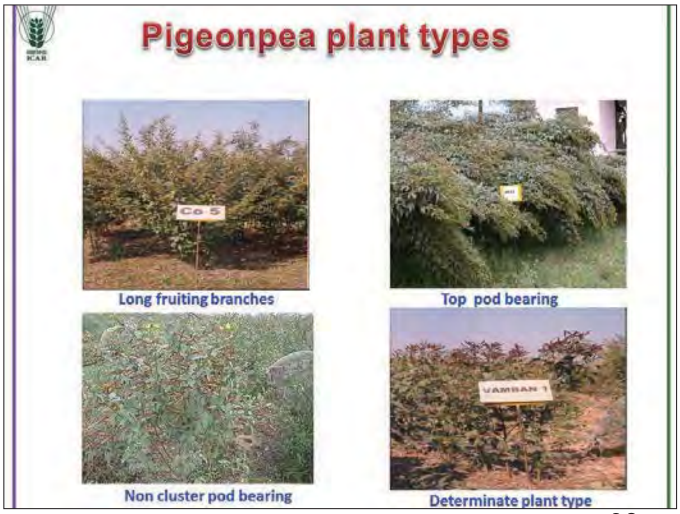

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Plant type

Long and medium duration

- Semi-dwarf plant type (1.5 – 1.8 m) for mechanized plant protection
- Open canopy with determinancy
- Non-cluster pod bearing
- Long fruiting branches for high yield
- Middle and top bearing
- Spreading type for intercropping in south and central India
- Compact plant type for intercropping in northern India

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Chickpea Sequence Information/Resources

Genome Assembly and Annotation Report
Kabuli type: CDC Frontier (*ca.* 738 Mb)
Varshney et al. 2013
Desi type: ICC 4958 (*ca.* 520 Mb)
Jain et al. 2013

Chloroplast Genome Annotation Report
Seeds from IARI, New Delhi (*ca.* 125 kb)
Jansen et al. 2008

Draft genome sequence of chickpea (*Cicer arietinum* L.) provides a resource for trait improvement

- Resources (SNPs and INDEL) will assist genomics-based breeding approaches such as genotyping by sequencing, genome-wide association studies and genomic selection.
- Identify regions (and candidate genes) across the genome that might have been greatly affected by selection during domestication and/or breeding.

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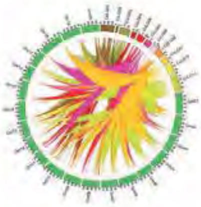
Pigeonpea Sequence Information/Resources

Genome Assembly and Annotation Report
ICPL 87119 (Asha) (*ca.* 500-600 Mb)
Singh et al. 2011; Varshney et al. 2012

Mitochondrial Genome Sequencing (*ca.* 545 kb)
Four genotypes: ICPA2039, ICPB2039, ICPH2433 & ICPW29)
Tuteja et al. 2013

Draft genome sequence of pigeonpea (*Cajanus cajan* L.), an orphan legume crop of resource-poor farmers



- Understanding of the genetic basis of many traits at genome level and allow the undertaking of genome-wide association studies involving thousands of pigeonpea accessions
- Insight into the genetic architecture of pigeonpea's drought tolerance and for screens to identify superior haplotypes for improvement

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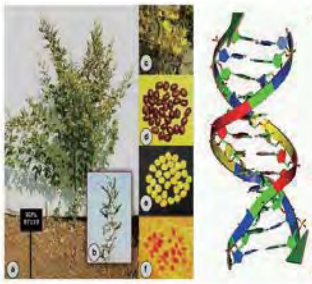
Draft Genome Sequence: Pigeonpea Becomes the First Sequenced Pulse Crop



- Provides access to
  1. ~45000 predicted genes
  2. large set of SSR and SNP markers
  3. Candidate genes for drought tolerance and disease resistance
- Insights into the evolutionary history
- Opened new avenues for re-sequencing of landraces and wild relatives, WGS and GWAS

Paradigm shift from orphan legume to a resource rich crop

34

Transgenic Chickpea

Trait: Insect (Pod borer) resistance **Gene:** *Bt*
Genotype: DCP92-3

Development of transgenic chickpea plants. A. Inoculated seeds in SIM, **B.** Germinated seedlings, **C.** AMEs preparation, **D.** AMEs in *Agrobacterium* suspension, **E.** AMEs containing multiple shoots, **F.** AMEs in Kanamycin selection, **G.** Elongated shoots in Kanamycin selection, **H.** Micrografting of Kanamycin resistant Shoot, **I.** Mature fertile transgenic plant

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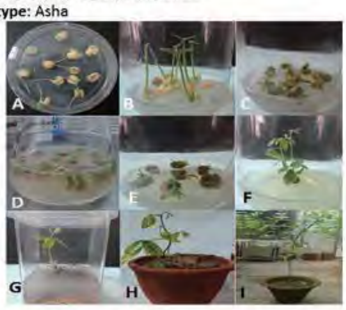
Transgenic Pigeonpea

Trait: Insect (Pod borer) resistance **Gene:** *Bt*
Genotype: Asha



Transgenic development in Pigeon pea : A. Inoculated seeds, **B.** Germinated seedlings, **C.** AMEs ready for cocultivation , **D.** Explants in *Agrobacterium* suspension, **E.** Explants in Kanamycin selection, **F.** Kanamycin resistant shoot, **G.** *In vitro* grafting of shoot, **H.** Acclimatization of plant, **I.** Mature fertile transgenic plant.

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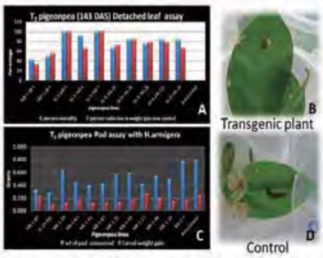
Insect Bioassay of transgenic lines

Generation	Plants	Mortality
T_2	25	25-100 %
T_1	12	10-60 %

Bioassay	Plants	Mortality
Whole plant	4	20-40 %
Detached leaf	41	0-80 %



Insect bioassay A. Graphical presentation of detached leaf bioassay performed on T_2 pigeonpea, B. Leaf of transgenic plants under infestation of *H. armigera* larvae, C. Graph showing results of insect bioassay performed on T1 pigeonpea pods, D. Non transgenic leaf infested by *H. armigera*

Fig. Whole plant bioassay in chickpea
A- Acrylic cage, B- Small iron cage with insect net, C- Large iron cage with insect net

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Other Initiatives

Marker Assisted Back Crossing adopted for introgression of drought QTL and resistance to diseases or their physiological races through MARS to desirable backgrounds

Promising Introgression Lines of JG 11 identified

38

Molecular Breeding

Development of mapping populations

Crop	Trait	Mapping populations
Chickpea	Heat	ICCRIL 12 ICC 4567 × ICC 15614
	Seed protein content	DCP 92-3 x T 39-1
Pigeonpea	Wilt	T 7 x Maruti
	Sterility Mosaic Disease	UPAS 120 x Asha

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MABC for introgression of *Fusarium* wilt (race 2) resistance in chickpea (BG 256 x Vijay)

Markers used in foreground selection and plants selected during different generations	BC3F2 (Set I)			BC2F2 (Set II)		
	Analysed	Scorable bands	Heterozygotes	Analysed	Scorable bands	Heterozygotes
TA 110	161	144	67	258	221	64
TA 37	161	149	66	258	220	95
Common heterozygotes for both markers for background selection			46			39
No. of SSR markers used for background selection			31			31
No. of plants after background selection (With % recurrent parent genome recovery)			29 (78-89%)			29 (72-84%)
Plants selected with higher background genome recovery			16 (90-93.5%)			13 (85-93%)

40

MABC for introgression of *Fusarium* wilt (race 2) resistance in chickpea

Disease reaction of parental and BC3F3 and BC3F2 lines carrying foc2 conferring resistance to race 2 of *Fusarium oxysporum*

Lines	FW incidence (%)	Disease Reaction
Parental lines		
Pusa 256	39.5	moderately susceptible
Vijay	6.7	Resistance
MABC lines		
VD2/145	0	Resistant
VC 16/10-2	0	Resistant
VD 2/116	0	Resistant
VC 35/5-4	5.2	Resistant
VC 35/5-8	5.7	Resistant

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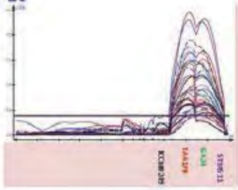
Introgression of drought QTLs in elite chickpea cultivars

Donor: ICC 4958

Recipients: DCP 92-3, Pusa 362, Pusa 372, ICCV 10



Drought QTL linked region used for foreground selection

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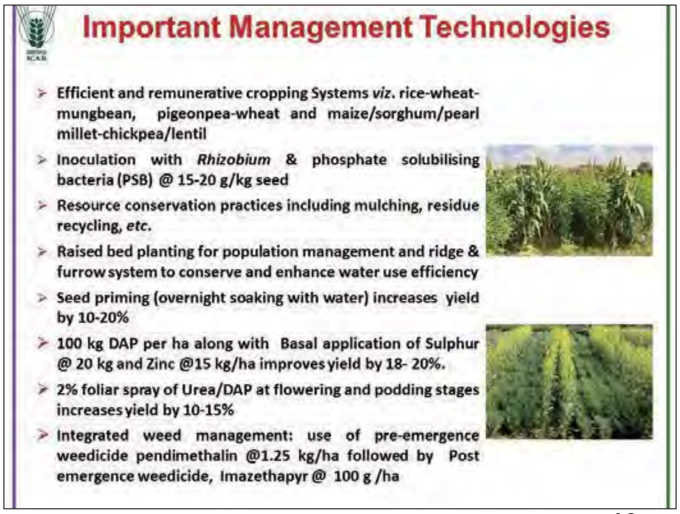

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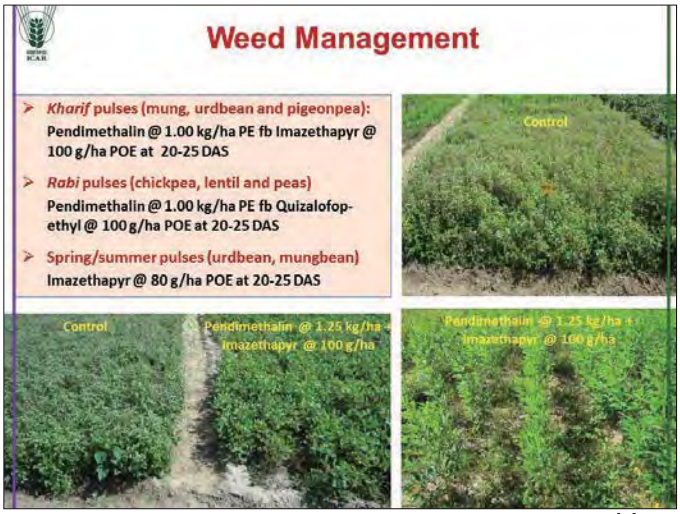

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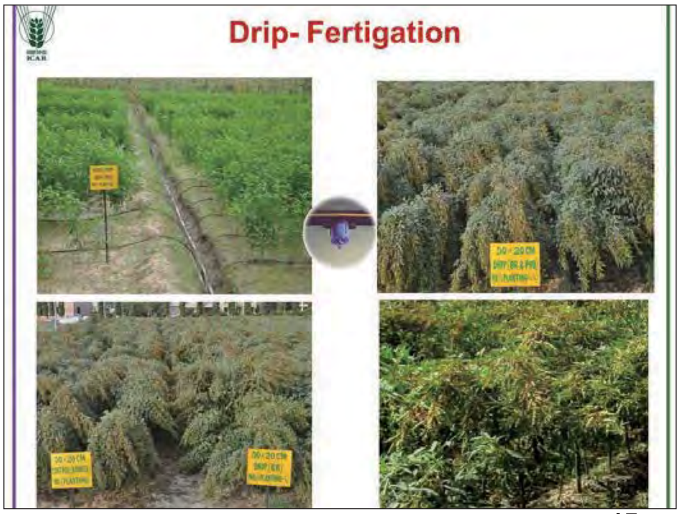

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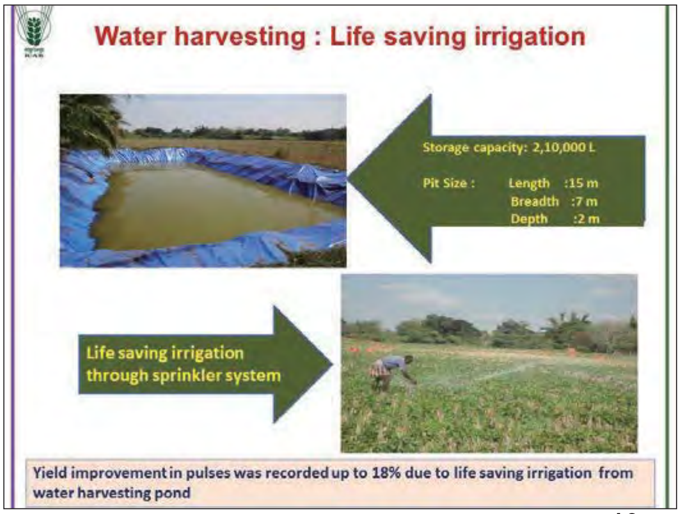

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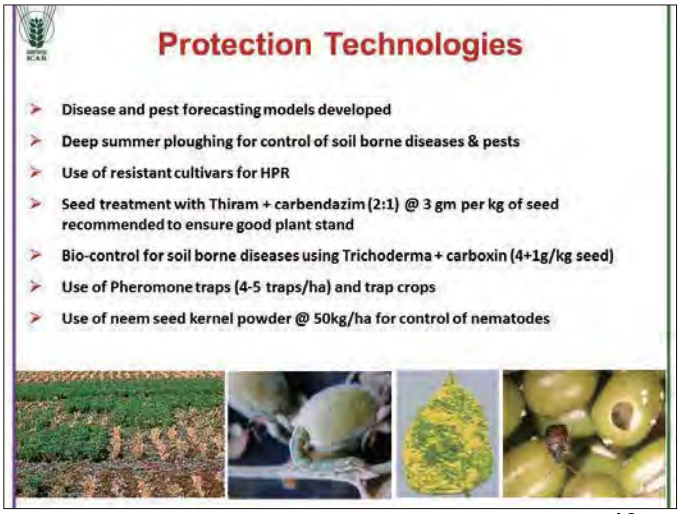

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Scope of Mechanization in Pulse Production
Field preparation - Ridge maker
Sowing- Tractor operated seed drill
Pre-emergence herbicide spray
Weeding through power operated weeders
Spraying – multi bloom sprayer
Harvest – combined harvester

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Dissemination of Technologies
Farmers' participatory seed production
Farmer to farmer extension model
Front Line Demonstrations
International and national training programmes
Farmers' days, field days, farmers' fair
Farmers' friendly literature
PulsExpert system

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Way Forward
Development of super early types
Photo-thermo insensitive varieties
Climate resilient varieties
Super nodulating plant types
Multiple disease resistance
Insect smart plants
Hybrid - pigeonpea
Transgenic varieties for biotic and abiotic stresess
Tools
Pre-breeding
Nanotechnology and binformatics
Genomics & molecular marker assisted breeding
Transgenic chickpea and pigeonpea
Nutrient & water management
Input Use Efficiency

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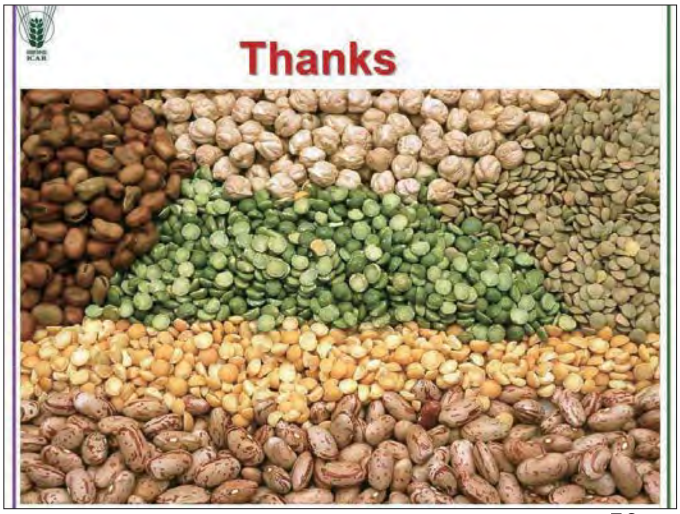
Thanks

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Chair Nakashima
Welcome to Session 2. My name is Kazuo Nakashima, Program Director of the Stable Agricultural Production Program of JIRCAS. I am the Chairperson for this session titled 'Legumes all over the world: Use of the diversity for improvement.' Please allow me to give an introduction about this session.

The legume family includes approximately 650 genera and 18,000 species worldwide. Among edible leguminous plant species, about 80 are economically significant. Researches are carried out over the utilization of genetic resources and further improvement. JIRCAS conducts researches to evaluate and utilize cowpea genetic resources and develop soybeans that are tolerant to adverse environments. These photographs, the left photograph shows various types of cowpea grains and cowpea dishes on the right.

Our research studies at JIRCAS have produced variable results. For instance, we have released the EDITS-Cowpea database of cowpea genetic resources. We have also succeeded in developing soybeans that are tolerant to high salinity conditions in the field. For more information, please view our posters later.

These are three presentations for this session. The first presentation is about the pulses research in India, especially chickpea and pigeonpea. And the second presentation is regarding the *Vigna* research under stress environments. The last presentation is about soybean research for disease resistance.

Similar to the previous session, 15 minutes will be allotted for presentations and 5 minutes for questions. So, before we begin Session 2, let us all switch our mobile phones to silent mode. Thank you for your cooperation.

Let's start the session. The first speaker is Dr. Girish Prasad Dixit. He is Project Coordinator of chickpea at the Indian Institute of Pulses Research, India. He has developed about 10 high yielding varieties of pulse crops which are very popular in India. The title of his presentation is 'Importance of pulses research in India: Chickpea and pigeonpea. Dr. Dixit, please go ahead.

Dr. Girish Prasad Dixit
Thank you Chairman. My name is Girish Prasad Dixit. I am chickpea coordinator for Indian National Program, and I have been asked by the organizer to speak on the pulses research activities in India with emphasis on pigeonpea and chickpea.

As you all know, pulses constitute an important dietary constitute for human and animals because of their richness in protein and other essential minerals, vitamins, dietary fiber. In India, over a dozen of pulse crops are grown in one or other part of the country. However, the most important pulse crops grown are chickpea and pigeonpea.

Here I have given the list of different pulses being grown there and among these crops, chickpea is number 1. The share to the total pulse production is about 50%. The next crop is pigeonpea, which has a share of about 20% to the total pulse production. So, if you take chickpea and pigeonpea together, roughly 70% of the total pulses comes from these two crops.

Other crops are mung bean, black gram, peas that is the dry pea, lentils, Phaseolus or kidney bean, Lathyrus, and there are other crops like cowpea, guar. Although they are not much popular as a pulse crop, but they are still being grouped under the pulse category.

Now, coming to the very important point, why pulses are so much important in India? As I mentioned that it is needed for the nutrition security because if you see the food habit of the Indians, they are mostly vegetarian and they are largely dependent for their protein requirement from pulses and the content of protein in the pulses is more than 20%. So, it is very much required for the nutritional security of the Indian population. Apart from the human health, it is equally important for the soil health. And there has been an estimate that about 1.5 million ton of nitrogen is annually fixed by the pulses and out of this, a very small quantity is being used by the pulses and rest is left in the soil and therefore they are very important for the sustainable production system. If you see in

India, there is a lot of pressure on the soil because of rice-wheat system, and because of that, the total factor productivity is going down, and therefore, policymakers are thinking very seriously to introduce pulses in between rice-wheat system so that you can diversify the system and make the system more sustainable.

Here I have tried to give the status of pulses in Asia. India is the major producer as well as consumer of the pulses and if you see the share, I think more than 50% production comes from India. Then, other important countries are China and Myanmar. Of course, Japan is not mentioned here because here you are growing peanuts and soybean and that is not included as pulses.

If you see the pulses scenario in India, there has been a stagnation in the acreage but production has increased by 5% in the last 6-7 years, but our requirement is much more and if you see the last 2 years, the weather was not very much favorable, and because of that, the production came down and the import was increased. In India, if you see the share of different pulses, 50% is chickpea, then there are other crops, the share is less than that. So, chickpea is very important as far as India is concerned.

Now, the issues which affect the pulse production. As mentioned by Dr. David in the morning that it is mostly grown as a rainfed crop in India, so the productivity varies over years, and because of that, the profitability is low if you compare with the cereals. And because of this wide fluctuation over years, the price realization is also very poor. So, wherever there is no irrigation, farmers have no other option, they go for the pulses. Most of the areas in the south and central India is like that only that is drought-prone and therefore farmers have no other option but to depend on pulses only.

Pulses are more vulnerable to disease and pest because they are protein rich. If it is protein rich, they are more attracted by the insect and pest also. So, keeping these things in mind, these are our focus areas. I have categorized under two groups, one is to improve the yield potential by different means like prebreeding, then we are trying to modify the plant types, and also we are in search of nutrient and water efficient types. Then, for maximizing the realization of the yield potential through different management practices, we have worked out the economy of different components. We are trying to reduce the yield losses through biotic and abiotic stresses through host plant resistance, to management practices. Also, another area to reduce the cost of production and to make it more economical, viable, mechanization and herbicides are equally important for pulses also. So, this is another priority area.

Here I have briefly given the achievements of these two crops i.e. what we have achieved in the last few decades. In chickpea, we have successfully reduced the duration by 25 days, and because of this, now the crop has been introduced in the new areas of south and central India where the window is of 100 days or so. Earlier we were not able to grow this crop in south India, but now because of reduction in the duration by 25 days, now this crop is fitting well in that system.

Another very important aspect is kabuli chickpea where we have increased the seed size from 35 gram to 55 gram, now it is called extra-large seeded kabuli and now India is exporting this kabuli chickpea to Middle East and other countries.

In general, pulses are not responsive to inputs. If you apply nitrogen or irrigation, they will not respond. There will be excessive growth resulting in very poor yield. But recently we have developed some chickpea varieties which are responsive to high nitrogen as well as irrigation and have very high level of resistance to wilt which is a very serious problem of all the chickpea growing areas in India.

As the crop is mostly rainfed, it is bound to suffer because of high temperature as well as drought during the reproductive phase. So, keeping these in view, we initiated very strong breeding program. Now, we have very good varieties which are tolerant to heat and also tolerant to drought.

In case of pigeonpea, we have successfully reduced the duration by 100 days. Earlier we had the traditional varieties where duration used to be about 220, 240 days. Now, we have varieties of 140 days. Because of that, now it is fitting well in pigeonpea-wheat system. Hybrids have come out in the last one decade. Several hybrids have been developed based on the cytoplasmic genetic male sterility system. I will be discussing later about this. Then, several machine harvest varieties in the case of chickpea have come.

Here, I have given the list of high yielding varieties pulses, all the crops, but if you see in the chickpea, it’s 89 and pigeonpea 36, so fairly good number of varieties are available in pulses. These are the trait specific varieties. More than 14,000 accessions are there in our gene banks, including landraces and wild species. And this is Wide Hybridization Garden recently been established at our institute at IIPR Kanpur where all the wild species and landraces arebeen maintained and has being shared to our cooperators in the country.

Another very important component is restructuring of plant type in chickpea. You see there is a demand from the farmer that you breed erect type and having podding on the top it can be available for machine harvest. And we have developed such varieties, spreading to erect type, podding on the top and now it can be harvested from the combine. So, a lot of material has been developed. They are in the multi-location evaluation, already we have commercialized some varieties for farmers.

Another very important trait is heat stress in chickpea. For high temperature, we have several cultivated as well as wild accessions which we have identified where the pollen germination and pollen tube growth is normal if the temperature goes beyond 35 degrees centigrade. So, it is a very important trait and now we are trying to transfer this trait in all our cultivated varieties in chickpea.

Herbicide tolerance is another very important component, and we have initiated this study very recently, 2 years back, and on the basis of 2 years screening, we have identified some of the herbicide tolerant chickpea lines. Now, we are going to use them in our regular breeding program.

Phosphorous is very important for the pulses. It is available in the soil, but plant is not able to use it. So, we are searching for genotypes which are having better phosphorous acquisition efficiency, and you can see some variability we have observed on basis of that, we can say that there is variability available for phosphorus use efficiency and now there is scope to use this component in our breeding program.

This is a facility which we have created for our breeders, particularly for chickpea breeders where they we can take two to three crops of chickpea in a single year. So, it is very good for the plant breeders for rapid generation advancement. So, it has increased efficiency of plant breeding program.

Now, the second crop is pigeonpea. Just like chickpea, here I have given the list of varieties for different traits. You can see, they are very popular and being adopted by the farmers. And very important aspect in the chickpea is to develop hybrids and in the last two decades a lot of efforts were made. Earlier, we had a genetic male sterility system, but it failed and because of that, now we have to work on the cytoplasmic genetic male sterility system and that has worked very well in pigeonpea. Now, we have standardized the restoration process. This was the first line which we evolved through the cross of Cajanas that is cultivated with this wild species, scarabaeoides and GT288 A was developed and this revolutionized the hybrid pigeonpea program in the country, and by using that line, we could see the first hybrid as GTH1 evolved in 2007 and after that a number of hybrids have evolved. Then, these are some of the hybrids developed by ICRISAT. They are very popular in central and south India.

Just like chickpea, in pigeonpea also, we are in search of lines which have combined tolerance to heat and drought because again it is a rainfed crop grown in a very hardy situation and we have identified certain accessions where the podding is normal even if temperature goes beyond 40 degrees centigrade temperature. Here, you can see some of the wild species. Scarabaeoides is a wild species of pigeonpea where we have screened and now it is being used in developing different plant types.

In the morning, David mentioned about the genome sequencing in chickpea as well as pigeonpea. Now a lot of genomic information is available both in cases of chickpea as well as pigeonpea. We have moved towards the utilization part that is how to use it in the molecular breeding program. We have identified large number of markers and now trying to integrate with our gene of interest to make this breeding procedure more efficient.

Another area is transgenic, pod borers is a major threat in the case of both chickpea as well as pigeonpea and we don't have any resistance source in cultivated as well as wild species. Therefore, transgenic is the only option and both in case of chickpea as well as pigeonpea at our institute at Kanpur, we have developed transgenic. It is in advanced stage of testing. Now, we are waiting for the signal from Government of India. Once it is given, we can go for the testing of this transgenic in multi-location trials so that it can be used in the breeding program for transferring this trait in the adapted varieties of different zones.

Another area is the molecular breeding where we have evolved several lines where the introgression of drought QTL as well as resistance genes in the cultivated types. You can see here the various mapping population being developed for different traits, how this introgression is going on. Then, for drought also how in the cultivated types we are transferring this drought tolerance from the donors to the adapted varieties. These are some of the management technologies being recommended by our agronomist and physiologist. Weed is a serious issue in the case of pulses and several management practices have been worked out. Chickpea is grown mostly in the drought situation and therefore moisture stress is a serious problem. We don't have irrigation in those areas. So, on the conserved moisture, it is being grown and farmers are being suggested to follow a drip system where you can economize the use of water, and this kind of water harvesting is being now encouraged. You conserve this water and try to give just one lifesaving irrigation by drip. It is going to enhance yield by 18 to 20%.

For the processing / milling at the farmers' level, some small milling structures are now being developed and now it is being popularized among the farmers.

Protection technologies have been standardized, whether it is biocontrol, seed treatment, biopesticides. Mechanization has a lot of scope and there is continuous demand from the farmers and our engineers have successfully developed different implements and now they are being popularized among the pulses farmers.

For dissemination of our technologies, Farmers' participatory seed production is very important component, we are developing varieties, then farmer to farmer extension model and there are other extension activities being followed.

Photo-thermo insensitivity is very important trait. In the case of mung bean and other crops it has been achieved but not in the case of chickpea and pigeonpea, so it is going to be a challenge. So, with this, I come to the end and before I close, I would like to thank the organizers for giving me opportunity to share my views about Indian Pulses Program. Thank you.

Chair Nakashima
Thank you for the informative presentation, Dr. Dixit. We were able to know the current situation about the research on the pulses in India, especially pigeonpea and chickpea. So, the floor is now open for discussion. Are there any questions or comments? No questions or comments? Okay.

Male Questioner
Thank you very much. I think it's great. You have achieved much progress in heat and drought tolerance in pulses. I want to know if there is any trade off between stress tolerance and quality of grain, sometimes we observe if some crop get to stress tolerant, it deteriorates the quality of grain. So, I want to know stress tolerant pulses variety, its quality is enough for farmers to be adapted or not.

Dr. Girish Prasad Dixit
Actually, some of the wild species have this trait, but there is some problem with respect to crossability with our cultivated types, but it is underway and very soon we will be able to transfer that trait. Once it is transferred, then the storage pests like bruchid and other insects can be managed by that.

Chair Nakashima
Okay. Next.

Male Questioner
One question that is also related with his question. When you develop some breeding lines, for example the good type to harvest, narrow line from wider line, or in some case the resistant line, his question and my question also may be same, is there any demerits or tradeoff some of the good quality when you developed your new varieties that was off, high yield was decreased?

Dr. Girish Prasad Dixit
Because of restructuring the plant types, it is not going to be affected. Once it is affected, we are not going to release it as a variety. If it is to be released as a variety, it should be more productive than what is being grown by the farmer. So, that criterion is always kept in mind, whether it is yield or any quality traits.

Male Questioner
Okay. In the case of the resistance to drought or something, is there some of the good character lost when you developed?

Dr. Girish Prasad Dixit
Through regular breeding, there is chance, but if you are going through molecular breeding, you are targeting a very specific trait. So, there is no scope of deviation from the quality.

Chair Nakashima
Okay. I'm afraid the time is up. So, thank you again, Dr. Dixit.

DOMESTICATION GENES AND STRESS ADAPTATION GENES IN THE GENUS VIGNA FOR SUSTAINABLE AGRICULTURE UNDER STRESS ENVIRONMENTS

Norihiko Tomooka

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NORIHIKO TOMOOKA holds a Doctorate degree in Tropical Agriculture from Kyoto University (Japan) and is a Plant Genetic Resources Specialist in Genetic Resources Center, NARO. He also has a position of Professor at Tokyo University of Agriculture, Japan.

His expertise is in the leguminous plants belonging to the genus Vigna. He worked at the Tropical Agriculture Research Center (TARC, presently called JIRCAS), Japan, Chai Nat Field Crops Research Center, Thailand, and at National Institute of Agrobiological Sciences (NIAS), Japan.

Currently, he is the Genetic Resources Coordinator of the Genebank Project in Japan, organized by Genetic Resources Center, NARO.

ABSTRACT

I propose a novel breeding strategy "Neo-Domestication" for sustainable food production especially under stress environments. It is estimated that the world food production should be doubled before 2050. In the past 50 years, world food production had increased 2.5 – 3 times owing to the yield increase of a few major crops, which is called "Green Revolution". However, this system depended largely on irrigation (water resource), industrial fertilizers and pesticides (both produced by fossil energy) and resource consuming high yielding varieties. Therefore, it is far from sustainable and causes water resource deficit, soil salinization, environmental pollution, etc.

Present agriculture has used 11% of the world land. One approach to increase crop production is to use lands that are currently not suitable for crop production. These include lands with high salinity, high acidity, and high alkalinity, those that are drought prone and those that have water-logged environment. Even among the lands presently used for crop production, about 70% are categorized as problem soils. To achieve stable crop production on various problem soils, new crops that can grow well on these lands are needed. Hence, I propose "Neo-Domestication" of edible wild species already adapted to problem soils. Leguminous plants have an advantage in sustainable agriculture because of their ability of symbiotic N fixation.

As the causative change of the domestication gene is generally a "Loss-of-Function" type, "Neo-Domestication" could be achieved by mutation breeding. Screening process can be facilitated by gene screening using NGS-TILLING, in case a target gene sequence is known. Since 10 wild species had been domesticated to become crops in the genus *Vigna,* diverse domestication genes could be identified from *Vigna* crops and be used for NGS-TILLING during "Neo-Domestication". On the other hand, more than 100 wild *Vigna* species had evolved by adaptation to diverse stressful environments including problem soils. Hence, wild *Vigna* plants are considered as rich sources of stress adaptation genes. In addition to "Neo-Domestication", these domestication genes and stress adaptation genes could also be used for the breeding of other crops.

KEYWORDS

Genetic Resources, Evolution, Domestication, Adaptation, Symbiosis

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Chair Nakashima
The next speaker is Dr. Norihiko Tomooka. He is Genetic Resources Coordinator in the Genetic Resources Center, NARO, Japan. He has studied on *Vigna* germplasm for a long time, and the title of his presentation is 'Domestication genes and stress adaptation genes in the genus *Vigna* for sustainable agriculture under stress environments.' Dr. Tomooka, please start the presentation.

Dr. Norihiko Tomooka
Thank you very much Mr. Chairman. My name is Tomooka. I am belonging to the Genetic Resources Center, NARO. Today, I want to talk four topics. At first, I want to explain about *Vigna*, then domestication genes and stress adaptation genes, then finally I want to propose some idea of neo-domestication.

This slide shows *Vigna* and *Phaseolus* are very closely related genus, and in case of *Phaseolus*, its distribution is restricted to America. But in case of *Vigna*, this is *Vigna*, it can be found in Africa (cowpea group), in Asia (adzuki bean group) and also in America. If you look at the evolution of *Vigna*, the prototype of *Vigna* is believed to be in Africa. Then, Eurasian *Vigna* appeared and then Asian *Vigna* and then finally *Phaseolus* and American *Vigna* evolved.

The flower morphology becomes gradually complicated from very simple floral morphology of African *Vigna*. It took about 5 million years to attain this evolution.

In this slide, I want to show some *Vigna* crops. This is adzuki bean, mung bean, cowpea, black gram, and this is tuber cowpea, this is bambara groundnut and moth bean and rice bean. These are the main *Vigna* crops.

From now, I want to talk something about domestication genes. During the process of domestication, the organ size usually becomes bigger from wild, it becomes non-shattering and the seeds become non-dormant and sometimes the architecture of the plant changed. These are the main morphological changes or physiological changes during the domestication.

This slide shows the domestication in Asia. In Asia, there are about 24 or 25 species of *Vigna* distributed, and from these 24-25 species, moth bean has been domesticated and adzuki bean domesticated, black gram domesticated, and mung bean domesticated, creole bean domesticated, and rice bean domesticated. Among these domesticated crops, I selected four crops for the comparison of the domestication genes. First, I analyzed domestication genes of adzuki bean and the results were published in these journals, then rice bean domestication genes analyzed and mung bean and black gram domestication genes were analyzed and published.

This is one result of the comparison of the pod shattering genes. This is the linkage map of each crop. Four pod shattering genes were detected. Adzuki bean gene on linkage group 7, this one, was our target for the gene cloning. We named it TIP gene. This slide shows the effect of TIP gene. The wild adzuki bean shattered when it matured and the cultivated one not shattered, but when we introduced TIP gene into cultivated adzuki bean, its pod became shattered.

Then, we tried to identify the reason of the shattering and we found that the lignification may be the cause of the pod shattering. The wild adzuki bean has a very thick lignin layer inside the pod wall, but cultivated adzuki bean has very thin lignin layer. The near isogenic line of cultivated adzuki bean with wild TIP gene, lignin layer – the red part shows the lignin layer - became very thick.

We tried to clone the TIP gene, and we found this thymine insertion is responsible for the loss of lignin accumulation inside the pod wall.

In case of soybean, there is still a problem of the pod shattering, especially under the dry conditions. Soybean pod shattering genes were recently reported by two different scientists, one is Shat 1-5 gene and the other is Pdh 1 gene, but the TIP gene of the adzuki bean is different from these two genes. So, we tried to introduce TIP gene into soybean.

This is mutant tip homo soybean pod, and this is mutant hetero soybean pod, and pod shattering was compared under the experimental condition (40°C 16hrs treatment). This mutant tip homo showed complete non-shattering phenotype, while mutant hetero showed 80% pod shattering.

This is the second example of the domestication gene, seed size increase gene. In this case, there are many, many genes detected. In total, 16 seed size genes were detected from four crops. This gene on the linkage group 2 was commonly found from these four crops. In this case, we have targeted this black gram seed size increase gene for the gene cloning.

This slide shows the effect of MOG (multiple organ gigantism) gene of black gram. When the MOG gene was destroyed, the plant became big and the leaf also became big and the seed also became big, but the cell size was not affected by this mutation.

We have identified the responsible gene, this is the MOG gene and when the 8 base deletion occurred, plant organs became bigger. In this case also, we tried to test this mutation gene effect using soybean. In this case, we used the RNAi method to lose the function of MOG gene and the plant became bigger. The seed size also became bigger. So, these two examples showed the domestication gene of adzuki bean or black gram can be applied to other crops, in our case to soybean.

From now, I want to talk about some stress adaptation genes in *Vigna*. There are many kinds of environmental stresses in the world. Total Japanese crop land is only 4 million hectares but the stress area in the world is big. Crops were suffered from these stresses. For each stress, we found stress adapted *Vigna*; *Vigna* marina, *Vigna exilis, Vigna vexillata, Vigna trilobata Vigna mungo, and Vigna stipulacea. Vigna marina*, it can tolerate up to 400 mM NaCl and the symbiotic rhizobium strains can tolerate up to 800 mM NaCl. So, we tried to identify the responsible genes of the saline tolerance by crossing and we found one major QTL responsible for this salt tolerance which can explain 50% of phenotypic variations. So, from Riverside habitat to Marine Beach habitat adaptation, one mutation has revealed to have very big contribution.

Then, I will talk about neo-domestication. Usually, if we found stress tolerant wild species, we cross it with stress susceptible crop and try to develop more resistant crop. The new idea (neo-domestication) is trying to domesticate stress tolerant wild species and develop new crop. It is called neo-domestication. Important thing is that the phenotypic changes during domestication were caused by loss of function type mutations. So, we can use mutagen to accelerate mutation and select the domesticated phenotype, a traditional mutation breeding methodology. And we tried to use *Vigna stipulacea* as an example of neo-domestication. We used EMS chemical treatment and grew the plants and we found new non pod shattering mutant and seed color mutants and at the same time, these seed color mutants showed loss of dormancy. So, these genes can be called domestication genes. But the process of the mutation breeding is very time-consuming and labor-consuming. If we know the gene sequence, we can use the Next Generation Sequencer screening (NGS TILLING), not by the phenotypic screening.

This is the final slide - my recommendations. We must learn more from diverse domestication events is the first recommendation. The second one is we must learn more from diverse adaption of wild plants. And it is better to include nitrogen fixation system of the wild plants for the sustainable crop production research. This is all. Thank you very much.

Chair Nakashima
Thank you for the interesting presentation. Dr. Tomooka explained about varieties of *Vigna* and he showed some domestication genes and adaptation genes. He also recommended neo-domestication for the sustainable culture and stress environments.

Now, the paper is open for discussion. Anybody has any questions or comments? No comments or questions? So, I have a question. You have succeeded to isolate some QTLs such as TIP and MOG. Can you find function of the genes: the protein function?

Dr. Norihiko Tomooka
Not yet clarified.

Chair Nakashima
Not yet. I see.

Dr. Norihiko Tomooka
It’s all isolated but not yet tested of the function.

Chair Nakashima
Thank you. Are there any questions or comments? Okay, please.

Male Questioner
You mentioned that MOG gene can increase the seed size and plant size of soybean, but this gene does not have an effect on seed number or the final yield?

Dr. Norihiko Tomooka
Yes. The seed size becomes double, but the number of seeds per plant is about half. So, the single plant basis the yield may be the same.

Chair Nakashima
Okay. So, it's time. Thank you, Dr. Tomooka.

Dr. Norihiko Tomooka
Thank you very much.

TOWARD THE DEVELOPMENT OF SOYBEAN VARIETIES RESISTANT TO RUST DISEASE

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NAOKI YAMANAKA holds a Ph.D. degree in Agriculture from Chiba University (Japan) and is a Senior Researcher of JIRCAS. His expertise is in the area of genetics and breeding in plant. After working at Chiba University as a JSPS Research Fellow, he has worked at JIRCAS. In his 15-years' career as a researcher, he has studied mostly on soybean. Currently, he is in-charge of a research subject of the Pest and Disease Control Project in JIRCAS.

ABSTRACT

Soybean is highly imporatnt for Japan as it is widely used in producing traditional soy foods as well as soybean oil. However, the domestic soybean demand in Japan is mostly meet by imports from other countries. Therefore, it is important for us to ensure stable soybean production in the coutries which supply large amount of soybean to the world market. South American coutries such as Brazil, Argentina, and Paraguay produce more than half of soybean in the world market. But in the tropical and subtropical regions of these countries, a soybean disease, Asian soybean rust (ASR) caused by *Phakopsora pachyrhizi* is one of the most serious threats to soybean growers together with drought. Thus, JIRCAS has been carrying out collaborative researches on the development of ASR-resistant cultivars with our pertner institutions in South America for more than 10 years.

Firstly, we have developed a reliable method of evaluating ASR resistance in soybean and surveyed geographical and annual variations of ASR pathogen in South America (Yamanaka et al. 2010). Our results reveal that virulence of South American ASR pathogen is highly variable and strong (Akamatsu et al. 2013). Therefore, a resistant cultivar carrying sutable ASR resistance cannot be expected by simply introducing single known major ASR resistance gene. Secondly, we have developed soybean breeding materials and tools which are useful in South America. Specifically, we have 1) identified resistance genes/alleles in the ASR-resistant soybean genotypes whose resistance genes/alleles were unknown (Hossain et al. 2015; Yamanaka et al. 2015a; Yamanaka et al. 2016); 2) explored DNA markers for newly and previously identified resistance loci, and 3) developed and evaluated soybean breeding materials carrying multiple ASR resistance genes (Lemos et al. 2011).

Through these works, it appears that introducing multiple resistance genes into single soybean genotype brings high ASR resistance. This high resistance also acts synergistically in gene pyramided soybean lines, when they are inoculated with the *P. pachyrhizi* races which are virulent to each of the pyramided genes (Yamanaka et al. 2015b). JIRCAS and our partner institutions in South America have carried out some marker-assisted breeding programs to introduce this high ASR resistance in South American soybean cultivars by utilizing the gene pyramided lines.

KEYWORDS

Asian soybean rust; Breeding; Gene pyramiding; Marker-assisted selection (MAS); Resistant variety

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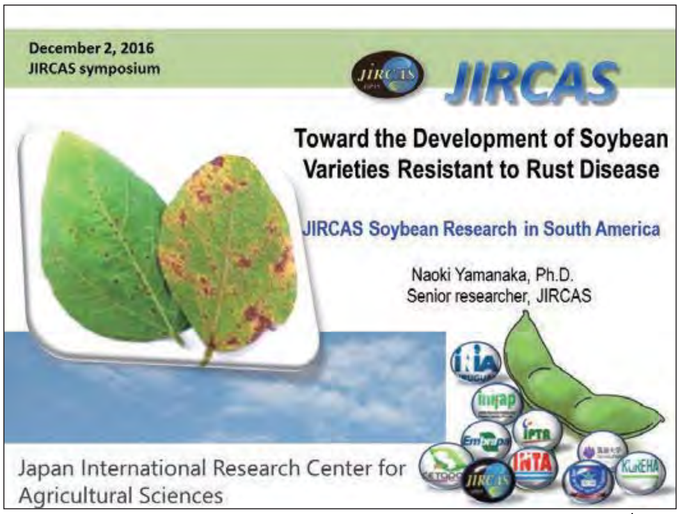
December 2, 2016
JIRCAS symposium
JIRCAS
Toward the Development of Soybean Varieties Resistant to Rust Disease
JIRCAS Soybean Research in South America
Naoki Yamanaka, Ph.D.
Senior researcher, JIRCAS
Japan International Research Center for Agricultural Sciences

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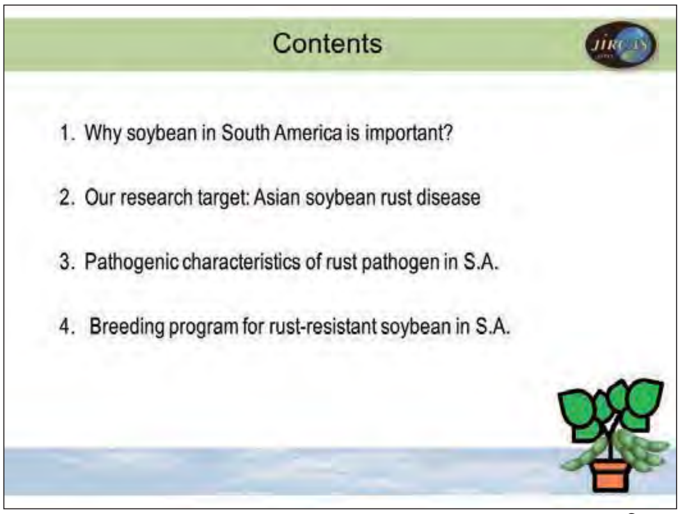
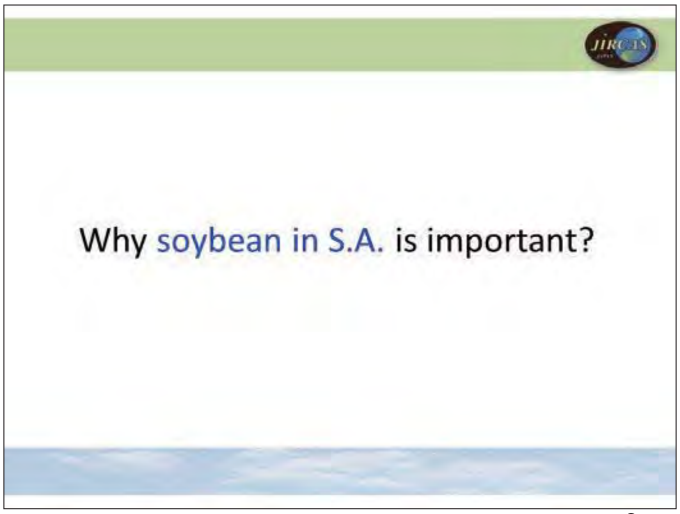
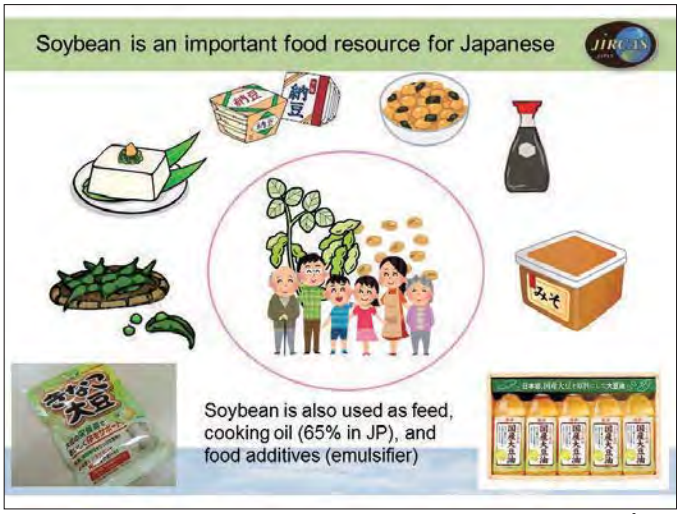

Contents
1. Why soybean in South America is important?
2. Our research target: Asian soybean rust disease
3. Pathogenic characteristics of rust pathogen in S.A.
4. Breeding program for rust-resistant soybean in S.A.

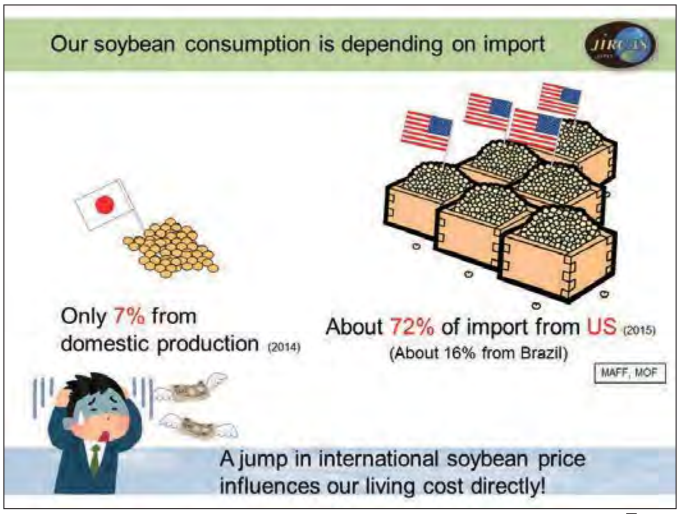
2


Why soybean in S.A. is important?

3


Soybean is an important food resource for Japanese
Soybean is also used as feed, cooking oil (65% in JP), and food additives (emulsifier)

4


Our soybean consumption is depending on import
Only 7% from domestic production (2014)
About 72% of import from US (2015)
(About 16% from Brazil)
MAFF, MOF
A jump in international soybean price influences our living cost directly!

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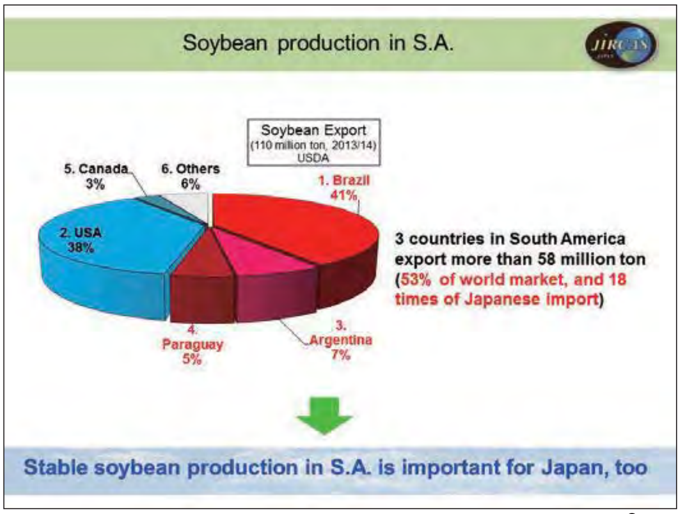
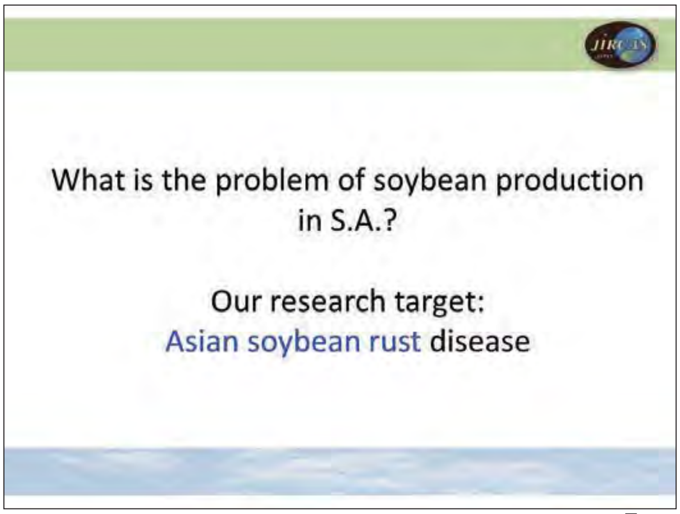

Soybean production in S.A.
Soybean Export
(110 million ton, 2013/14)
USDA
1. Brazil 41%
2. USA 38%
3. Argentina 7%
4. Paraguay 5%
5. Canada 3%
6. Others 6%
3 countries in South America export more than 58 million ton (53% of world market, and 18 times of Japanese import)
Stable soybean production in S.A. is important for Japan, too

6


What is the problem of soybean production in S.A.?
Our research target:
Asian soybean rust disease

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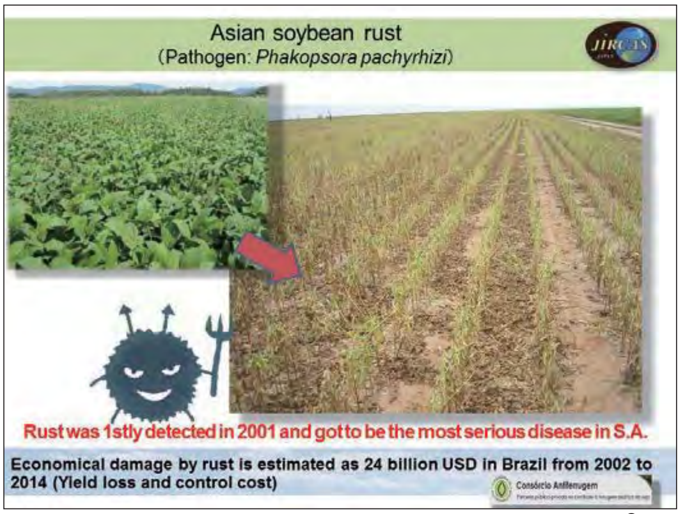
Asian soybean rust
(Pathogen: *Phakopsora pachyrhizi*)
Rust was 1stly detected in 2001 and got to be the most serious disease in S.A.
Economical damage by rust is estimated as 24 billion USD in Brazil from 2002 to 2014 (Yield loss and control cost)
Consórcio Antiferrugem

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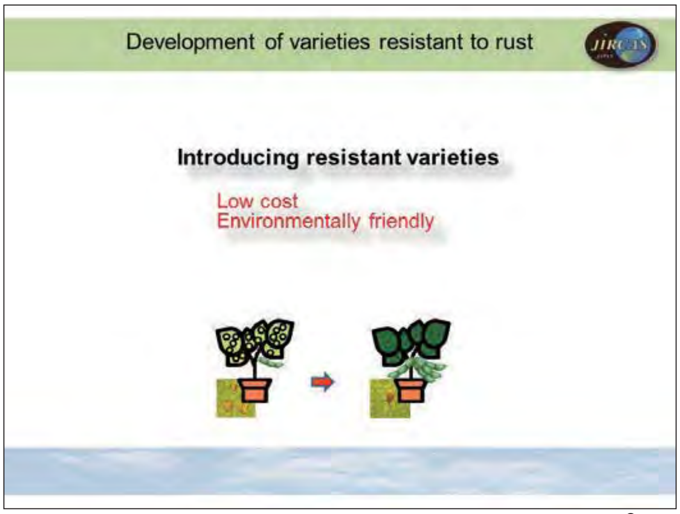
Development of varieties resistant to rust
Introducing resistant varieties
Low cost
Environmentally friendly

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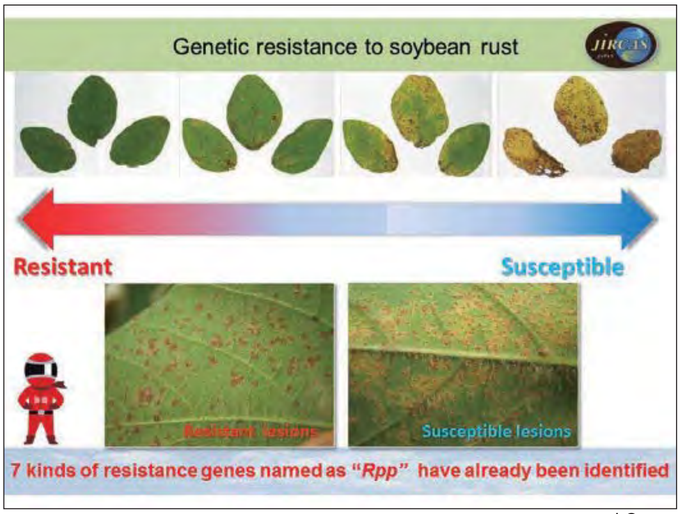
Genetic resistance to soybean rust
Resistant
Susceptible
Resistant lesions
Susceptible lesions
7 kinds of resistance genes named as "*Rpp*" have already been identified

10


Characteristics of soybean rust in S.A.
At least 7 resistance genes are available for breeding
Which gene is effective?
How much and how long it will be effective?
We decide breeding material and strategy based on the pathogenicity of pathogen
Rpp1
Rpp2
Rpp3
Rpp4
Rpp5
Research Subject (1) with the partner institutions in S.A.

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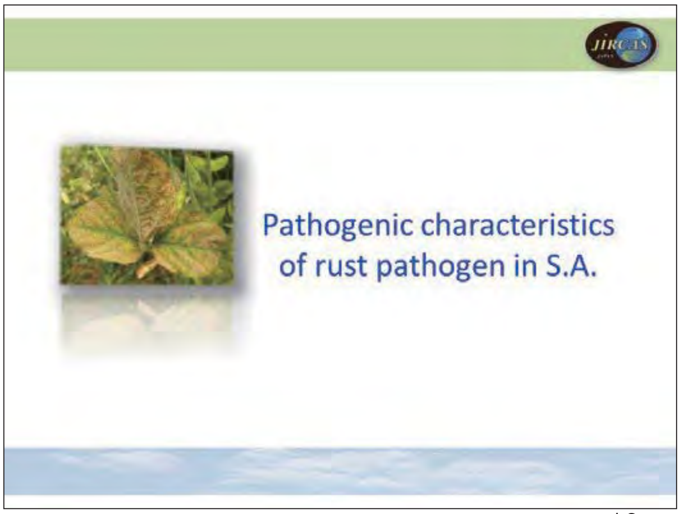
Pathogenic characteristics of rust pathogen in S.A.

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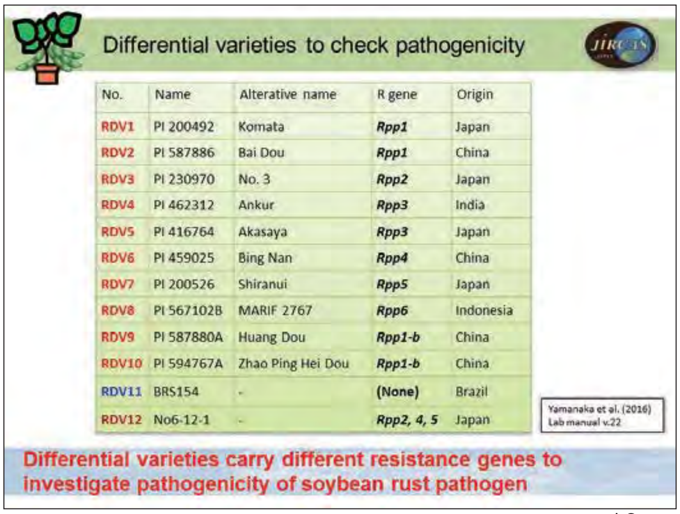

No.	Name	Alterative name	R gene	Origin
RDV1	PI 200492	Komata	*Rpp1*	Japan
RDV2	PI 587886	Bai Dou	*Rpp1*	China
RDV3	PI 230970	No. 3	*Rpp2*	Japan
RDV4	PI 462312	Ankur	*Rpp3*	India
RDV5	PI 416764	Akasaya	*Rpp3*	Japan
RDV6	PI 459025	Bing Nan	*Rpp4*	China
RDV7	PI 200526	Shiranui	*Rpp5*	Japan
RDV8	PI 567102B	MARIF 2767	*Rpp6*	Indonesia
RDV9	PI 587880A	Huang Dou	*Rpp1-b*	China
RDV10	PI 594767A	Zhao Ping Hei Dou	*Rpp1-b*	China
RDV11	BRS154	-	(None)	Brazil
RDV12	No6-12-1	-	*Rpp2, 4, 5*	Japan

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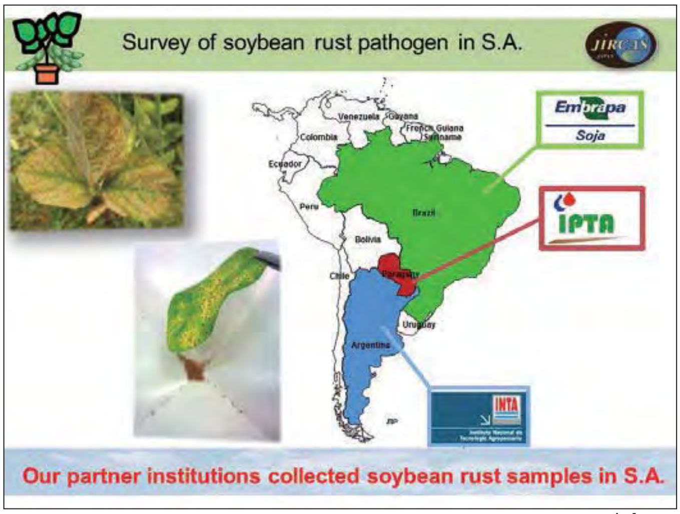

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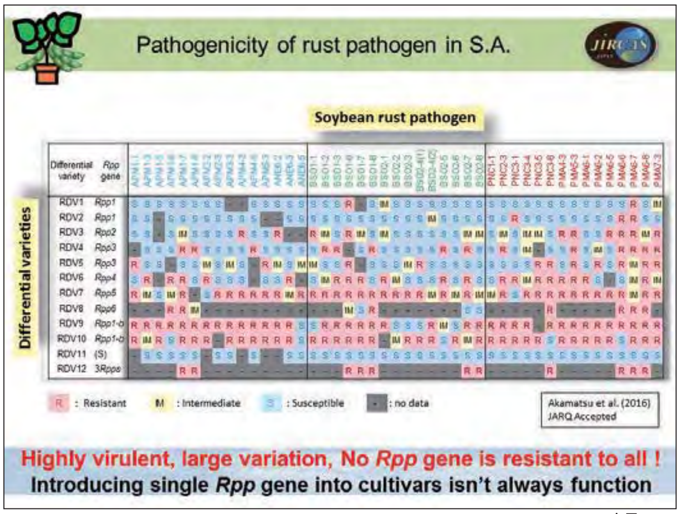

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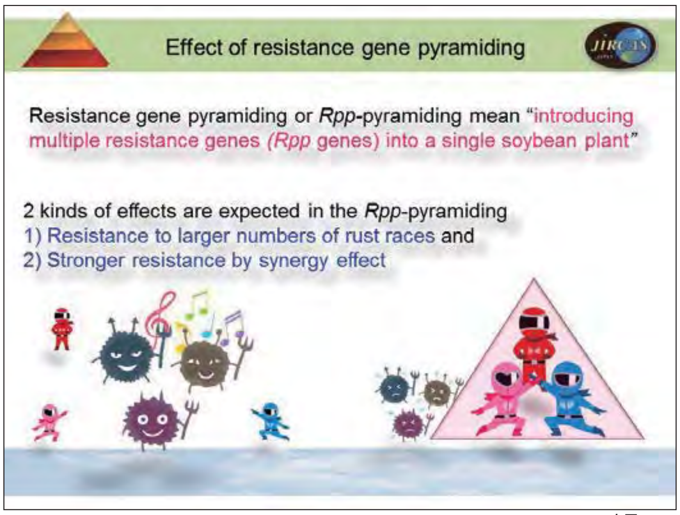

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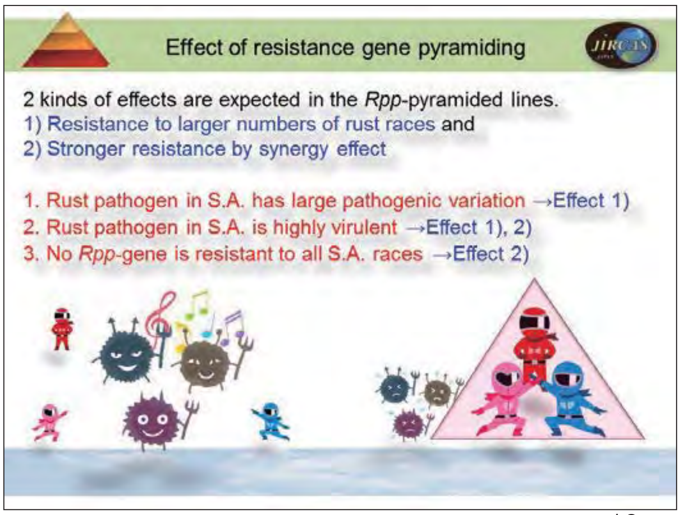

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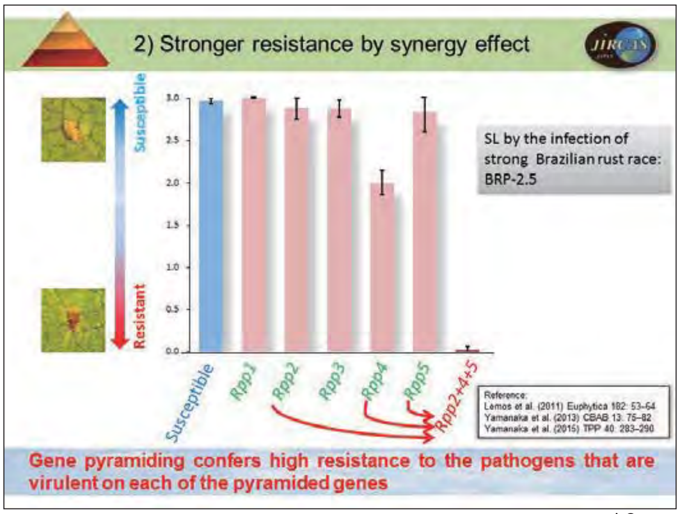

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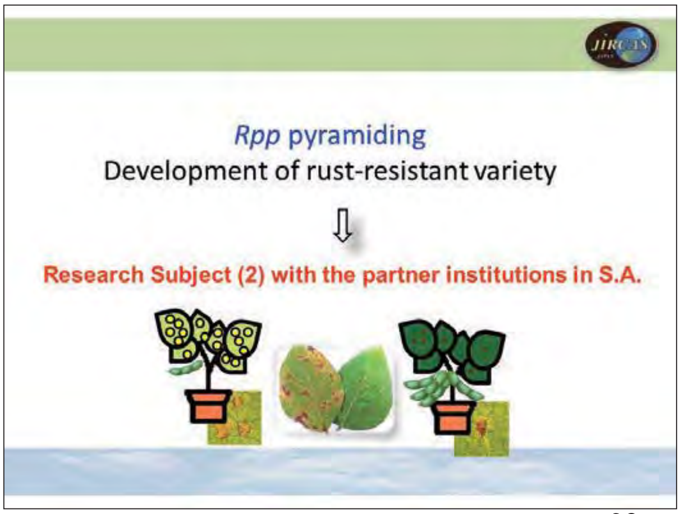

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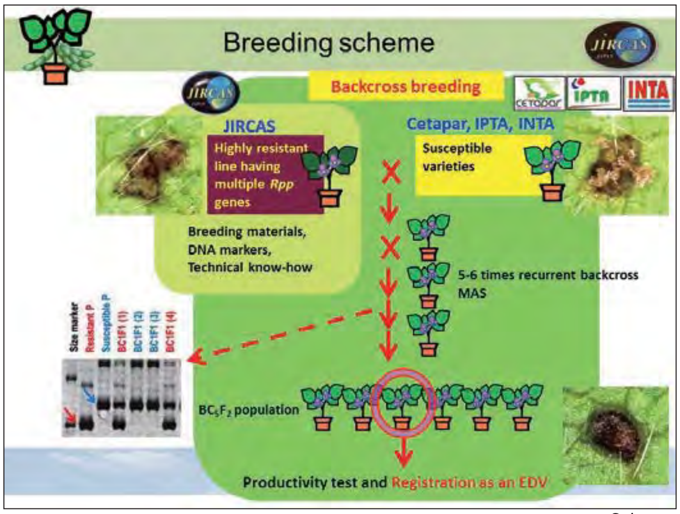

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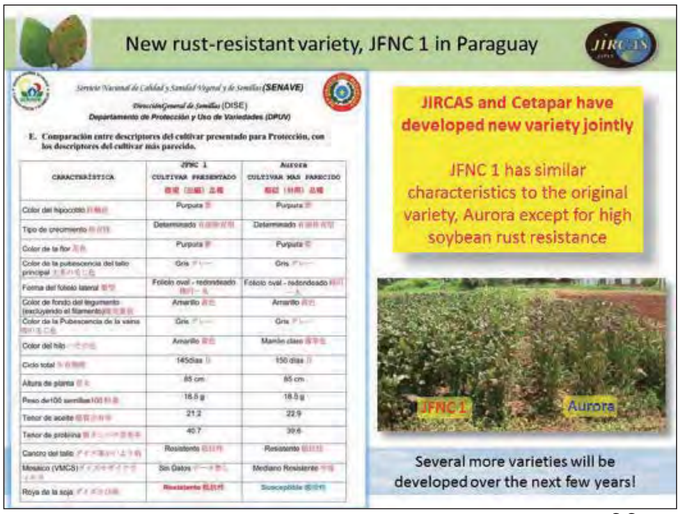

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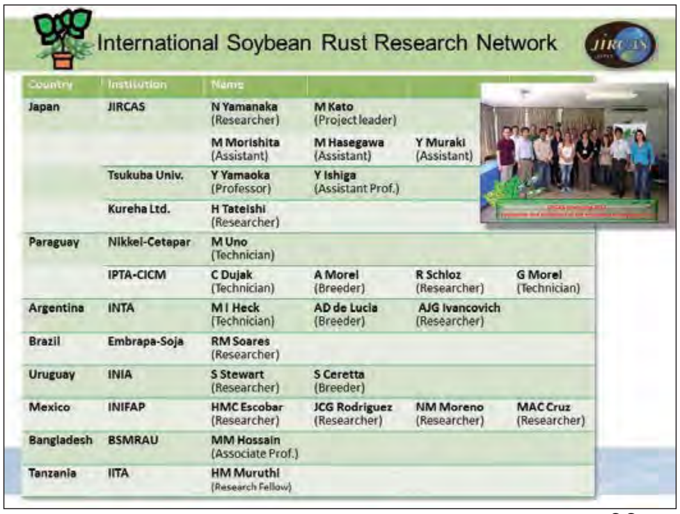

Country	Institution	Name			
Japan	JIRCAS	N Yamanaka (Researcher)	M Kato (Project leader)		
		M Morishita (Assistant)	M Hasegawa (Assistant)	Y Muraki (Assistant)	
	Tsukuba Univ.	Y Yamaoka (Professor)	Y Ishiga (Assistant Prof.)		
	Kureha Ltd.	H Tateishi (Researcher)			
Paraguay	Nikkei-Cetapar	M Uno (Technician)			
	IPTA-CICM	C Dujak (Technician)	A Morel (Breeder)	R Schloz (Researcher)	G Morel (Technician)
Argentina	INTA	M I Heck (Technician)	AD de Lucia (Breeder)	AJG Ivancovich (Researcher)	
Brazil	Embrapa-Soja	RM Soares (Researcher)			
Uruguay	INIA	S Stewart (Researcher)	S Ceretta (Breeder)		
Mexico	INIFAP	HMC Escobar (Researcher)	JCG Rodriguez (Researcher)	NM Moreno (Researcher)	MAC Cruz (Researcher)
Bangladesh	BSMRAU	MM Hossain (Associate Prof.)			
Tanzania	IITA	HM Muruthi (Research Fellow)			

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Chair Nakashima
Our last speaker for this session is Dr. Naoki Yamanaka. He is Senior Researcher of JIRCAS and he studied on the soybean for about 15 years in JIRCAS. Today, he will present on 'Toward the Development of Soybean Varieties Resistant to Rust Disease.' Dr. Yamanaka, please go ahead.

Dr. Naoki Yamanaka
Thank you Dr. Nakashima for the kind introduction. Good afternoon, ladies and gentlemen. I am Naoki Yamanaka, Senior Researcher of JIRCAS. It is my great pleasure to introduce our research in this symposium. The title of my presentation today is 'Toward the Development of Soybean Varieties Resistant to Rust Disease.' And this is one of JIRCAS soybean research activities in South America.

In my presentation, at first I would like to talk why soybean production in South America is important. In second, our research target: Asian soybean rust disease. And third, pathogenic characteristics of rust pathogen in South America. Finally, I would like to introduce our breeding program for rust-resistant soybean in South America.

First of all, let me explain why soybean in South America is important. As you may know, soybean is an important food resource for us, Japanese. Soybean is used for various Japanese foods, Tofu, Natto, Sho-yu, Miso and so on. Soybean is also used for feed for livestock, cooking oil material, and sometimes we use it for food additives such as emulsifier.

Soybean is very important; however, our soybean consumption is depending on import. We can produce only 7% of our consumption. So, we have to import, and about 72% of imported soybean comes from US, the 1st producer in the world. So, a jump in international soybean price influences our living cost directly. This is the problem.

How do we solve this problem? One solution is soybean production in South America. This slide shows us major soybean exporters in the world market. Three South American countries; Brazil, Argentina, and Paraguay export more than 58 million ton of soybean, and this is equivalent for 53% of world market and 18 times of Japanese import. I mean huge amount. So, soybean production in South America gets to be more stable or increase and soybean price gets to be cheaper, we can import more soybean from South America. So, stable soybean production in South America is important, not only for their country, but also for Japan.

Then, what is the problem of soybean production in South America? One serious problem is our research target: Asian soybean rust disease. Asian soybean rust disease is caused by the pathogen *Phakopsora pachyrhizi*. Soybean rust was firstly detected in South America in 2001 and got to be the most serious soybean disease there. This picture shows the soybean field seriously damaged by this disease. You can see the soybean plants lost their leaves before maturation. So, farmers cannot expect a yield in this situation. According to South America Anti-Rust Consortium, economical damage by this disease is estimated as 24 billion USD only in Brazil from 2002 to 2014. So, soybean rust is a very serious problem. So, we decided to study on development of varieties resistant to rust to control this disease, because introducing resistant varieties has merits, low cost and environmental friendly.

For genetic improvement, genetic resistance to pathogen is necessary. Fortunately, for soybean rust, seven kinds of resistance genes named as *Rpp* have already been identified. If soybean plants carry the resistance gene and the pathogen is avirulent to that resistance gene, soybean plants show resistant reaction like this picture of immunity, so soybean plant can keep green healthy leaves. Contrastingly, if soybean plant doesn't have any resistance genes, actually most of cultivars, or even the resistant variety, if the pathogen is virulent to that resistance gene, soybean plant shows susceptible reaction to produce lots of spores like this picture, the leaves of plant yellow and fall.

As I mentioned, at least seven kinds of resistance genes are available for breeding, but which gene is effective and how much and how long it will be effective. This is important point because we decide breeding material and strategy based on the pathogenicity of pathogen. This is important work. So, we carried out this important work with our partner institutions in South America.

Next, I would like to show the results of this collaboration, pathogenic characteristics of rust pathogen in South America. To determine pathogenicity, pathogenic characteristic of pathogen, differential varieties carrying different kind of resistance genes are needed. This list shows our differential variety set consisting of 12 varieties, 10 of 12 varieties carrying single *Rpp* gene differently and one variety has no resistance gene. This is a susceptible check. And one line carrying three genes. About this line, I am going to explain later.

Our partner institutions collected soybean rust samples in their country and then they inoculate these samples to the differential varieties and they evaluate the reaction on the differentials.

This slide shows the results, pathogenicity of rust pathogen in South America. These are the soybean rust pathogenic samples collected in Argentina, Brazil, and Paraguay. Actually, they have collected more than 140 samples in 7 years, but here I show only partial data. And these are differential varieties.

In this table, Red R shows resistant reaction was observed. So that resistance gene was effective to that pathogen. Blue S means susceptible reaction was observed. So, that gene was ineffective. In other words, the pathogen was virulent to that resistance gene. Yellow IM means intermediate reaction was observed. This phenotype is phenotype between resistant and susceptible. Resistance genes show the resistance little and pathogen showed virulent partially.

What we get to know? The first, as you can see, many S reactions were observed. So, South American pathogen is highly virulent. In second, each pathogenic sample shows different pattern against different varieties, so South American pathogen has large variation. And third, this is most important point, some resistance genes tend to show resistant reaction to the pathogen with high frequency, but there's no resistance gene resistant to all tested samples. So, if we introduce the single resistance gene into cultivars, we cannot expect stable resistance for that variety.

Now, we know that South American pathogen is very strong, how do we defeat it? Our choice is gene pyramiding.

Please let me explain about gene pyramiding. Resistance gene pyramiding or *Rpp*-pyramiding, in case of soybean rust, means introducing multiple resistance genes, in case of soybean rust, *Rpp* genes, into a single soybean plant. Two kinds of effects are expected in the *Rpp*-pyramiding. First, resistance to larger numbers of rust races. In second, stronger resistance by synergy effect. Please remember the characteristics of the South American rust pathogen. South American rust pathogen has large pathogenic variation and highly virulent, and there is no resistance gene resistant to all South American races. For the first character of the pathogen, pyramiding effect 1 is useful. For the second character of the pathogen, both effects are useful. And for the third character of the pathogen, pyramiding effect 2 can defeat it.

Okay, next, let me explain a little bit more about the second effect of pyramiding, stronger resistance by synergy effect. This graph shows the sporulation level by the infection of strong Brazilian rust race BRP-2.5 in susceptible variety, resistance varieties carrying single gene, and *Rpp*-pyramid line. Susceptible variety and resistance varieties carrying single gene showed moderate level of sporulation or maximum level of sporulation to produce lot of spores to be susceptible like this picture. Contrastingly, the *Rpp*-pyramided line carrying three genes showed almost no sporulation to be highly susceptible phenotype. This is one typical example of the pyramiding effect. Gene pyramiding confers high resistance to the pathogens that pathogens are virulent on each of the pyramided genes. So, now we know that resistance *Rpp* gene-pyramiding should be useful for the development of resistance soybean rust variety. So, we decided to use *Rpp* gene pyramiding for breeding. And we carried out this work with our partner institution in South America.

This slide shows our breeding scheme carried out with our partner institutions; Cetapar, IPTA in Paraguay and INTA in Argentina. We, JIRCAS, develop and provide highly resistant line carrying multiple resistance genes as breeding materials together with DNA markers and technical know-how to use them. Our partner institutions, they have their own varieties. These varieties are nice to show good adaptability or productivity in their countries, however, unfortunately, susceptible to rust. So, we carry out backcross breeding by using our *Rpp*-pyramided line as donor parent and their soybean variety as recurrent parent. After 5 or 6 times recurrent backcrossing and marker-assisted selection, we choose several lines. And after productivity test in multi-locations, we choose one single line as candidate variety that shows the strong resistance by gene pyramiding but similar agronomical characteristics as the recurrent parent, and we register it as an **E**ssentially-**D**erived **V**ariety.

JIRCAS and Nikkei-Cetapar started this breeding program 7 years ago and we developed a new rust-resistant variety, JFNC 1, **J**IRCAS and **F**oundation **N**ikkei-**C**etapar **1** in Paraguay. We applied variety registration just last month, so this variety has not been released yet in the market. But we have already confirmed JFNC 1 has similar characteristic to the original variety, Aurora except for high soybean rust resistance. This picture shows the JFNC 1 and Aurora are growing in soybean rust-occurring field in Paraguay. JFNC 1 keeps more green leaves than Aurora. Under the rust disease controlled condition by fungicide, these two varieties show similar agronomical characteristics each other. Except for JFNC 1, several more varieties are under development. So, over the next few years, we will complete the development varieties and release them in near future.

In the end of my presentation, I'd like to thank my colleagues in Japan and my staffs in JIRCAS and especially my friends in our partner institutions in South America.

In this presentation, I could introduce part of our collaboration with Argentina, Brazil, and Paraguay, but our International Soybean Research Network is expanding to other surround regions and other countries, for example, Uruguay, Mexico, Bangladesh, and Tanzania. So, by developing good rust-resistant variety in these countries, I hope soybean rust disease gets to be a minor disease or past disease in this country in some day. That's all of my presentation. Thank you for your attention.

Chair Nakashima
Thank you very much for the nice presentation, Dr. Yamanaka. He has showed that JIRCAS and the partner institutions in South America have succeeded to introduce the high rust resistance in South American soybean cultivars by pyramiding resistance genes. So, it's open for the discussion. Are there any questions or comments? Okay.

Male Questioner
At first, I appreciate your considerable activities and work. As you successfully introduced gene resistance to rust and soybean, have you ever illustrated the effects of that gene in other component like yield and yield component in soybeans, its effect? Effect of that gene and yield component on other traits?

Dr. Naoki Yamanaka
Do you mean under the soybean rust occurring condition or without soybean rust disease occurring condition?

Male Questioner
In two conditions comparison. You introduced the gene successfully. Have you elucidated the effect of that gene on other traits like yield component?

Dr. Naoki Yamanaka
Okay. These resistance genes some of them have already isolated and it is NBS-LRR gene, the R gene, and it does not influence the other characters, only the resistance. We carefully checked the developed line if there is any other effect by these genes, but until now we have not observed. So, basically, that gene influences on the resistance only.

Chair Nakashima
Okay? Are there any questions or comments?

Male Questioner
Thank you for your presentation. Is there any update on the biochemical basis of your gene?

Dr. Naoki Yamanaka
Sorry, we haven't done any work regarding that.

Chair Nakashima
Are there any questions or comments? Can I ask one question? How is the plan for the release of the practical variety in Latin America? When can you release the practical variety?

Dr. Naoki Yamanaka
As I introduced the first variety has just applied registration. So, we have to wait for the result first. I think not so long time it takes, but after that, we are planning to ask the farmers to cultivate this variety.

Chair Nakashima
Thank you. I hope this will be used in Latin America. Okay. It's almost time, so thank you very much, Dr. Yamanaka. It's now time to close this session. I think we were able to share valuable information on some interesting research topics related to pulse research in India and some interesting genes of *Vigna* and breeding research of soybean against disease. I would like to close this session by thanking all the presenters for their contributions. Please give a big hand to the speakers. Thank you very much.

Questioner

Questioner

Session 3

Livelihood with legumes:
Value addition and nutritional enhancement

Chair:

***Yukiyo Yamamoto*,** JIRCAS

CONTRIBUTION OF LEGUMES TO SMALLHOLDER AGRICULTURE AND LIVELIHOOD SUSTENANCE IN SUB-SAHARAN AFRICA: EVIDENCE FROM MALAWI, GHANA AND GUINEA

[1]*Yaw Agyeman Boafo, [2]Linda Chinangwa, [1]Boubacar Siddighi Balde

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YAW AGYEMAN BOAFO holds a PhD in Sustainability Science from United Nations University Institute for the Advanced Study of Sustainability (Japan) and is currently a Project Researcher at the the Integrated Research System for Sustainability Science (IR3S), The University of Tokyo. Yaw's research interest is broadly within the field of ecosystem services and resilience in socio-ecological systems, food security, climate change vulnerability and adaptive capacities and rural development.

Yaw Agyeman Boafo

LINDA CHINANGWA holds a PhD in Conservation Biology from Bangor University (Wales). She has been a JSPS-UNU Postdoctoral Fellow at the Institute for the Advanced Study of Sustainability, United Nations University (UNU-IAS) since August 2016. Her research and career interests are primarily in forestry, natural resources management, ecosystem services, agriculture, livelihoods and sustainable development viewed from the social and economic perspective of rural communities.

BOUBACAR SIDDIGHI BALDE holds a PhD in Managerial Economics from the United Graduate School of Agricultural Sciences (UGSAS), Tottori University, Japan, and is currently a Project Researcher at the Integrated Research System for Sustainability Science (IR3S), University of Tokyo, where he explores the food security impacts of industrial crop expansion in Sub-Saharan Africa. He conducted research related to food security, poverty alleviation, land use change analysis, etc.

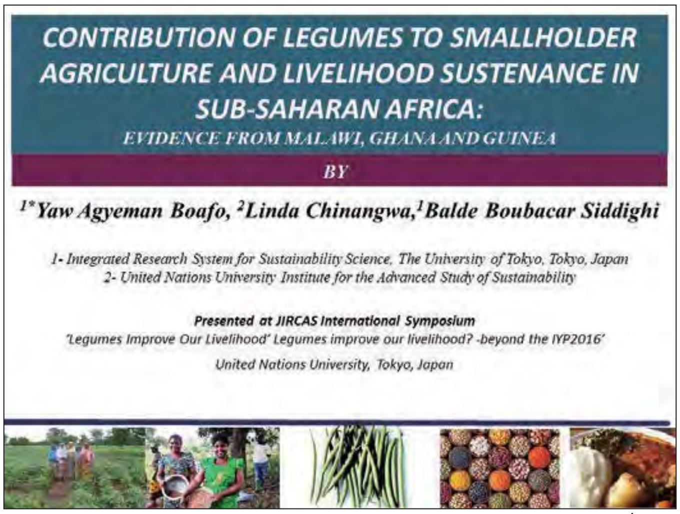
Yaw Agyeman Boafo
Linda Chinangwa
Boubacar Siddighi Balde

ABSTRACT

Leguminous crops, including cowpea (*Vigna unguiculata* L. Walp.), groundnut (*Arachis hypogaea)*, soybean *(Glysine max* L. Merril) and common bean (*Phaseolus vulgaris* L.), are among the most important and widely grown crops in Sub-Saharan Africa's (SSA) diverse ecological zones. These legumes are multipurpose, hence their production is crucial for the African population especially smallholder households, in terms of food security, nutrition, generation of income, and maintenance of local agroecosystems (i.e., improving soil health and fertility). Characteristically, legumes are known to thrive under low rainfall and poor soil conditions and require minimum capital investment in comparison with other crops. In the face of rapid and unprecedented population growth being experienced in SSA, where the majority is engaged in smallholder agriculture, coupled with the effects of climate variability and change on agriculture, maintaining agronomic practices that help maintain high crop yields and at the same time enhance soil productivity is imperative towards enhancing sustainable development. The promotion of legume production among smallholder farmers in SSA is, therefore, plausible. Against this backdrop, the objective of this study is to further highlight and discuss the role of legume production among smallholder agriculture and livelihood sustenance in SSA by drawing evidence from three African countries namely Ghana, Malawi, and Guinea. Using examples from these countries, elements such as major types of legumes cultivated, area harvested in comparison with other major crops, production quantity, and contribution to global production are examined. The study further assesses some of the country level utilization froms as well as the major challenges impacting on the sustainable promotion and production of legumes. Additionally, we underscore the opportunities associated with upscaling practices associated with legume production among smallholder farmers.

KEYWORDS

Rural households, Legumes, Smallholder agriculture, Climate change


CONTRIBUTION OF LEGUMES TO SMALLHOLDER AGRICULTURE AND LIVELIHOOD SUSTENANCE IN SUB-SAHARAN AFRICA:
EVIDENCE FROM MALAWI, GHANA AND GUINEA
BY
1*Yaw Agyeman Boafo, 2Linda Chinangwa, 1Balde Boubacar Siddighi
1- Integrated Research System for Sustainability Science, The University of Tokyo, Tokyo, Japan
2- United Nations University Institute for the Advanced Study of Sustainability
Presented at JIRCAS International Symposium
'Legumes Improve Our Livelihood' Legumes improve our livelihood? -beyond the IYP2016'
United Nations University, Tokyo, Japan

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CONTENT
1. Key facts about Agriculture in Africa
2. Legumes contribution to agriculture and livelihood sustenance:
i. Ghana
ii. Malawi
iii. Guinea
3. Challenges and Opportunities in Legume Production
4. Recommendation and Way Forward

2


KEY FACTS ABOUT AGRICULTURE IN AFRICA
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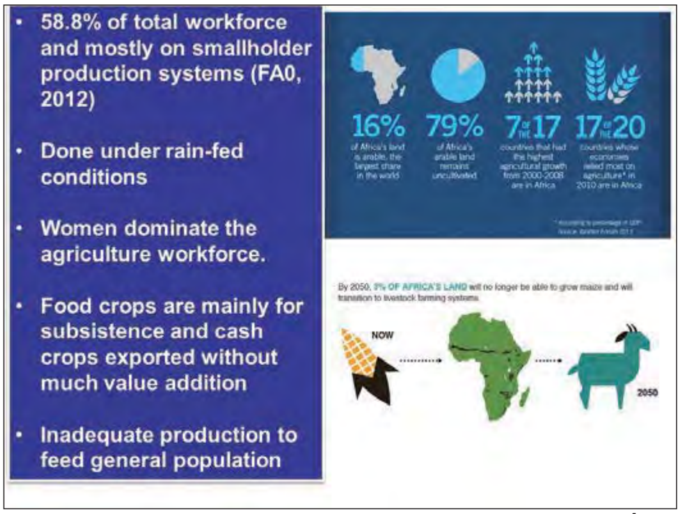
58.8% of total workforce and mostly on smallholder production systems (FA0, 2012)
Done under rain-fed conditions
Women dominate the agriculture workforce.
Food crops are mainly for subsistence and cash crops exported without much value addition
Inadequate production to feed general population
16%
79%
7 of 17
17 of 20
NOW
2050

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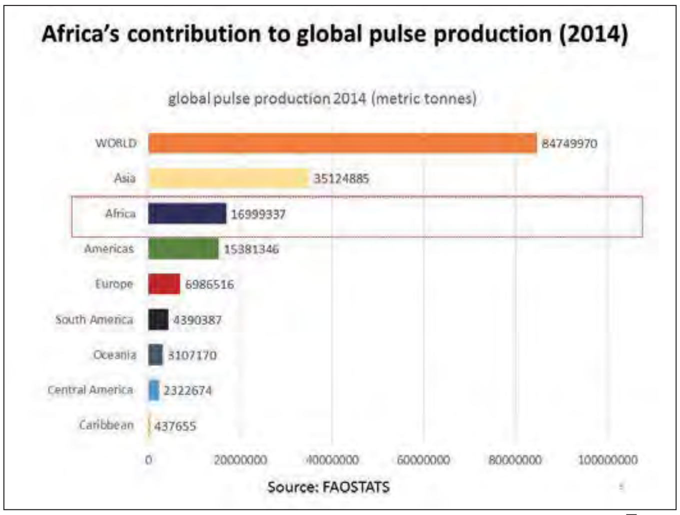
Africa's contribution to global pulse production (2014)
global pulse production 2014 (metric tonnes)
WORLD 84749970
Asia 35124885
Africa 16999337
Americas 15381346
Europe 6986516
South America 4390387
Oceania 3107170
Central America 2322674
Caribbean 437655
0
20000000
40000000
60000000
80000000
100000000
Source: FAOSTATS

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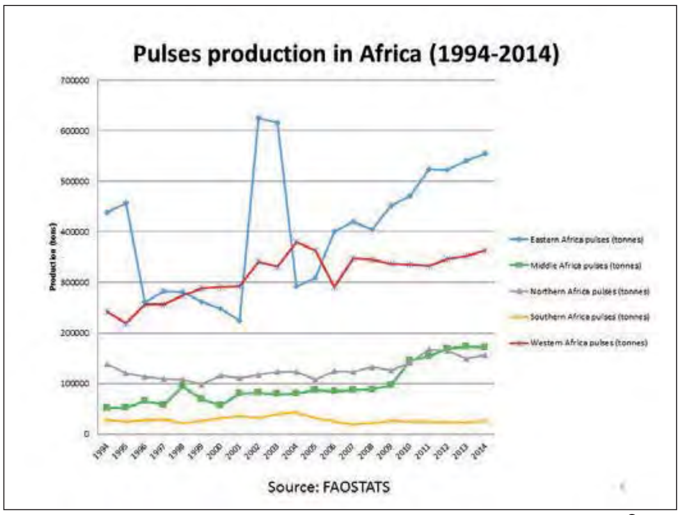
Pulses production in Africa (1994-2014)
700000
600000
500000
400000
300000
200000
100000
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Eastern Africa pulses (tonnes)
Middle Africa pulses (tonnes)
Northern Africa pulses (tonnes)
Southern Africa pulses (tonnes)
Western Africa pulses (tonnes)
Source: FAOSTATS

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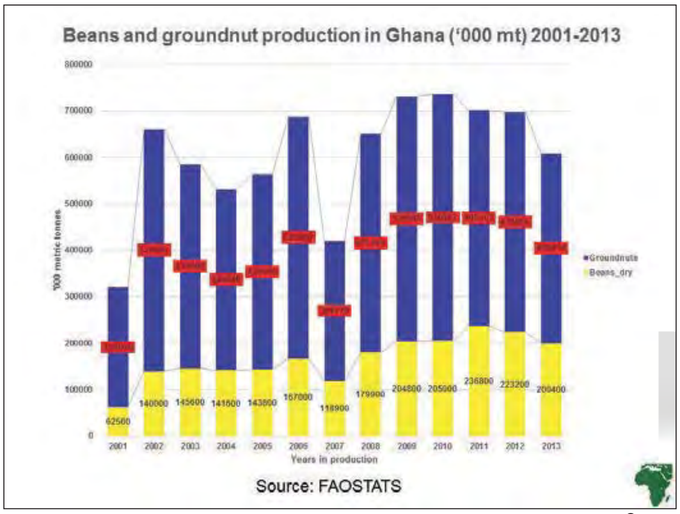

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The Ghana Grains and Legumes Board

- Set up under the Ministry of Food and Agriculture (MOFA)
  - ✓ Production of Foundation Seeds of Cereals and Legumes.
  - ✓ Production and Supply of Vegetatively Propagated Planting Materials
  - ✓ Provision of Agro-processing Services.
  - ✓ Management of Farmers Certified Seeds and the National Seed Security Stocks.

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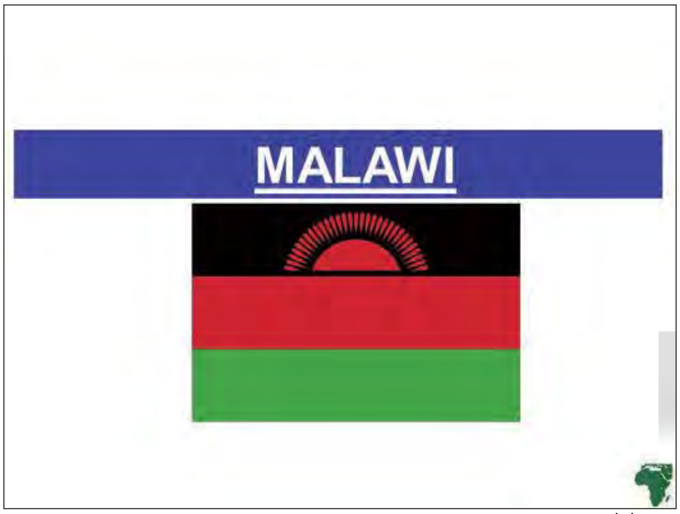

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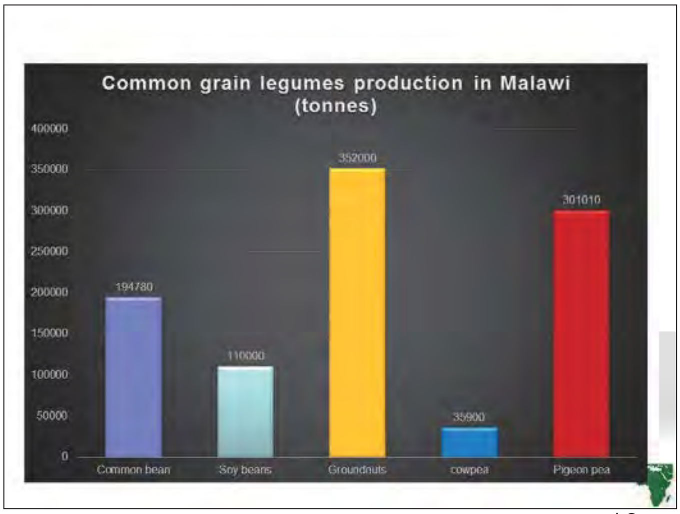

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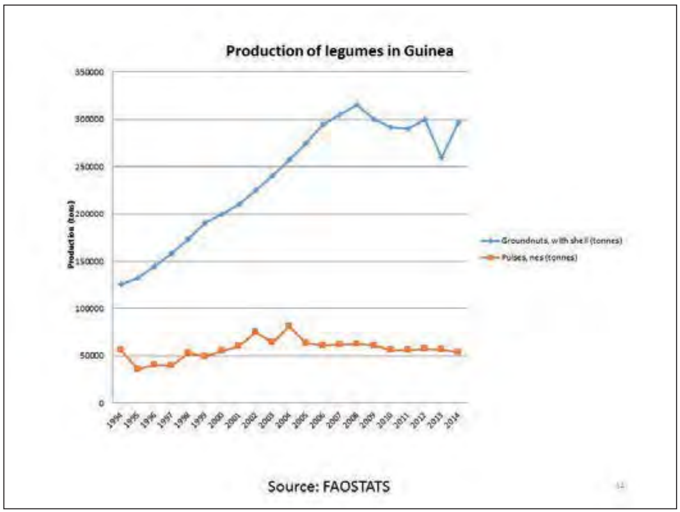

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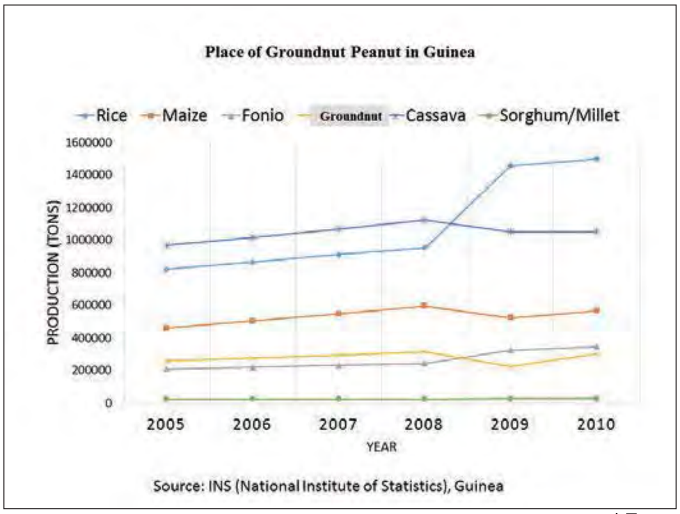

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Direct and Indirect Contribution of legumes livelihood sustenance

- Peanut crop has the unique characteristics of being both food crop and cash crop in smallholder production systems.
- Potential for income generation
- It is a also an important commercial crop, since peanut is the basic commodity for a wide range of commercial products such as oil, snack food and animal feed and other by products use.
- Peanut is also a key ingredient in culinary preparations.

16

- **Utilization of groundnut by-products**
  - ✓ **Making soap from rotten groundnuts**
  - ✓ **The extraction of groundnut oil**
  - ✓ **Groundnuts shells are used as fertilizer by farmers.**
  - ✓ **Groundnuts shells are also used by farmers as a mulch to trap moisture into soil.**

17

CHALLENGES AND OPPORTUNITIES

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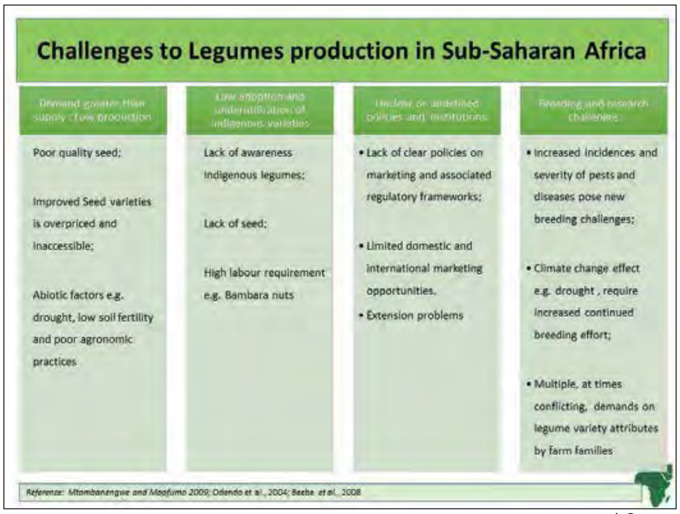

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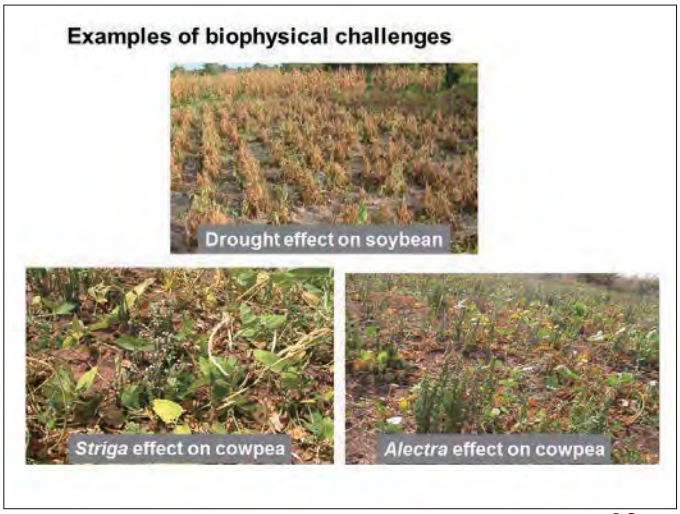

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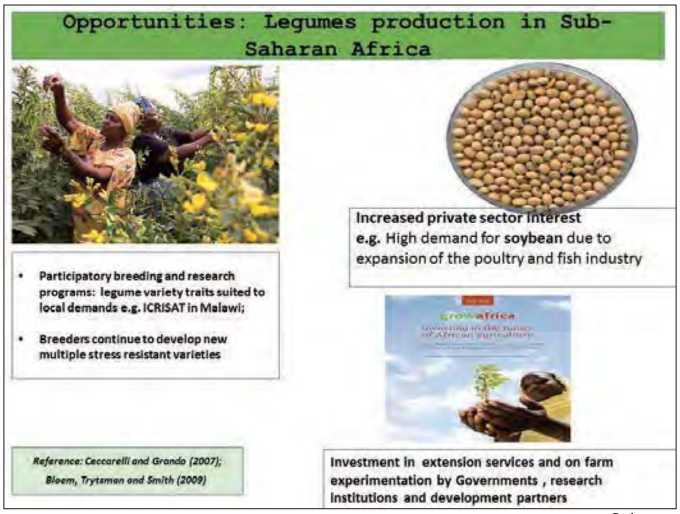

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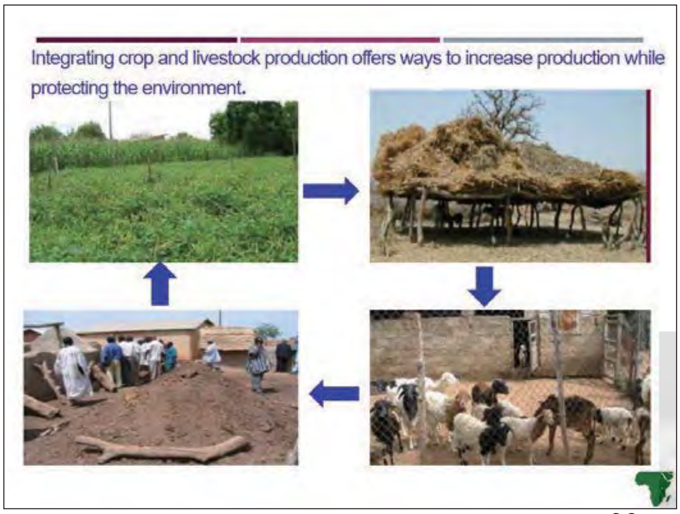

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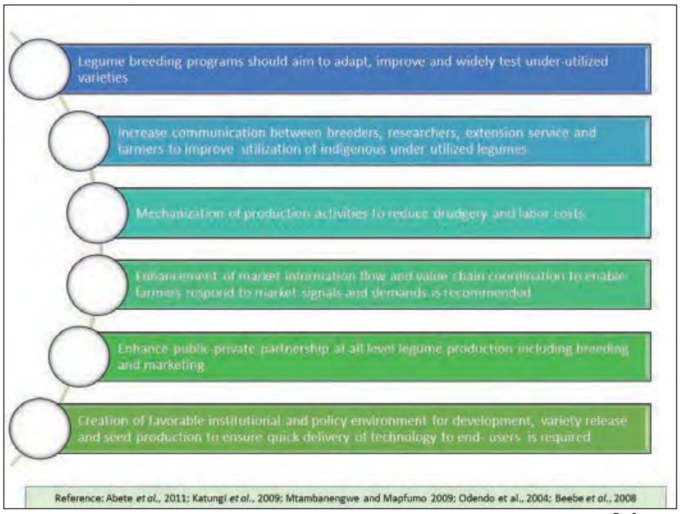

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Thank you!

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Chair Yamamoto
Good afternoon, ladies and gentlemen. My name is Yukiyo Yamamoto, Program Director of JIRCAS. I will chair the Session 3, 'Livelihood with legumes: Value addition and nutritional enhancement.' In the Session 1 and Session 2, we reviewed the cropping system production and the diversity of legumes from the viewpoint of agriculture and science. In this Session 3, we would like to consider how legumes are utilized in our life by some examples in Africa and other countries.

In this session, we will provide three presentations. The first topic is contribution of legumes to smallholder agriculture and livelihood sustenance in sub-Saharan Africa: Evidence from Ghana, Malawi, and Guinea by Dr. Yaw Agyeman Boafo, Dr. Linda Chinangwa, and Dr. Boubacar Siddighi Balde. On behalf of all, Dr. Yaw Boafo will present today. So, Dr. Boafo, please come to the stage. I will briefly introduce our speakers. Dr. Boafo is a project researcher at the Integrated Research System for Sustainability Science at the University of Tokyo. His research interests are ecosystem services and resilience in socioecological systems, food security, climate change vulnerability and rural development. So, when you are ready, please give your presentation.

Dr. Yaw Agyeman Boafo
Right. Thank you very much, Yamamoto-san. As she elaborated, I will be speaking on behalf of my team. My name is Yaw Agyeman Boafo and my colleagues are Linda and Boubacar. We are all postdocs. Boubacar is with me at the University of Tokyo whiles Linda operates right here from at UNU.

Our talk today will be on the contribution of legumes to smallholder agriculture and livelihood sustenance in sub-Saharan Africa. Unlike most of the other presentations, ours will be more generic, not very technical because we will give a very good overview of what's happening in Africa in terms of agriculture and legumes based on secondary data. So, I will start by just giving a few facts about agriculture in Africa, then I will highlight some key leguminous produce in Africa with reference to Ghana, Malawi, and then Guinea. From there we will talk about some of the challenges and opportunities in legume production across Africa with reference to the case study countries. We will end with the recommendations and some issues moving forward.

Until now, we have had opportunities to listen to some presentations already this morning. One of the key ones was by David Bergvinson. He highlighted some of the issues that has to do with legumes in Africa, but I just want to say that in Africa, when it comes to agriculture, it's a very important livelihood and also economic activity, and some of the facts show that almost about 60% of people are involved in this activity. Then, most of the agriculture in Africa is done under rainfed conditions, meaning that majority of farmers rely on nature for any sort of water to support the agriculture systems. And then another interesting fact is that women dominate the agriculture sector in Africa. That's something that also has not been ignored. Then, most of the crops are food crops that are produced for subsistence. That means that they are produced for consumption in the households and then a little bit of it sold, then some of the cash crops that are produced in terms of agriculture, much value is not added, most of them are sent abroad for value addition. Examples include cocoa, cotton, and coffee. One of the keys as I highlighted earlier, there is inadequate production of staple crops when it comes to agriculture or with reference to our food production for consumption.

I found this also very interesting when it comes to percentage of arable farmlands in Africa, some of the latest data shows that about 60% of Africa's farmland is arable. Then, out of that, 79% is uncultivated, even though agriculture has the most important livelihood activity there. The one that we also have to take note is that by 2050, 3% of Africa's land will no longer be able to grow maize as they will transition to livestock. Maize is a very important staple crop across Africa. It's actually one of the most important staple crops across Africa. It may be opportunities and challenges for households and communities.

Within the context of the topic, when it comes to pulse production in Africa, based on some of the latest stats from the FAO, we found out that Africa in 2014 produced about 20% of the global pulse production. That is 84 million 749, 970,000 thousand tonnes. Africa made about 17 million tonnes of our own. That means about 20% compared to Asia which was about 40%. So, Africa still contributes a very substantial amount to global pulse production in you pull out this in context. Within Africa also, if you look at the sub-regions in Africa, we can think of very different sort of production patterns across the sub-regions. With emphasis of West Africa, for example, which is in the red, Western Africa produces great at the moment, but the most important region as you can see is the Eastern part of Africa, and I think the last presentation highlighted some places like Malawi, Kenya as important areas of production. The rise and falls actually reflect the combined impact of human and natural factors including unstable political and governance systems on the production system. In terms of natural factors, rainfall unpredictability and drought are major concerns across Africa.

Going forward, I will just try and highlight briefly a few issues when it comes to the chosen countries for this presentation. There are Guinea, Ghana, and Malawi. Starting with Ghana, I came up with this data from Food and Agricultural Organisation online database (FAOSTAT) together with Ghana's Ministry of Food and Agriculture and it showed that in Ghana, beans and groundnut are two of the most important legumes that is produced in Ghana. And if you look at over the last 10 years, we can see that in the year 2000, for instance, there is a bit of an increase, then there is a decrease as well. So, the trends fluctuate and I think it is similar to global trends. It is fair to say that production mimics global volatility as was implied in the presentations this morning. It's all because of a number of factors. Clear amongst them is the issue of rainfall and also issues of lack of inputs such as fertilizer and pesticides. This can also be as a result of the high poverty levels of rural farmers in Ghana. Considering widespread cultivation of legumes couple with the numerous challenges in production, the government through the Ministry of Food and Agriculture has what we call the Ghana Grains and Legumes Board. It has very important purpose because you understand that it's an important contribution to livelihoods. The main aim is that they are supposed to be in charge of production of foundation seeds of cereals and legumes so that it can be accessible to farmers across board. Also, production and supply of vegetatively propagated planting materials in this sort of context, and these are done with other agencies, then provision of agro-processing services, then also the management of Farmers Certified Seeds and the National Seed Security Stocks. This board is very important because the government understands the importance of this produce or these products for national food security and also livelihood systems.

In Malawi, my colleagues and I came up with this graph to highlight the most important legume that is cultivated in a country. And we can highlight groundnuts as the most important leguminous crop, similar to Ghana. Groundnuts is very important especially in meeting Malawian rural households' food and income needs. Pigeonpea is also highly cultivated. The trends in production for these crops are shown on the graph with data from 2014 FAOSTATS.

With reference to Guinea, groundnuts is also a very important legume that is produced. That's the trend that we found across the whole of Africa, and then if you compare it to pulses overall, groundnut actually weighs highly when it is compared to all other pulses that are grown in Guinea. If you also want to put it into context and look at the production of groundnut with respect to in comparison with other food crops, groundnut doesn't really rank highly. You can see from here that groundnut is not really highly ranked but it's normal to food crops like maize, fonio and rice are very important in Guinea, but groundnuts still contribute significantly to household diet.

I want to highlight some of the direct and indirect contributions that these legumes made across Africa as far as livelihood systems are concerned. So, peanut or groundnut, as we know, is very important for food, and some of the photos here, this is made in different countries. So, in Ghana, you can also look at this one from Guinea that was highlighted, and like I said, women play an important role in the cultivation, production, and processing of these sort of legumes, most of the time manually done. Of course, it contributes a lot to income. In Northern Ghana, for instance, where I do a lot of research in rural northern Ghana, groundnut production has been fund to be very important because it's one of the main crops that fetches a lot of income for households and also because they don't need to apply a lot of fertilizer and is often cultivated even during the long dry season. It's also an important commercial crop in some countries, especially like Guinea, and then also groundnut is also an important ingredient for some other forms of food as I highlighted earlier on. In terms of the use of byproduct for groundnut, we wanted to say that in many households in the rural parts of Africa, actually groundnut byproduct is used for soap and it's something that contributes a lot to some households who do not have other sources or diversified sources of income. So, they make soap for the household use and other things like that. Groundnut oil is also very important for household food security. Then, we also have it's been used for fertilizer, some of the byproducts are very important for fertilizer and mulch.

So, in terms of challenges, I want to highlight much of what I have here in my presentation have being talked about in the earlier presentations not just in Africa but in India and South America. It tells of the common issues we face. But in Africa, more specifically, I think I have mentioned that the demand for legumes for diverse uses especially consumption is actually greater than supply. That is something that we have in terms of many people across Sub-Saharan Africa not being able to have access to leguminous crops for various reasons. Other challenges include poor quality of seeds and issues of low adoption. Underutilization of indigenous varieties is also very common because big companies or multinational companies like Monsanto introduce some of the hybrid varieties and some of these ones can have some side effects on the soil. Others may be too expensive to acquire. Some of them also require the use of a lot of fertilizer which people might not be able to afford.

Then, there's also unclear and undefined policies and institutions on legumes as a crop. This is one of the biggest challenges that we face in Africa when it comes to production of not just legumes but in most of our food crops, because even though Ministry of Food and Agriculture does a lot of work across the countries in Africa, there are a lot of challenges that they face when it comes to directly providing support like input or extension services to farmers to produce these crops. So, sometimes change in trends or change in knowledge of the use of some of these crops is a big problem. We can highlight extension services because one of the biggest challenges when it comes to production of legumes in Africa, there is less extension available to many people. Then, I will talk about climate change which I highlighted early on as a big impact on that.

These photos here are from my research field in Northern Ghana as well as from some published work. So, I come across a lot of these when I am doing my research with low crop farmers. Droughts impacting on soybean production is a huge issue in many parts of Northern Ghana. Then, I want to talk about *Striga* effect and also *Alectra.* These sorts of prostrate weeds are very, very harmful to most of the crops that are grown, and a lot of farmers do not have enough money to be able to buy pesticides which also has its own effect. So, you find the whole acre of legumes being destroyed by these biophysical challenges. In Ghana, the Savanna Agricultural Research Institute (SARI) is working hard to research on improved legumes for use by poor rural farmers.

In terms of opportunities, I am also happy to hear most of the presentations that were made by the Director from ICRISAT and he talked about some of the genomes and some of the many attempts that have been made to promote different varieties and that is something that I am excited about. I think most of the information available shows that there is a lot of work ongoing when it comes to promotion and also investments into that. So, in Northern Ghana, for instance, there is this project that MEDA is running in collaboration with the Canadian Development Agency, it's called GROW, Greater Rural Opportunity for Women, where women are being encouraged to grow soybean and are being aided with ready market. This approach is helping boost not just their income but also their diets as a whole. These are very important things that I think we should keep promoting across board.

Legumes can also be critical as far as the integration of crops and animal production is concerned. I highlight the ways that some of the byproducts can contribute to when it comes to feeding not just animal, but since the animal droppings or cow dung can be used and then processed into some sort of humus and fertilizer. That can be processed. So, that whole cycle is very important and it should be encouraged. There is also the opportunity for using community knowledge and also using the local knowledge to promote people's awareness of the importance of – instead of always using knowledge systems that are maybe more friendly to people. So, this is important in many ways.

There's a few things that my team would like to highlight in this presentation when it comes to recommendation and way forward. There is an issue of legume breeding programs which aims to adopt and improve and use widely tested under-utilized varieties, and like I said, it's very good to keep up with this sort of ongoing activities. We can also highlight the issue of increase communication between breeders, researches, extension service, and farmers. My personal experience in Northern Ghana says that it's very important to have most access to extension and advisory services. That's one of the biggest complaint by local farmers in Northern Ghana, and I think that is something that needs a lot of attention. Enhancing of market information flow and value chain coordination to enable farmers respond to market signals and demands is recommended. This is also a very big challenge, and I think that is important because we realized that most of the time value is not added to the produce that is done that is done by local people. So, we need to look at the value chain of most of these important legumes and then see how we can support farmers or give them the needed knowledge to enhance their productivity and also provide market access for them so that you can have that sort of desire to continue production. Enhancing public-private partnership is important and in this sense, even research institutions, universities or other relevant entities need to collaborate. We should out ways to engage the local people at the inception of research projects, also find more practical ways to lead their research results to be practical and also be send to the local communities.

So, as a whole, these are the things that we wanted to share in this presentation. I hope I have been able to at least make some relevant inputs to this symposium. Thank you.

Chair Yamamoto
Thank you very much. So, the floor is open. Are there any questions or comments on his presentation? Yes, please.

Male Questioner
Thank you for very informative presentation. I would like to ask perspective of production of soybean as a food crop. So, you mentioned about GROW Africa project, they are concerned about this, but I want to know your perspective.

Dr. Yaw Agyeman Boafo
Okay. All right. Thank you very much. In the last 5 years, I have had opportunity to work with farmers in Northern Ghana, and they talk about the continued decline of the fertility of their soil, meaning that most of their staple food crops that they grow like maize and millet are not as productive as it was in the past. But at the same time, we are talking about soybean as a crop that does very well even within that sort of poor and infertile environment. So, the hope is that the GROW project need to be sustainable. I think it is very important because a lot of women consider the soybean to be a female crop, something that they can easily produce without having access to fertile land. In many parts of Africa, women are also limited in terms of the access to the “good land”, due social inhibitions and hierarchical systems So, I think it is very important that projects like GROW are active in this direction. I hope that this project can continue to promote such activities as it has the potential to help improve livelihood and food security of households.

Chair Yamamoto
Thank you very much. Are there questions or comments? Dr. Boubacar Balde, do you have any additional information or comments as one of the co-authors, if you have. Just a moment, please use the microphone.

Dr. Boubacar Balde
So, as Dr. Yaw mentioned earlier that our research relies purely on secondary data, so we don’t have much to tell about primary data. So, if any questions, we would like to answer. But at the moment, I don’t have any comment to add.

Chair Yamamoto
Okay, thank you very much. Are there any questions or comments? Okay. Thank you very much, Yaw.

Dr. Yaw Agyeman Boafo
Thank you, Yamamoto,-san.

NUTRITION IMPROVEMENT OF CHILDREN IN AFRICA USING SOYBEAN AS A MAJOR PROTEIN SOURCE

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YASUHIKO TORIDE joined Ajinomoto Co., Inc. in 1981. He was involved in the business of amino acids for animal feed and led studies on nutrition improvement with amino acid (lysine) fortification in rural communities in developing countries including China, Syria and Ghana. From 2005 to 2009, he worked at Ajinomoto Europe in France where he was in charge of R&D in Europe. He assumed his current post at R&D Planning Department in 2009 and has been directing nutrition improvement projects in developing countries including Ghana, Malawi and India. He earned his Ph.D. in Agricultural Chemistry from the University of Tokyo. His current interest is to establish a sustainable business for nutrition improvement in developing countries while forming strategic partnerships with various social sectors.

ABSTRACT

Soybean is a key ingredient for the nutrition improvement of children in Africa because it is locally available in many countries and rich in essential nutrients such as protein and fat. The following two examples of fortified foods with soybean as the main protein source will be presented for the discussion.

1) Fortified complementary food supplement in Ghana

In Ghana, the traditional complementary food is fermented corn porridge with sugar called “koko”. Since it is composed of only corn and sugar, it does not contain sufficient amount of protein and micronutrients for the growth of weaning children. The insufficient supply of protein/amino acids and micronutrients is considered to be the cause of malnutrition problems such as stunting and anemia. Complementary food supplements using locally available soybean, amino acid (lysine), sugar, palm oil, and micronutrients were formulated and tested for its nutritional efficacy. The delivery models for providing nutritional supplements and its ability to reach the target population were also studied.

2) “Ready to Use therapeutic Food” for the treatment of severe acute malnutrition

Currently, Ready to Use Therapeutic Food (RUTF), composed of milk protein and peanut as main ingredients, is widely used for the treatment of severe acute malnutrition. The innovative formulation of RUTF using soybean as the main protein source and supplemented with amino acids was developed and tested for its efficacy.

In both cases, the use of amino acids to improve the quality of the protein is key to achieving good efficacy as a food product for nutrition improvement.

KEYWORDS

Nutrition, Children, Soybean, Amino Acid, Africa

REFERENCES

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Eat Well, Live Well. AJINOMOTO.

Nutrition Improvement of Children in Africa Using Soybean as a Major Protein Source

December 2, 2016
Yasuhiko Toride, Ph.D
Executive Professional
Ajinomoto Co., Inc.

1

About Ajinomoto Co., Inc.

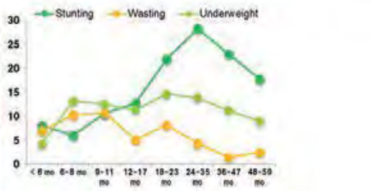
- Established : 1909 in Japan
- Expertise : Food Science and Amino Acid Nutrition
- Net sales : USD 12 billion (2015)

"Eat Well, Live Well."

2

Introducing Nutritional Supplement "KOKO Plus" for Traditional complementary food (fermented corn porridge) in Ghana through Social Business

Traditional Complementary Food "koko"



Improving Nutrition of Children Aged 6 – 24 months
→ Window of Opportunity for Nutrition Improvemen

Nutrition Supplement
"KOKO Plus"
composed of soybean powder,
amino acid (Lysine),
micronutrients and sugar

3

Importance of Protein /Amino acid sources in the formulation of KOKO Plus

Selection of Protein sources

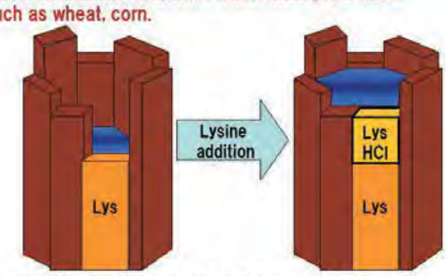
Possible protein sources

Cow pea: locally available but quality / supply is not stable
Ground nut: Difficult to control Aflatoxin contamination
Soybean: locally available, stable quality & supply.
Local production is increasing.
Nutritionally well balanced.

4

Lysine Fortification can improve Protein Quality

Lysine: an essential amino acid most deficient in proteins of cereals such as wheat, corn.



Left: Protein utilization is limited with the deficiency of Lysine
(Water level in the barrel stand for the level of protein utilization.)

Right: By adding small amount of Lysine, the efficiency of protein utilization is improved

Since 1995, Ajinomoto supported studies on Lysine fortification in 5 countries (Pakistan, China, Syria, Bangladesh and Ghana)
Impact of Lysine fortification on the health, nutritional status and growth of children was demonstrated.

5

Formulating KOKO Plus to satisfy WHO recommendation

	Energy (kcal)	Protein (g)	Lysine score	PDCAAS	Utilizable Protein (g)	PE ratio
Recommendation	260 - 270		1	> 0.75 or .80	4 – 6.5	6 - 10
KOKO (Maize + Sugar)	277	3.77	0.46	0.39	1.47	2.12
KOKO + KOKO Plus	231	6.91	1	0.85	5.90	10.2

6

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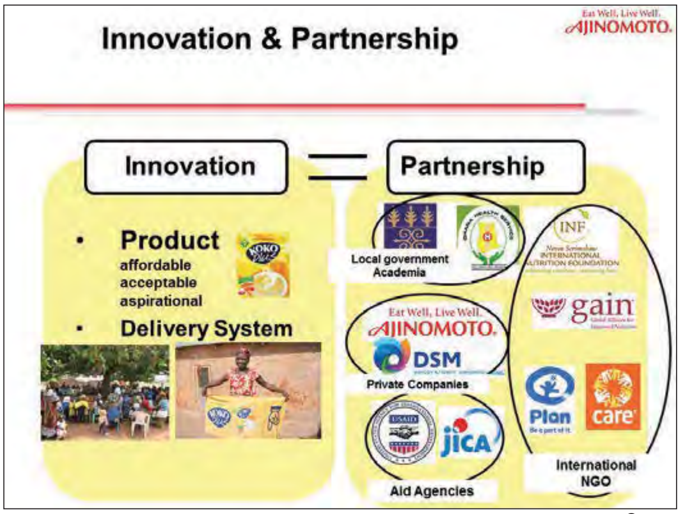

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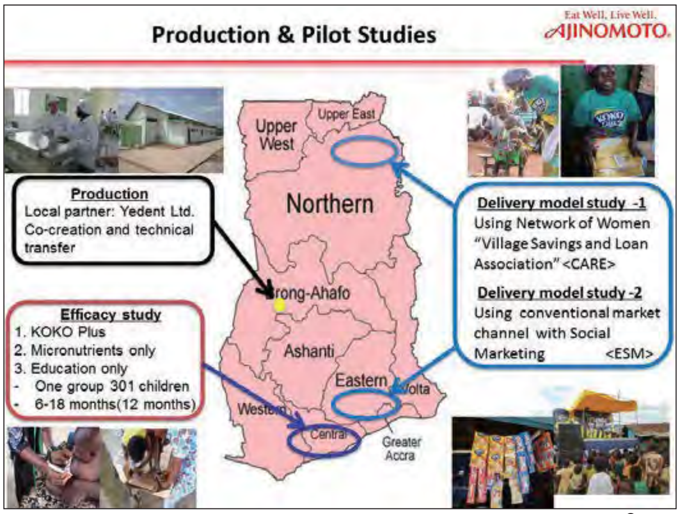

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Summary of Nutritional Efficacy Study

1. KOKO Plus, the combination of Protein (amino acids) and Micronutrients, is most effective in

① preventing stunting
→ Comparison of Height for Age Z Score using a model analysis assuming 100 % delivery rate

② preventing Anemia
→ Comparison of Hemoglobin level

③ preventing infection
→ Comparison of acute infection

10

10

confidential

Development of RUTF (Ready to Use Therapeutic Food)

What is RUTF?

Target	Sever acute malnutrition of children from 6 months to 5 years old.
Treatment	Community based Management of Acute Malnutrition (CMAM) Given for 6~8 weeks (200kcal/kg/day) in the community
Distribution	UNICEF and NGO buy it from suppliers and local governments distribute it.
Current product	Only Milk-peanut type is approved. This product, Plumpy'Nut® is developed by Nutriset (France). 70% of the product is produced in EU and USA
Market	Market size is 35000MT/y in 2015 (10% of potential market).

Plumpy'Nut

UNICEF welcome new type of RUTF which satisfy the following conditions;
1) Evidence of nutritional effect, 2) Safey,3) Reasonable price, 4) local production
Current RUTF ingredients: Milk= expensive, Peanuts paste=risk of aflatoxin

Ajinomoto and Valid Nutrition collaborate to develop new Innovative RUTF using locally grown ingredients (soy, maize, sorghum), low risk of aflatoxin (no use peanut) and good protein quality with supplemented amino acids, and good texture.

*Valid nutrition established idea of RUTF treatment to improve severe acute malnutrition 11

11

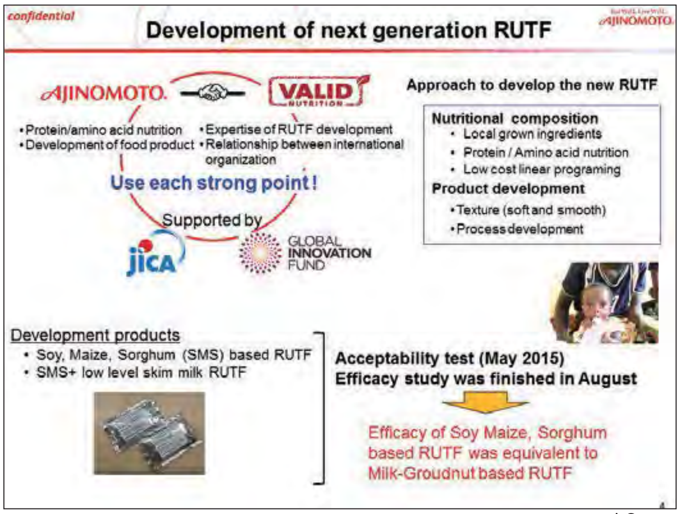
Problems of Protein sources in the Current RUTF formulation

Milk Protein
- expensive in Africa
- Lactose intolerance in African children
  → Cause diarrhea

Ground Nut
- Difficult to control Aflatoxin contamination

12

12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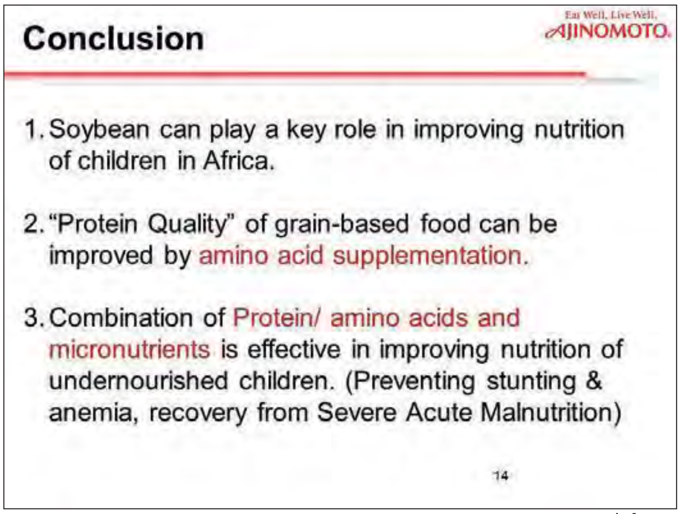
Development of next generation RUTF
AJINOMOTO.
AJINOMOTO.
VALID NUTRITION
•Protein/amino acid nutrition
•Development of food product
•Expertise of RUTF development
•Relationship between international organization
Use each strong point!
Supported by
JICA
GLOBAL INNOVATION FUND
Approach to develop the new RUTF
Nutritional composition
• Local grown ingredients
• Protein / Amino acid nutrition
• Low cost linear programing
Product development
•Texture (soft and smooth)
•Process development
Development products
• Soy, Maize, Sorghum (SMS) based RUTF
• SMS+ low level skim milk RUTF
Acceptability test (May 2015)
Efficacy study was finished in August
Efficacy of Soy Maize, Sorghum based RUTF was equivalent to Milk-Groudnut based RUTF

13


Conclusion
Eat Well, Live Well.
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1. Soybean can play a key role in improving nutrition of children in Africa.
2. "Protein Quality" of grain-based food can be improved by amino acid supplementation.
3. Combination of Protein/ amino acids and micronutrients is effective in improving nutrition of undernourished children. (Preventing stunting & anemia, recovery from Severe Acute Malnutrition)
14

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Chair Yamamoto
The next presentation is ‘Nutrition improvement of children in Africa using soybean as a major protein source’ by Dr. Yasuhiko Toride. Dr. Toride is a Senior Advisor in Ajinomoto Company, Japan. He conducts nutrition improvement projects in developing countries including Ghana, Malawi, and India. So, please give the presentation Dr. Toride.

Dr. Yasuhiko Toride
Thank you very much. My presentation is about ‘Nutrition improvement of children in Africa using soybean as a major protein source.’ Incidentally, my previous speaker talked about situation in Ghana and also Malawi. And I also introduce a project in Ghana and Malawi as an example of using soybean as a major protein source for nutrition improvement.

I belong to Ajinomoto Company which is a food and also amino acid company. Our expertise is food science and amino acid nutrition. So, we believe by applying this expertise, we think we can make unique contribution to nutrition improvement as this motto shows, Eat Well, Live Well.

First, I would like to introduce a project in Ghana, which is to introduce nutrition supplement as a complementary food supplement, which is called KOKO Plus. In Ghana, most commonly used complementary food or weaning food is called Koko, which is made of fermented corn and sugar. Because this porridge is made of only corn and sugar, it is not sufficient in protein, amino acid and also micronutrients like vitamin and mineral. So, that is one of the important reasons for the malnutrition during the weaning period. As this figure shows, from 6 months, the complementary food will be given to the children and especially this stunting (stunting means lower height than average.) increases quite rapidly up to 30% at the age of 2 years old. This is mainly due to the insufficient supply of nutrients during this period. And important point is this stunting is not just low height but also closely related to the development of intellectual capability or the immune system. That means to improve this stunting situation is very important. This period of 6 months to 24 months is very important and this is called window of opportunity for nutrition improvement.

To improve this nutrition situation in this period, we developed nutrition supplement which is called KOKO Plus, which is added to this porridge called Koko. Key composition is roasted soybean powder and amino acid, Lysine, and micronutrients and sugar. Actually because this is made of roasted soybean and also sugar, the taste is exactly same as the traditional Japanese food which is called Kinako. So, it is quite interesting.

When we formulate this KOKO Plus, we have to select protein sources. So, there are several candidates. For instance, cowpea, as several previous speakers explained, cowpea is widely locally available in Ghana, but quality and supply is not so suitable for the commercial production of this type of supplement. Groundnut is also produced in Ghana but the key point is it’s a bit difficult to control Aflatoxin contamination. On the other hand, soybean which is locally available and relatively stable quality and supply and actually Ghanaian government is promoting local production and so we expect bigger production in the future. As you know, that is nutritionally well balanced.

So, we decided to use soybean. And also we use amino acid, Lysine, to improve the protein quality. This figure shows the principle of Lysine fortification. This is called a barrel model, and each piece represent the essential amino acid in the protein. Usually, in the cereal protein, cereal means corn, rice, or wheat, the most deficient amino acid is Lysine. Because the Lysine level is low, the efficiency of protein utilization becomes low. So, this water level shows the protein utilization efficiency. If small amount of Lysine, for example, Lysine hydrochloride, is added to this cereal protein like this, the protein quality becomes higher. In this case, the total protein quality becomes better. This is the principle of Lysine fortification. And we use this principle to improve the protein quality of the product, KOKO Plus.

We formulate this supplement KOKO Plus to satisfy WHO recommendation. For instance, this is the recommended value during the period of 6 months to 24 months. And traditional food which is called Koko is not sufficient in especially utilizable protein, but if we use KOKO Plus instead of sugar to traditional food Koko, this can satisfy utilizable protein requirement of the children. So, this is the key principle, and of course, we also try to satisfy micronutrient requirement by adding micronutrient to the mixture.

The important point is that the taste of the Koko with KOKO Plus should be acceptable for local people, because food culture is quite conservative. If the taste is quite different from the traditional one, they will not accept it. So, we conducted acceptability test in collaboration with the University of Ghana and confirmed that this KOKO Plus can be acceptable for the local people.

For this project, two important factors are innovation and partnership. For the innovation, we have to have a product which is affordable for the local people, including high poverty area and also acceptable in terms of taste and flavor and aspirational, aspirational in this case means that mother feels proud of providing this kind of supplement to their children for better nutrition.

Another challenge is delivery system. We have to establish a delivery system to reach the target population. So, to achieve this, we have a wide range of partnership which includes local government and academia and also partnership with donor agencies like JICA and USAID and also international NGOs.

So far we conducted pilot studies with local production. The local production was done in partnership with local producers which is located around this area, the center of Ghana. Because this area is in fact soybean producing area, so it is easy to get constant supply of soybean in this area. So, we established the production facility in collaboration with a local partner and introduced a production system by transferring technology, experience, also creating together the best production system.

Using the product which is produced from here, we conducted a nutritional efficacy study in central region and we also conducted delivery model studies. We studied systems to deliver this kind of product to the target population in two areas, one in northern part which is very high poverty area in collaboration with international NGOs and another in the eastern region which is close to the capital city Accra by using the conventional market channel with social marketing.

As I explained, we conducted a nutritional efficacy study to demonstrate KOKO Plus can really improve the nutrition of children. So, the key point is KOKO Plus which is a combination of protein/amino acid and micronutrients worked better than micronutrients alone in preventing stunting as shown in the comparison of height for age Z score. We could also show that KOKO Plus was effective in preventing anemia which is caused by iron deficiency by comparing hemoglobin level. We could also show that it was effective in preventing infection by comparing acute infection markers.

Then, I would like to show the second example of the nutrition improvement in Africa, which is in Malawi. The example is development of ready-to-use therapeutic food. This ready-to-use therapeutic food is used to treat children of severe acute malnutrition from 6 months to 5 years old. This severe acute malnutrition means that without treatment they may not be able to survive. So, right now, UNICEF is promoting this ready-to-use therapeutic food, which is a kind of complete nutrition food to treat severe acute malnutrition. Currently, this RUTF, ready-to-use therapeutic food is produced mainly in France, and it is composed of milk protein and peanuts. Our challenge is to develop a formulation which is safe and with a reasonable price. And a key issue is whether we can produce it locally in Africa. The current formulation use milk protein and groundnut as protein sources. But there are problems about milk protein. It is expensive in Africa and it’s not easy to get supply. It is also well known that many of the African children are lactose intolerant, that means the milk protein causes diarrhea. And it cannot be used for the treatment of severe acute malnutrition.

There is a problem with another protein source, groundnut, which is difficulty in controlling Aflatoxin contamination. So, that’s why we tried to develop innovative formulation by using soybean, maize, and sorghum as raw material, which are locally available ingredients.

This project was done in collaboration with VALID Nutrition which is Irish NPO, which has been involved in RUTF production in Malawi for many years. So, by combining expertise of Ajinomoto, especially the amino acid nutrition expertise and their experience in RUTF, we tried to develop the innovative formulation for RUTF. This project was supported by JICA and also Global Innovation Fund. So far we could develop the formulation with soy, maize, and sorghum. One of the key points in the product development is we supplement several amino acids to improve the protein quality of soy maize sorghum formulation to make it comparable with the current milk-based formulation. We already completed acceptability test to confirm that taste of this new formulation is acceptable for the children in Malawi. Also, we conducted an efficacy study to confirm the recovery of the children from severe acute malnutrition. So far, we could confirm the efficacy of the RUTF with soy, maize, sorghum supplemented with amino acids was almost equivalent to the current formulation which is milk groundnut based RUTF.

This is the conclusion of my presentation today. First, the soybean in Africa can play a key role in improving nutrition of children because of the stable production and quality, and also we expect production of soybean in Africa will increase in the future. So, the soybean will play a key role in improving nutrition.

Then, when we think about protein source, protein quality is decided by amino acid balance, so protein quality of grain-based food can be improved by amino acid supplementation as shown in our study in Ghana and also Malawi. As for the nutrition improvement, the key message is this combination of protein, amino acid and micronutrient is effective in improving nutrition of malnourished children, especially preventing stunting, anemia, and recovery from severe acute malnutrition. Thank you very much for the attention.

Chair Yamamoto
Thank you very much. Dr. Toride introduced the trials to improve the children's nutrition in Africa using the KOKO Plus and also the potential of the new type of RUTF like the soy, maize, sorghum constituent. So, are there any questions or comments on his presentation? Yes, please.

Male Questioner
Thank you. I have one interest about your amino acid supplement. Is this amino acid supplement from legume or other crops or what is the donor source? Is it shareable or secret?

Dr. Yasuhiko Toride
Actually, Ajinomoto is a leading producer of amino acid itself by using fermentation technology, biotechnology. So, each amino acid is produced by fermentation or biotechnology. That purified amino acid is added to the protein. So, it's not vegetable or animal source protein. It's pure free amino acid.

Chair Yamamoto
Okay? Any other questions or comments? Yes, please.

Male Questioner
Thank you for nice contribution to nutrition in Africa. My question is that I may have missed hearing, what type of micronutrient is added, not only Lysine, also micronutrient you mentioned, what type of that?

Dr. Yasuhiko Toride
Micronutrient is added as a micronutrient mixture which is vitamin and mineral mixture. Especially in this case, mineral like iron or zinc are quite important as minerals. As for vitamin, vitamin A, vitamin B, and so on are quite important.

Male Questioner
The cost to produce such additions is very high or small?

Dr. Yasuhiko Toride
Not small, but to satisfy the micronutrient requirement, if we use only locally available ingredients, the cost will become much higher. So, in this case, to use industrially produced micronutrients or amino acid is the cost effective way to satisfy the requirement of children.

Chair Yamamoto
Any other questions or comments? Yes, please.

Female Questioner
It is very interesting to have the information about this kind of challenges to eradicate the severe acute malnutrition. My question is very simple and just from interest but how much does it cost for the moment as unit price to produce this kind of package and then of course, this can be used in the aid project or something, but for the further dissemination and utilization by the local people, how is the target price you are…?

Dr. Yasuhiko Toride
Okay. So, in the first case in Ghana, actually we plan to distribute it as a commercial product or in a commercial channel. In this case, we try to distribute it at the cost of around 10 US cents or 10 yen per package, which we believe is within affordable price range for most of the Ghanaian people. In the case of the RUTF, ready-to-use therapeutic food for severe acute malnutrition treatment, the cost is a bit higher, which is 30-40 cents per

package, but this is not what we call B to C business. We plan to supply it to UNICEF. That means UNICEF will buy it and distribute it through the local government network.

Chair Yamamoto
Thank you very much. Okay, the last question or comments, please. Yes.

Male Questioner
If UNICEF buys and distributes to the mothers, how sustainable is this going to be if for any reason UNICEF withdraws from buying, what is the next target population?

Dr. Yasuhiko Toride
Actually, for severe acute malnutrition, it is very difficult to ask children of severe acute malnutrition to bear the cost. That's why it has to depend on the donors' money like UNICEF. It is almost impossible to distribute it through market channel. Of course, as you say that whether it is sustainable or not depends on how we recognize the importance of treating severe acute malnutrition because without this treatment these children will die. So, it is quite urgent issue, so why not support this from donors' money? That's I think the principle for this RUTF.

Chair Yamamoto
Thank you very much Dr. Toride. It's a very interesting presentation. Thank you.

BEANS & PULSES IN THE WORLD

Kiyomi Hasegawa

Beniyabis, Beniya Hasegawa Store
beniyahasegawa@gmail.com (Japan)

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KIYOMI HASEGAWA graduated from Hosei University and worked at Seibu Department Store. After leaving Seibu, she founded Beniyabis (Beniya Hasegawa Store) in Yokohama in 2001. She currently serves as president of the company. Her goal is to help sell local beans, promote awareness of regional dishes, and do research on local beans in relation to organic agriculture, traditional dishes, and the lifestyles of small scale farmers that have been passed down through generations.

ABSTRACT

Beans & pulses (hereinafter called “beans”) are among the most important staple foods in the world, and they are indispensable especially in developing countries. In Japan, soybean and Adzuki (red mung bean) are consumed in everyday life, especially soybean, which is rich in protein and made more nutritious through fermentation. Natto, miso, and soy sauce are the most typical and well known fermented soybean products.

Landrace soybean/bean refers to bean crops grown from seeds that have been gathered locally. There are between 10,000 to 100,000 kinds in various parts of Japan. In the past, soybean was traditionally called “Azemame” (ridge beans) because it was cultivated for consumption in the ridges between ricefields. Good nutritional balance was therefore inevitable as essential amino acids are consumed by eating rice and soybean together. However, the mechanization of agriculture has also reduced the Azemame landscape and scenery in Japan. This explains why landrace bean is closely associated with traditional farmhouse meals.

There are approximately 20,000 species of *Leguminosae*, and it is estimated that there are 80 edible types throughout the world. Among these, 30 are classified as commercially and economically important.

The place of origin varies according to the bean type, and customs and traditional behaviors surrounding eating can still be observed in regions throughout the world.

I have been researching beans (landrace, wild bean and commercial bean) around the world since 2012 and I have visited 43 countries. My purpose for visiting overseas is to conduct research on beans, particularly landrace species, local and traditional recipes, and the lifestyle of small scale farmers in each country. I cover 3 themes with my research: First, I explore the origin of the beans (adzuki bean, soy bean, common bean, fava bean, chick pea and others) and I examine the beans (landrace bean including improved varieties); Second, I visit small scale farmers or local typical households to see how they produce beans for sale and consumption, and to observe traditional cuisine preparations and bean cooking demonstrations. Third, I conduct interviews to gather anecdotes and backgrounds behind the recipes, especially in relation to special occasions. For example, we have a recipe for Kuromame (black soybeans) which is made for the New Year. My interview targets are as follows:

1. Research institutions for beans and grains, NPOs, businesses
2. Typical households
3. Restaurants (family-run, small eateries) and organic markets (outdoor and indoor), organic shops etc.

KEYWORDS

landrace, improved bean, commercial bean, wild bean, traditional recipes, small scale farmers,

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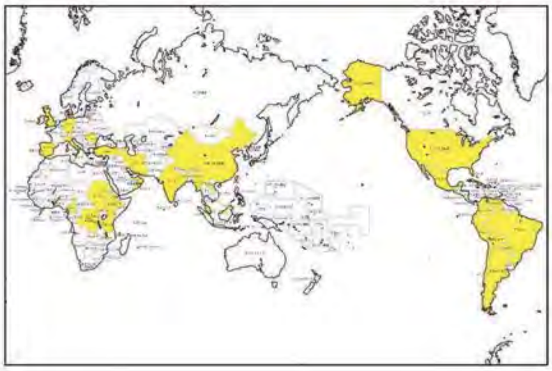
世界の豆事情

Beans&pulses in the world

べにや長谷川商店　長谷川清美

Beniyahasegawa store ,Kiyomi Hasegawa

1



訪問国

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Country visited　　43 countries

July ～Aug 2012	March～April 2013	July～ September 2013	July～ September 2014	July～ September 2015	June～ September 2016
Portugal	US	Myanmar	China	Taiwan	UA
Bolivia	Mexico	Malaysia	Mexico	Laos	Cuba
Peru	Colombia	UK	Brazil	Myanmar	Mexico
	Guatemala	Malawi	Colombia	Italy	Ecuador
	Nicaragua	Kenya	Turkey	Serbia	Colombia
	El Salvador	Tanzania	Iran	Bolivia	Argentina
		Rwanda	Lebanon	Paraguay	Congo
		Ethiopia	Cyprus	Brazil	Cameroon
		Spain	Sudan	Chile	Benin
		Italy	Italy	Peru	Oman
		Germany		Colombia	Azerbaijan
				Venezuela	India
				UAE	
3 countries	6 countries	11 countries	10 countries	13 countries	12 countries

3

取材目的とテーマ

Purpose and topics of my visit oversea

◆(小豆、大豆、いんげん、そら豆、ひよこ豆などの)豆の原産地と考えられている場所を訪ね、その土地でつくられている在来の豆を調べる。

to visit place considered to be origin of the beans (azuki bean, soybean, common bean, fava bean, chick pea and so on) and to examine the land race species, local beans.

◆在来の豆とその生産者(なるべく有機農家)、各地の伝統料理(特に豆料理)のリサーチ

Research in beans of land race species and local and traditional recipes and small scales farmer, preferably organic farmer

※在来の豆「land race species, local bean」

在来とは自給用に自家採取で数十年つないでいる豆としているが、商用の栽培種も含まれる。

'land race species' 'local beans' refer to crops grown from seeds that were home gathered, but commercial beans are included.

4

豆料理(特に家庭料理、郷土料理、伝統料理)のリサーチについて

research in recipes for cooking beans (especially home cooking, local cuisine, and traditional cuisine)

◆実際に一般家庭に訪問し、豆をつかった料理のデモンストレーションを拝見する。

◆料理にまつわるエピソードや背景,特に行事との関連をみる。

例)日本のお正月料理の黒豆

・to visit small scaled farmer or local typical households to have the cooking demonstration for beans or traditional cuisine by them and see their beans production for sale and their consumption.

・to learn various episodes and backgrounds behind the recipes, especially in relation with special occasions.

For example we have a recipe for Kuromame which is made for the New Year, beans cuisine for festival something like that.

5

地域性

locality

◆都会と農村の食の違い

Difference in urban and rural food

◆地域性(海岸、山間、乾燥地帯など)

Locality (coastal, mountain, arid areas)

6

その他
and so on

◆日常の暮らしや農業にまつわる農村での伝統的慣習
Traditional practice which is related to daily life in the rural area

◆生物多様性にも関連した農業以外の環境分野でのリサーチ
research in non-agriculture areas such as environment in relation to biodiversity.

7

取材対象
Interview targets

1、一般家庭(農村、都市)
Typical household

2、飲食店(家族経営など小規模な店)、市場、スーパーマーケット、オーガニックショップ
restaurants (preferably family run, small eateries) and organic outside or inside market, supper market, organic shop etc.

3、CIATなど豆や穀物の研究機関、NPO、企業
Research institutions for beans and grains, NPO, businesses

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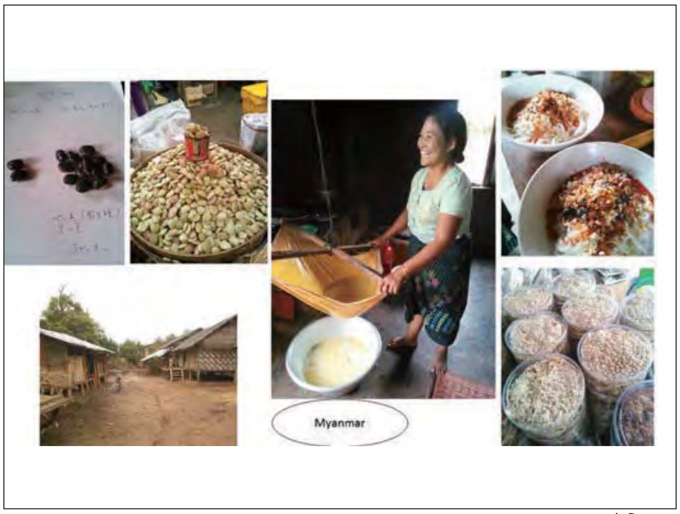

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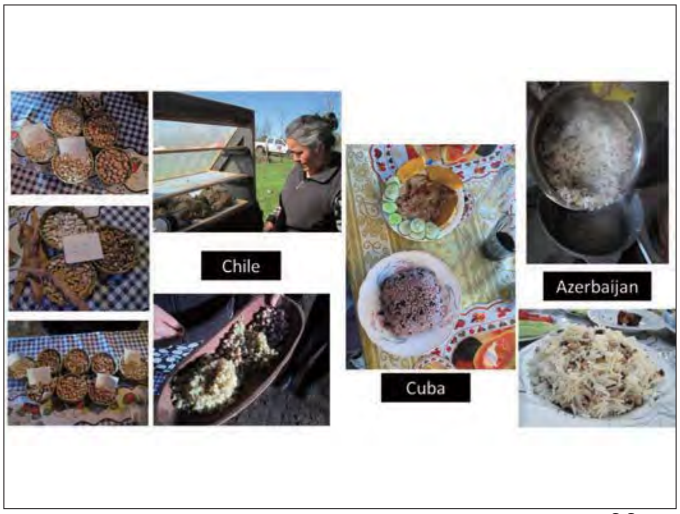

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Chair Yamamoto
The last topic of Session 3 is ‘Pulses and beans in the world’ by Ms. Kiyomi Hasegawa. Ms. Hasegawa is the President of Beniyabis, Beniya Hasegawa Store which is the family-owned trading company of various local beans. She is interested in variety of beans, food culture and livelihood of small scale farmers, and this presentation is made by the Japanese language, so please ready and set your earphone when you need. Dr. Hasegawa, please.

Ms. Kiyomi Hasegawa
Good afternoon, ladies and gentlemen. Very nice to meet you all. My name is Hasegawa from Beniya Hasegawa Store. My company is headquartered at Hokkaido area alongside the Okhotsk sea, and our town is alongside the sea and about 90 years ago, my grandfather started a general bean store and mainly dealing with the local farmers and we started the business back then as a family business. We have been dealing with the local beans in the neighborhood basically in Hokkaido. Therefore, the mission of our store is to distribute and eat and support the local beans culture in the local area. So, I think when we apply this culture to the world, I have started to investigate into the local beans around the world, how they are used in cooking, how the beans are supporting the lives of the people. So, I am interested in this particular topic and I have been traveling all around the world.

The yellow areas are the countries where I have actually visited. In the South America for the last 5 years, I was able to visit almost all of the South American countries, particularly in regard to the common beans. Well, the Andes Mountain actually seems to be considered to be an origin of many beans and therefore my journey was focused around the South American area. Since 2012 to 2016, I was able to take visit of a total of 43 countries so far.

Now, the objectives and themes of my interviews and the visits are as follows: Well, I am organizing cooking classes and I am particularly specialized in bean dishes and related culture and the living of the people and also broadly speaking I am very much interested in the traditional farm recipes as well. When we visit the areas that are considered to be the origin of the seeds, first I need to look into the particular local beans in that particular area, and on top of that, I will communicate with the organic farmers in that particular area, and I want to respect the small lot farmers and therefore I am mostly researched into the small scale farmers in the traditional origin of these beans. In many countries, it seems that what we call land raised species and local beans and all these names are assigned for the beans originated in that area, but definition in my opinion is that the crops need to be grown from the seeds that were home gathered. So, there are self-seeds growing that is happening in the local market, and actually back in July this year, I have published a book called ‘Handbook of the Japanese Beans’ and I didn’t include any commercial cultivars and I only covered the land raised or the local beans of Japan, and also in terms of the recipes, I mostly highlighted the traditional recipes maintained and kept at the farmhouses around Japan.

I usually visited the farmhouses and the local farmers. What I particularly believe important is the relatively senior households, over 60 years old and so forth, where they are familiarized themselves with a traditional farm cooking on their own and they are well versed in the traditional cooking ways. I ask them to show the demonstration of the cooking which they are using the beans. And also I investigate into the events where it is relevant to such cuisine or the dishes using the beans. Also, I am interested in differences between urban and rural food and also the geographical differences, for example depending on whether the area is coastal, mountainous, or the arid areas, perhaps the type of dishes is different and I am looking into these localities as well.

On top of that, it is not just the traditional dishes, but also there are more traditional practice in not just cooking and the farming area. And also when we start to look into the cooking and also seeds and beans, I always come across with the environmental issues such as how to retain biodiversity and so forth. So, these are also the research subjects as well.

The interviews for my research were usually the typical households as well as the restaurants who are not a part of the chain restaurants, rather restaurants which were run by the family and providing the foods as organic as possible without using the chemical spices, and CIAT in Columbia or other institutions such as gene banks or other crops research institutes and NPO and sometimes corporations are the targets of my interviews.

These are excerpts from my book published in July titled, ‘The Handbook for Beans in Japan.’ And a total of 185 species of the beans are now included in my book. So, one of the example is in the Hiroshima Prefecture, Western Japan, I visited her house to learn about the way she cooks and this is adzuki beans but this is called *gukineburi*. This is the bean home gathered over 70 years and *gukineburi* is always used in adzuki bean rice. Also, it is in the form of cakes and sweetened and used in the confectionary as well.

Another example on the right is the village called Hishima which is actually an island in Ehime Prefecture, Western Japan, and in the name of the *bunzu* bean and again this is sort of an adzuki bean and used in the red bean soup and so forth.

This is an example from Myanmar. The chickpea is quite often used in the dishes, particularly the germinated common beans. So, this is a germinated version of the common beans. And then stirred, boiled version of the germinated common bean is quite often used for their dish. This is they called *rapei*, the dried tea leaves are made into a pickle. So, pickled tea leaves are put together with the fried beans and on far left, this is the chickpea grinded and then the grounded chickpea is now made into a sort of a tofu like cake. This is a noodle, rice noodle and this is combined with the starch from the chickpea and also ground sesame as well. Now, this is a tofu like chickpea product and this lady cooked this tofu and they have a family business of creating this type of bean cake, and also using powder of groundnut and using the flower of chickpea, they were producing such foods. This is a rice cake per se but with the chickpea flowers. Again, this is the chickpea processing factory per se. This is more of the family factory that they have.

On the right, the lower one is that after making tofu like lower one and then they usually fry such tofu so that they can enjoy it in the form of the snacks. So, once the tofu was cooled down and then they fried and cooled down again and eating as a snack. And then after grinding the chickpea and then put into water for a night.

Here is again Myanmar and they did a demonstration for me for their cooking. When you visit the Southeast Asian countries such as Myanmar, you will see the soybeans called *shanpepo* or *peposhi*. There are so many variations in the name where the fermented soybeans were made into something like a Natto or miso or soy sauce and then they are sold in storefront. And then usually the powders were made into a cake and there was crushed once again and then put together with spices or meat or anything else and then usually they eat when they put together with rice, and then that’s a part of their main cuisine cooking for their day-to-day life.

I have so many slides regarding Myanmar, but this is another case. I asked a family to show me the variations of the beans that they eat day by day and this is the cowpea and then raw cowpea were grounded and then put together with chili or other seasonings and they are eating as such. And also there is steamed pea and then also this is bitter pea and I was able to see lot of this kind.

I am not sure what kind of the beans is this, however they are picking seeds at home so this is self-seeding products.

These are the examples from Italy, Sardinia. Of course, this is an island of Italy and Myanmar and all these are the local beans I have found in this area. In Laos, I think this is rice beans, but there are so many different colors of the beans put into one pot and they were eating as such. Also, this is a part of the slow food certified bean near lake Trasimeno in Italy. In a single pod, many colors of the beans are observed, and when it comes to the local beans, it is quite often that the many colored beans actually coexist in a pod.

This is the example of Bolivia, and near the lake Titicaca, the pea and the common pea were observed like this, and this grandma is aged 82 years old and they are separating the beans from the pods.

Again, this is the example of Bolivia, and this is how they eat Tarwi. This is a strong bitterness in alkaloid and therefore they need to put these dried beans into a river for a week or two weeks and then after that they need to boil and then they will sell. And after that they will dry out the beans again and then they will store for a long time. Particularly the alkaloid Tarwi is also used as expelling worms from the human beans.

And then here again is example of Bolivia and also from Mexico, you will see something like a hamburger. This is something that a black common pea is now grounded and put into a paste per se. And then this is turned into a hamburger and that was quite often observed in the lunchtime. And then in Cuba, there are NGO served as a gene bank and there are the sisters who were operating the NGO.

This is from Mexico. This is called *mani* from the Maya tribes, and this is one of the cuisines that they have, and this is called *tamalu* with the beans.

And then this example, this is a Venezuela *karoutaneguro*, the black pea and avocado soup, and this is actually something that I found in an urban restaurant and presentation of this dish was just superb.

This is a Cuban dish, and also something like a red bean rice and this is called corn bean and that's how they use it. This is the ridge bean and then Japanese version is on at the bottom, and also one in Benin and Ecuador and both of them were the wood beans and then usually with beans are grown in order to demark the border alongside the ridge and Benin and Ecuador are using wood beans to be planted alongside the ridge as common practices.

Then, this is Peru's gene bank and also another example is Bolivia. This is the wild bean and this is the photo from a lake, Titicaca and this is one of the highway.

This photo is from India and also Argentina. There were black bean and white bean and then there are locust bean in white and black and when people got cold, usually the soup of the locust bean is used. Lentils was mentioned in the earlier presentation, however this is considered to be a vegetable and that's how they eat in the local market, and this is like mustard and this is full of mustard and they were eating like this. So, this is just from Benin.

The next is Burkina Faso and Ethiopia. On the left, you will see Nigeria *akara*, the cowpea in Burkina Faso, so donut made out of cowpea were quite common in Western part of the Africa.

Now, something similar to Natto is also found in Benin and Burkina Faso as well. In Benin, this is called *afiti* but in Burkina Faso, this is called locus bean, and process of how they are making is quite similar. Usually, the seeds out of wood bean are boiled and this soup was really sticky as well. So, this is how they store the beans.

Also, the example from Ecuador. They are just playing a game. There is a traditional game in Ecuador, and here is a man who is biting the bean and when you bite and then if they found a little bit bitter, then they will use for the game. On the other hand, when they bite the bean and if the taste was sweet, then they will use for cooking. Sorry, I used up my time. Thank you very much for your kind attention.

Chair Yamamoto
Now, Ms. Hasegawa has presented on the food culture around beans both in Japan and outside of Japan. Any questions or comments?

Female Questioner
Well, you visited many places so far. What was beyond your imagination? Where there anything that surprised you or any cooking methods that surprised you a lot?

Ms. Kiyomi Hasegawa
Something beyond my imagination was such that something that I believed that should exist both in Japan or perhaps Asia, for example, very sticky Natto type of products using the soybean, Burkina Faso or Benin, I was able to come across with exactly the same ways of producing Natto and the type of beans exist to serve something like Natto and I started to wondering where the method come from. Well, how we eat is that sticky beans are now made into a soup and then they eat as a soup. However, the taste itself is very similar to Natto of Japan, so that was actually a discovery beyond imagination. That was quite interesting. Thank you very much. Anything else?

Female Questioner
Hasegawa-san, you are located in Hokkaido and you are using the network of the small scale farmers and the women network and growing the local seeds and also selling the local beans. Based on your experience, the storage, preservation of the local beans and also utilization of the local species of the beans, what do you think is important, what would be beneficial or profitable for the local people, are there any comments from that point of view?

Ms. Kiyomi Hasegawa

Well, not exactly limited to Japan, but when you go to the farming area in the world, usually, women are the key, women are the breadwinner and women are the workforce, and it is true that in Japan, there are many women's group and agricultural cooperatives within the small villages and communities, those in 60s and 70s, they are actually selling their handmade jam or other products that they sell in the local markets as well. So, product development from a small community, it doesn't have to be as critical as product development. It's something that product which is very good for your health because for example for soybeans, Natto or other fermented products could be produced in small scale as well. So, perhaps younger women as well at the level of very small municipalities or in the small communities, once the small communities start to work, then they will serve for the preservation of the locally traded products, not just limited to the local species. And I think local community would be the best one to preserve that well.

In Japan, we have a wider network of the distribution. However, in overseas, people face with difficulties and apply a distribution in a large area. And still they would have to start earning good profits. So, think about the ways how to overcome that issue, then product development for the small community and usually when it comes to food, women capability will be quite useful. Therefore, network of housewives for example, a group of five of seven or ten is sufficient enough and the empowerment of such small group of women will be quite useful. And perhaps some initiative could start from such local group of people. And at the level of the administration or government or municipalities for example, when I visited Salta of Argentina, municipalities of the town were quite enthusiastic about the women empowerment there and the product development coming out from the neighborhood of Salta and then they started to deliver the products to the local stores in the more urban areas. And I think that empowering the smaller community would actually be beneficial for the empowerment and the profit making of the people around the world.

Chair Yamamoto
Thank you very much, Hasegawa-san. We have finished Session 3. By the three presentations, we were newly aware of the potential and the benefits provided by beans in our life. Thank you very much for your contribution, presentation and discussion. Thank you very much.

Questioner

Session 4

Panel Discussion

Moderators:

Kunihiro Doi, JIRCAS

Satoshi Tobita, JIRCAS

Panelists:

David Bergvinson, ICRISAT

Robert Abaidoo, KNUST, Ghana

Gretchen Neisler, Michigan State University, USA

Moderators: Kunihiro Doi and Satoshi Tobita

Panelists: David Bergvinson, Robert Abaidoo, Gretchen Neisler

Scene on the stage (1)

Scene on the stage (2)

Panel discussion

Panelists

Dr. David Bergvinson, ICRISAT
Dr. Gretchen Neisler, MSU, USA
Dr. Robert Abaidoo, KNUST, Ghana

1

Summary of the previous sessions

- Long-mutual history of legumes and human
  - Domestication & food culture
- Power of legumes/pulses
  - Nutritional value
  - Important roles for sustainable environment
- Research efforts: Potential of legumes/pulses
  - Breeding & genetic enhancement
  - Agronomy & systems diversification
  - Symbiotic N fixation
  - Processing and value addition

2

How legumes and pulses can contribute to SDGs?

3

How research on legumes and pulses can contribute to SDGs?

4

How research on legumes and pulses can contribute to SDGs?

- Impacts (potential contributions to goals)
  - Food and nutrient security → 2, 3
  - Soil health and land sustainability → 12, 13
  - Biodiversity and cropping systems → 15
  - Value addition and poverty alleviation → 1, 8
- Approaches to SDGs
  - Science-based and demand-driven technology innovation
  - Inclusive approach for different regions and societies = Partnership of stakeholders

5

Moderator Doi

Welcome to the panel discussion, final session of this symposium. I will introduce the panelists on the stage, but they have already introduced them, David Bergvinson, Director General of ICRISAT, and Dr. Gretchen Neisler from Michigan University and Robert Abaidoo from Kwame Nkrumah University. And maybe the audience will be afraid about there are no Japanese scientists, don't afraid Dr. Tobita is one of the best legume scientists. He will manage this session. Dr. Tobita, it's yours.

Moderator Tobita

Okay, thank you. Before going in the panel discussion, I want to summarize today's symposium previous sessions. Previous sessions, we had already revisited long and mutual history of legumes and human. This is about domestication and food culture. We have known the power of legumes and pulses like nutritional value and important roles for sustainable environment. We have learned in the previous sessions about research efforts, describing about the potential of legumes and pulses. For example, breeding and genetic enhancement and agronomy and systems diversification and symbiotic nitrogen fixation and processing and value addition.

Today, we would like to propose the theme of the panel discussion as to be Sustainable Development Goals and legumes and pulses. So, it seems a little bit stiff theme but it needs to be discussed here because this year, 2016 is International Year of Pulses, so that's why we are organizing this symposium.

Also, 2016 is also the starting year of efforts of SDGs toward the attainment in 2030. So, in this session, we will discuss about the role of legumes, pulses in SDGs. In other words, how legumes and pulses can contribute to SDGs. JIRCAS is a research institute, so we should be more focused on the research. So, this is a new theme, now the theme is how research on legumes and pulses can contribute to SDGs?

I think these are keys for discussion. One is about impacts. That means potential contribution to global goals. It's something like food and nutrient security. It's contribute to goal 2 and 3. And soil health and land sustainability contributing to the goal 12, 13, and biodiversity and cropping systems is to 15. Value addition and poverty alleviation is number 1 and number 8. Also, we are conscious about the key of this discussion is approaches. I picked up some approaches to SDGs. One is science-based and demand-driven technology innovation, and second is inclusive approach for different regions and different societies, which means the partnership of stakeholders is very, very important.

Sorry for my long introduction. Then, from the panelists, I think all of the panelists are authorities of research and development. So, we would like to have recommendations and ideas of this theme, how research on legumes and pulses can contribute to SDGs. Who will start? David?

Dr. David Bergvinson

Okay. Thank you very much. Contribute towards 11 out of the 17 SDGs if I run through the list. You have mentioned many of them. One I think that's really key and this meeting supports is Goal 17 around partnerships that I think is, we look at the Sustainable Development Goals, they will only be realized country by country, and so we need a roadmap to achieve, one, grain legume self-sufficiency, realizing value addition, and by so doing we bring in women and youth into the agenda for achieving the Sustainable Development Goals, and we articulate, as you mentioned, the demand-driven approach or what are the needs of the country and the farmers within it and if we do that, our research will enjoy higher rates of adoption and impact. So, I think a good list here but I think we can even go farther as far as other Sustainable Development Goals that grain legumes can contribute towards.

Dr. Robert Abaidoo

Thank you David. I want to be a bit more siloed, let me start off, and then just say that for all what we heard today, it's all about legume growth, use, and to be able to grow, produce, and use, the source of the nourishment has to be looked at very critically. So, if I should pick one of these, I will go for issues on soil health and land sustainability. That's the issue with 12 and 13, which by extension what will be the basis for all the rest actually. So, if we don't have a healthy soil, there's no way we are going to have a healthy plant and there's no way you have a use of what has been done. It is unfortunate that in many cases, we look at the above ground product, nice plants, nice seeds, nice colors, but where have these come from, we don't sort of really appreciate it. It is also possible that it's more difficult to carry out soil health research. It takes longer to bring it into the fore. In addition, even growing legumes, it's only recently that we're trying to make additional external inputs. We've always said that grow legumes without fertilizer, grow legumes without nitrogen. Now, we all learned that for legumes to be nutritious, they have to provide all the nutrients, both primary, secondary, and even the micronutrients. So, we may ask the question, where do these come from? Yes, mother soil will give, but for how long? So, for real sustainability, we need to look at how we replenish what's the legumes stick out. It may take us a very long time, but I can say for sure, if we ignore this totally, then none of these issues are going to be achieved, because if we don't have the nutrients in the soil that needs to be taken up by the plant where legumes grow, then after a point, we deprive ourselves of life, because in the ancient Rubrica times we said that all life began from the soil. Do we still believe in that?

Dr. Gretchen Neisler
Thank you very much for the opportunity to participate in this panel. My comments are going to come from a development intervention implementer and also someone who sits within the higher education framework of international development and research, which is in most days a very interesting intersection to be sitting in. I think the first thing that I want to say about how research on legumes and pulses can contribute to Sustainable Development Goals is that we've got to coordinate our efforts better. I cannot say strongly or emphatically enough how important it is that we are not duplicating efforts in this front. And so often we run into each other in the field and we realize that we have been working on some of the same work and toward some of the same end goals. So, I would like my colleagues who are representing funding agencies or part of large institutional systems to please help us to come up with a way to coordinate our work better so that it is more efficient and more effective.

Next, I would like to say that from a research standpoint, it's really important that prior to conducting the science, you know what your end game is and in order to make an impact, a positive impact on Sustainable Development Goals, your science must be relevant, it must be contextual, and it must be reasonable. To measure the scale of your impact or of our work, researchers must have a benchmark to compare their output. This is what we share with our researchers at Michigan State University and we encourage them to do the frontend work to be able to have that comparative metric. Effectiveness of legume research depends on being able to deliver end products that are adopted. You should know going in that sustainable change takes a long time, and sometimes those of us that are implementing interventions are caught in a cycle of a 3-to 5-year project funding window, which is very difficult to impart change in that timeframe.

Scientists cannot stigmatize impact evaluation. They must be willing to use possible failure and setbacks as a driving force for their research development. And I would also include here that it is not a good idea to stigmatize scientists for their failure, but rather how do we fail forward and learn from what it is that we failed on.

Impact assessments allow us to see beyond a single objective and see the whole picture. For example, priorities have long been increased on crop yield, but in some areas, this is not the most valuable feature to farmers. Once there is a realization that the science might have strayed from the end goal, we must redirect and we must be able to redirect in an efficient and effective manner in order for this impact to be realized.

Moderator Tobita
Okay, thank you for the panelists. In the first round, we had recommendations and ideas about our efforts for the SDGs in terms of the legumes and pulses research. So, from the floor, do you have any questions or comments in these recommendations? If any? Okay. Next, I emphasize the approaches of SDGs. One is inclusive approach. Do you have any ideas on the inclusiveness of our research activities to contribute to the SDGs?

Dr. David Bergvinson
As I mentioned, inclusive at multiple levels. First is the government having ownership of the goals. I would remind us that we still don't have the indicators for these goals approved yet, which a year into it is a bit concerning, but having the commitment of the leadership but also as we do our research, as mentioned, making sure it's relevant and contextualized, demand-driven approach, so engaging farmers in the design of technology so it's appropriate for both men and women farmers, also engaging the value chain actors, especially the industry that will create the market for pulses, and I think the other area of inclusiveness is creating awareness among consumers of the environmental footprint our modern food system has, and for us to manage our modern food system in a sustainable manner, especially with regards to water. And clearly, grain legumes will play a very important role for enabling us to live within the ecological boundaries of our planet, which we all share.

Dr. Robert Abaidoo
Yeah, let me guess out that if we consider the fact that the pulses and the grain legumes as old or even older than the human life, which means that the other ones are speaking a particular language, and the language keeps changing, especially the scientists. In what way are we going to speak the language that the farmer on the sand speaks so as to encourage or motivate the adoption. If we include them in identifying the problems, then becomes the problem-based research we've been talking about, but we need to speak to them their language that they understand. So, it's not simply including them, but making them appreciate and understand why you do such a thing, what's the impacts are going to be, why is it that they must adopt what you are sharing with them. If we show them sufficient evidence, why is adoption so low even though the scientists keep publishing, very flourishing, and interesting detail if they understand what we do, you have to modify, come up with soft science language and not sequestrations at all so that they can pick these things easily and run with it.

Moderator Tobita
Robert, is that some specialized, especially for African case, that's the universal case, how do you think this language?

Dr. Robert Abaidoo
Well, I can give you an example. We now call something farmer suffering fatigue. Every one of us will go knock on your doors can you answer some few questions for me, and now some farmers are even more likely to ask you to pay them for their time before they answer your questions. Is that a communication that we should have, is that a collaboration that we should have? So, probably, each one of us is going there at a different time, which they are really tired of us and I believe the same for many other areas as well. Farmers now think that, oh the scientists are just living on us, they get to their project, they come and use us for the – they take statements or they leave for a month and they live better. We go there in our fancy cars and fancy land cruisers rather than in a way probably they look like. So, I think that we need to change the approach, look at better ways of including them in the research process, because if they become tired of the service, we can never trust the answer they give you.

Moderator Tobita
Okay, Gretchen-san, maybe you have experienced in Africa and Latin America or many places. Do you have any different ideas or reasons for societies? How do you think?

Dr. Gretchen Neisler
I think one of the most important things that I have learned is that each place that we go in to, it's important to understand and really wrap your head around what the stakeholder groups look like, what is the historical, political nature around those stakeholders and how have they historically come together and worked together or not. And I think oftentimes what we need to remember is that most of the stakeholders that we are working with do not feel empowered to be change agents in their own context, in their own country. And that is something that needs to begin happening upfront in the work that we're doing with them.

I think the other thing that I have really come to appreciate is how scientists message their work and is that message appropriate for the stakeholder audiences that we are working with. And I can tell you from my experience in doing faculty development work with our researchers that most scientists have an enormous struggle to be able to message their work in a way that's compelling to a multitude of audiences, and this is why we need to lean on structures of cross-disciplinary teams in doing this work, because it cannot just be message and information coming from technical experts. There's got to be a cross-disciplinarity of what it is that we are trying to convey to the stakeholders that we're working with.

Moderator Tobita
Okay. Do we have any comments from the floor? Yes.

Questioner (Dr. Satoru Muranaka)
Thank you very much Chair. My name is Satoru Muranaka from JIRCAS. Let me take this opportunity to thank all speakers to give us comprehensive speeches and presentations, and we really learned a lot. So, just Dr. Neisler mentioned multidisciplinary approaches. We always use, we as scientists, about who is we, we need to really complement and understand everything what the people really need and then we need provide information to convince the users or the beneficiaries to adapt those technology that we can deliver to them like in my experience, in cowpea, there is a bunch of varieties, improved varieties of cowpea is developed but

it's not accepted by the consumers because they are lacking of this necessary preference trait like taste, like seed color, size. Those are really the factors we breeder or scientists didn't have the clear understanding of what the consumer is really liking. Then, the socioeconomic or because of this traditional, historical issues of the beans with the people, we need to have some people who really understand these historical issues to give breeders the information to build a strategy for the breeding. Then, if we work as a team with the multidisciplinary people, then we can have some kind of a comprehensive things we can deliver. So, it might be little bit slightly different from the inclusive but we also need to be inclusive for all of these different regions of this science areas. Thank you.

Moderator Tobita
Any response from the panelists? No? Okay. So, finally, I would like to ask the panelists very shortly about what are the most prioritized research issues to achieve the SDGs in the research of the legumes and pulses. That's the final question to the panelists.

Dr. David Bergvinson
In my mind, it's really around the science of delivering adoption that considers the decision-making process for smallholder farmers in the production of grain legumes, and I think as scientists we often neglect the whole delivery of technology thinking that someone else will do it, and I think if we were to achieve the SDGs in less than 14 years, we better accelerate the delivery and adoption of our technology.

Dr. Gretchen Neisler
I think that my comments are very connected to what was just said. I think it's important to recognize how much has already been accomplished in terms of science and technology in the development of that good work. But I think that what we need to do is spend a little bit of time really focused on how do we take what we currently have at our disposal and bring that to the people, to the end user, and do that in coordination with what it is we are continuing to develop in our labs and through our research programming, because all of us need a little shot in the arm of some positive reinforcement that what we're doing is actually making a difference. And I totally agree with David's comment that if we are going to achieve these goals in 14 years, we need to light a fire under our feet or perhaps other pieces of our anatomy.

Dr. Robert Abaidoo
Let me ask something to David, what have we really done right and what have we really done wrong in the many years that we have done this? Do we have to continue the same way or is this something that we need to do a reevaluation to identify the best direction to go? That's also research entity, and I believe that if we don't get the research path right, then it will be very difficult to achieve this in the 14 years, if we are unable to achieve those earlier ones as indicated.

Moderator Tobita
Okay. Thank you very much. It's almost time to close the panel discussion. We think we had a productive discussion with the panelists and the audience. Now, we recognize that research can enhance the potential of legumes and pulses and this science-based innovation and inclusive approach that is an important key to achieve the SDGs. From the panelists, this path is raised. So, how do we make the environment for the inclusive approach for the scientists' side, that is also a very important key for researchers. Thank you for your cooperation indeed.

Moderator Doi
I should say the words for closing the symposium. We are aware that the legumes have an important role in quality development for human beings. That word "Quality" was last year's symposium theme. So, we eat more legumes for our health and we research more legumes for achievement of SDGs. Then, please join us with a big applause to our excellent panelists. Thank you very much.

Questioner

Closing Remarks

Osamu Koyama

Vice President, JIRCAS

It's 17:10 sharp, so the program went very well, very punctual. Thank you very much for your cooperation. I appreciate this opportunity to deliver a few concluding words and with a little bit more of your patience, I would like to give my impression about today's symposium and our future relating to this symposium.

At JIRCAS, we and agriculture researchers in general fully recognize the importance of leguminous crops in achieving development goals, such as the Sustainable Development Goals, particularly in achieving food and nutrition security. However, this recognition is not so common or so deep particularly among ordinary people in Japan partly because pulses are not major food items in Japan. In this symposium, we focused on the multidimensional roles of these important crops as viewed from different perspectives. We accumulated knowledge on these crops, including crop development history, domestication history, global and regional and local production and consumption situation, biodiversity as well as cutting-edge research results, with some beautiful pictures. All presentations were very interesting to me. Given the limited time we had, I would say that we were able to cover a wide range of topics that are useful toward maximizing the power of leguminous crops in agriculture and in livelihood and dietary development activities.

I sincerely hope that this one-day event renewed and enhanced our recognition of these important crops. Needless to say, the issues of agriculture and livelihood and dietary development that we are facing now are very complex issues, and that resolving these issues require a collaboration among various research disciplines. In the final panel discussion, the need to carry out multidisciplinary research was also raised. Legume research alone is obviously not sufficient. There are still many challenges that need to be addressed and we still have much to learn. So, we certainly need more of this kind of events in order to continue our activities on this issue.

This event was organized in relation to the International Year of Pulses. However, our activity on leguminous crops will continue for the coming years. This occasion should be a good starting point for the coming activities.

JIRCAS can play an important role and we stand ready to work with many partners combining researchers with various research fields; however, we will keep our affectionate eyes on leguminous crops, which will be a key component of our research in the future.

I would like to take this opportunity to thank all our speakers, especially Dr. David Bergvinson, DG of ICRISAT, and Professor Emeritus Kazumi Maeda from Kochi University, for the excellent keynote speeches, and our session chairs and moderators for their good summarizations and moderations. I would also like to offer special words of gratitude to our co-organizers, the United Nations University Institute for the Advanced Study of Sustainability, for allowing the use of this nice facility and our cooperators, the Agriculture, Forestry and Fisheries Research Council of the Ministry of Agriculture, Forestry and Fisheries, Japan Pulse Foundation for providing us very tasty sweets, and the FAO Liaison Office in Japan and the J-FARD.

Last but not least, thank you to all symposium participants and to everyone involved in planning this event. We are truly grateful for your valuable contributions and attendance. Thank you very much.


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How research on legumes and pulses can contribute to SDGs?

Program

9:30-10:00	**Registration**

Opening Ceremony

10:00-10:05	Opening Remarks	***Masa Iwanaga***	President, JIRCAS
10:05-10:15	Welcome Address	***Masamichi Saigo***	Director General, Agriculture, Forestry and Fisheries Research Council Secretariat, Ministry of Agriculture, Forestry and Fisheries (MAFF)
		Kazuhiko Takemoto	Director, Institute for the Advanced Study of Sustainability, United Nations University (UNU-IAS)

Keynote Speech

10:15-10:20	Introduction of Keynote Speakers	***Chair: Kunihiro Doi***	Director, Research Strategy Office, JIRCAS
10:20-10:55	Potential of legumes: Global needs and challenges	***David Bergvinson***	Director General, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
10:55-11:25	The acceptance of soybean and groundnut into southeast Asia -From "10,000 years history of legumes and man"-	***Kazumi Maeda***	Professor Emeritus of Kochi University

11:25-11:40	**Tea/Coffee Break (Group Photo)**

Session 1 Legumes in agriculture: Sustainability, environment, and development

11:40-11:45	Introduction	***Chair: Satoshi Tobita***	Director, Environment & Natural Resource Management Program, JIRCAS
11:45-12:05	An overview of legume cultivation in Japan	***Makita Hajika***	Director, Field Crop Research Division, Institute of Crop Science, NARO
12:05-12:25	Legume-based cropping systems for improving soil environments in sub-Saharan Africa	***Robert Abaidoo***	Professor, Kwame Nkrumah University of Science and Technology, Ghana
12:25-12:45	Impact pathways of legumes: Increasing bean productivity and nutritional quality of family diets in the Western Highlands of Guatemala	***Gretchen Neisler***	Director, Center for Global Connections in Food, Agriculture and Natural Resources, Michigan State University (MSU), USA

12:45-13:55	**Lunch**

Session 2 Legumes all over the world: Use of the diversity for improvement

13:55-14:00	Introduction ***Chair: Kazuo Nakashima***	Director, Stable Agricultural Production Program, JIRCAS
14:00-14:20	Inportance of pulses research in India: Chickpea and pigeonpea ***Girish Prasad Dixit***	Project Coordinator, Indian Institute of Pulses Research, India
14:20-14:40	Domestication genes and stress adaptation genes in the genus *Vigna* for sustainable agriculture under stress environments ***Norihiko Tomooka***	Genetic Resources Coordinator,Genetic Resources Center, NARO
14:40-15:00	Toward the development of soybean varieties resistant to rust disease ***Naoki Yamanaka***	Senior Researcher, JIRCAS
15:00-15:30	**Tea/Coffee Break**	

Session 3 Livelihood with legumes: Value addition and nutritional enhancement

15:30-15:35	Introduction ***Chair: Yukiyo Yamamoto***	Director, Value-Adding Technologies Program, JIRCAS
15:35-15:55	Contribution of legumes to smallholder agriculture and livelihood sustenance in sub-Saharan Africa: Evidence from Malawi, Ghana and Guinea ***Yaw Agyeman Boafo*** ***Linda Chinangwa*** ***Boubacar Siddighi Balde***	 Integrated Research System for Sustainability Science, The University of Tokyo United Nations University Institute for the Advanced Study of Sustainability Integrated Research System for Sustainability Science, The University of Tokyo
15:55-16:15	Nutrition improvement of children in Africa using soybean as a major protein source ***Yasuhiko Toride***	Director, R&D Planning Department, Ajinomoto Co. Ltd., Japan
16:15-16:35	Beans & pulses in the world ***Kiyomi Hasegawa***	President, Beniyabis, Beniya Hasegawa Store, Japan

Session 4: Panel Discussion

16:35-17:10

Moderators: Kunihiro Doi and Satoshi Tobita

Panelists: David Bergvinson, Robert Abaidoo, Gretchen Neisler

- Comments from the panelists
- Discussion on the points presented by moderators

17:10-17:15

Closing Remarks

Osamu Koyama Vice President, JIRCAS

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