Bridging cassava to community: simple practices of connecting research - industry - community for sustainable food system

N Khumaida¹*, SW Ardie¹, YA Purwanto²
¹Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University Bogor Indonesia
²Department of Mechanical and Biosystem Engineering, IPB University Bogor Indonesia
*corresponding author: nurul_khumaida@apps.ipb.ac.id

Abstract. Indonesia is one of the third largest world cassava producers, however, Indonesia was still importing cassava to meet domestic demand. Indonesia utilizes cassava for food and feed, while the use of cassava for bio-energy is also emerging. To support the high cassava demand, Bogor Agricultural University (IPB) is actively involved in the cassava development program. The multidisciplinary research activities in the university include breeding, ecophysiology, plant biotechnology, pest and disease management, also agricultural engineering. Designing research based on the industry- and community-demand is as important as delivering the research results to its users. Starting in 2017, the cassava research team in IPB implement simple practices to gain insights into market demand on cassava products and to deliver research results to the market. Through a Technology Based Pre-Enterprise Program, we introduce a one stop shopping concept for cassava based products and technologies to the industry and community with the brand name of Catalyst – Cassava Life Style. However, collaboration from various stakeholders is needed to realize the added value of cassava in Indonesia.

Keywords: new variety, the nursery industry, start-up, commercialization

1. Introduction

Indonesia is the third-largest cassava producer in the world after Nigeria and Thailand, but Indonesia still importing cassava from other countries [1]. This data shows that there is an increase in cassava demand and consumption in Indonesia, either for food, animal feed and industrial raw materials including bio-fuel. Cassava products available for industrial use in Indonesia need to be increased quickly. Initial steps for increasing cassava production can be done by providing high-quality cassava seedlings, so cassava plant with high growth rate and high productivity can be obtained.

The domestic demand for cassava products has not been fulfilled, so Indonesia has imported cassava from several other countries. The volume of Indonesian cassava imports in 2011-2015 based on the Ministry of Agriculture in 2016 [2] in the form of fresh and processed reach 2,351 tons, with total import value around 1.1 billion USD. The volume and value of imports in 2011 to 2016 were respectively 435 thousand tons (211 million USD), 856 thousand tons (384 million USD), 94 thousand tons (107 million USD), 365 thousand tons (160 million USD), 600 thousand tons (257 million USD) and in 2016 from January to May amounted to 383 thousand tons (140 million USD). Cassava imports from 2014 to 2016 were only processed products in the form of cassava starch flour, shredded cassava and cassava pellets from Thailand, Vietnam and Myanmar.

Innovation to provide large quantities of high-quality seedlings can be done through in vitro techniques. In vitro cassava seedlings, which have been developed through long research and already registered as patents titled “Composition of tissue culture media for in vitro cassava seedlings propagation”. The most prospective innovation award has been obtained, which is 103 Innovations in 2011 (Superior Quality Cassava Seedlings Production Technology through In vitro Techniques), 106 Innovations in 2014 (High Productivity Cassava Variant-1), and 2017 at 109 Innovations Plus with the title "Cassava Variants for Supporting Food Industry".
Accordingly, IPB new cassava seedlings varieties produced from in vitro propagation techniques become a solution to meet large-scale seedlings demand. Production of cassava seedlings using in vitro techniques will guarantee the quality of the seedlings, such as true to type and free of viruses/diseases. True to type seedlings means it will be identical to the mother plant [3]. The produced seedlings are the new IPB cassava varieties with high productivity and high starch content (around 26-30%), also with very low HCN levels (8.57-14.02 ppm), and other superior characters [4,5].

Another problem faced by many cassava-based industries is a limitation on the availability of new cassava varieties for industrial use, as starch flour and processed food ingredients. Therefore, the research products from IPB cassava breeding team can be further developed to meet those industrial needs. This new variety can be used for developing cassava-based industries and products, such as mocaf (modified cassava flour) and various mocaf-based products. In addition, mocaf can substitute the use of wheat flour, another advantage of mocaf is gluten-free, so can be consumed by people with gluten allergies, as well as children with special needs (autism). The development of mocaf-based products is an action to reduce the consumption of wheat flour.

Nguyen (2018) reported that the food system is composed of several sub-systems (e.g. farming, waste management, input supply system, etc.) and interacts with other key systems (e.g. energy system, trade system, health system, etc.). Furthermore, a sustainable food system (SFS) is a food system that delivers food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised [6, 7]. The point is profitable (economic sustainability), bring a positive impact to society and the environment (social and environmental sustainability). [6]. Thus, sustainable food system understanding, especially on cassava commodity really needed for building sustainable industries.

This research objective was to develop a model for transforming several research results into products that can be developed by society and industries, also promoting the concept of a transdisciplinary approach to raise cassava potential value to increase community life quality.

2. Methods

Development of new cassava varieties was carried out through induction of mutations with physical mutagens, gamma-ray irradiation at doses of 0, 15, 30, 45, and 60 gray (Gy) on six cassava genotypes (Jame jame, Ratim, Adira 4, Malang 4, UJ5, and Gajah). Qualitative and quantitative character evaluation was done referring to Fukuda *et al.*, 2017 [8]. Furthermore, heritability analysis and genetic stability were figured out to select several mutants as elite lines. The preliminary yield trial continued with multi-location yield trials were carried out in several regions with a similar ecosystem. The series of cassava mutation breeding steps trough gamma-ray irradiation shown in Figure 1.

![Figure 1](image)

**Figure 1.** Series of cassava mutation breeding steps trough gamma-ray irradiation on several cassava genotypes to produce cassava elite lines (high yielding and high starch content)

This research series of in vitro propagation experiments using MS base media with adding auxin and cytokinin in various combinations. The produced plantlets followed with acclimatization procedure to produce high-quality seedlings. Dissemination of this research results to the community is carried out through various training and through various media (print, website, brochure, and social media). The downstream activities are
carried out by applying to CPPBT program, which including preparation of business model canvass (BMC), product development, logo design, and designing marketing strategies.

3. Results and Discussion

3.1. Efficient Breeding Program: Gamma Irradiation of Five Cassava Genotypes (Manihot esculenta Crantz)

Cassava breeding through conventional breeding approach faces some limitations, such as ploidy level, high heterozygosity, inbreeding depression, and low genetic variability caused by clonal propagation that is commonly used for this plant. High genetic variability is one of the important aspects for successful breeding activities on clonally propagated crops such as cassava. Mutation induction using gamma irradiation is a strategy to increase genetic variability. Joseph et al., 2004 [9] reported that gamma irradiation (Co60) at the rate of 50 Gy could successfully induce mutation in cassava in vitro variety PRC-60a. That study reported that more than 50% of mutant lines showed variability in morphology compared to the wild type plants.

Mutation breeding using gamma-ray irradiation on six genotypes (Jame-jame, Ratim, UJ-5, Malang-4, Adira-4, and Gajah), has produced several elite lines that show high yield and high starch content traits [4, 5]. A series of cassava mutation breeding steps presented in Figure 1. Several numbers of cassava elite lines that obtained through the mutation breeding approach show high yielding characteristics, and diverse of morphological characters. The elite line also shows different cassava phenotypes, as presented in Table 1.

| No | Elite line | Plant height (cm) | Stem diameter (mm) | Colour of young leaf | Leaf color | Number of storage root per plant | Potential yield (ton ha⁻¹) |
|----|------------|------------------|--------------------|---------------------|------------|---------------------------------|--------------------------|
| 1  | G1-025     | 424.67           | 2.04               | Purplish green      | Light green| 4                               | 38.9                     |
| 2  | G1-15-4-3  | 427.0            | 21.2               | Purplish green      | Light green| 4                               | 46.2                     |
| 3  | G1-15-5-1  | 401.3            | 19.5               | Purplish green      | Light green| 8                               | 48.6                     |
| 4  | G2-15-1-1  | 442.50           | 2.18               | Purplish green      | Light green| 4                               | 35.0                     |
| 5  | G2-15-3-3  | 414.33           | 2.00               | Purplish green      | Light green| 7                               | 50.2                     |
| 6  | G2-15-4-4  | 408.0            | 26.2               | Purplish green      | Light green| 5                               | 44.9                     |
| 7  | G2-15-5-3  | 417.7            | 21.0               | Purplish green      | Light green| 7                               | 66.8                     |
| 8  | G3-15-1-3  | 404.7            | 23.1               | Purplish green      | Light green| 5                               | 49.1                     |
| 9  | G3-15-2-2  | 362.0            | 20.1               | Purplish green      | Light green| 7                               | 49.4                     |
| 10 | G3-15-4-4  | 402.7            | 20.8               | Purplish green      | Light green| 6                               | 56.1                     |
| 11 | G2D1-222   | 294.0            | 20.3               | Purplish green      | Light green| 6                               | 30.2                     |
| 12 | G2D1-422   | 292.5            | 16.4               | Purplish green      | Light green| 3                               | 29.0                     |
| 13 | G2D1-522   | 281.3            | 20.8               | Purplish green      | Light green| 4                               | 30.8                     |
| 14 | G4D1-222   | 341.33           | 19.9               | Light green         | Dark green | 6                               | 31.0                     |
| 15 | G4D1-132   | 356.0            | 24.3               | Light green         | Dark green | 6                               | 29.6                     |
| 16 | G4D2-123   | 275.3            | 21.2               | Light green         | Dark green | 6                               | 57.0                     |
| 17 | G4D3-113   | 269.0            | 16.7               | Light green         | Dark green | 4                               | 41.6                     |
| 18 | G5D2-223   | 276.3            | 19.5               | Light green         | Dark green | 5                               | 48.9                     |

Cassava plant breeding through induction of mutations with physical mutagens in the form of gamma-ray irradiation has been shown producing several elite lines (Table 1). The existence of several elite lines is important to be immediately utilized by the community and other stakeholders. However, it still requires several other stages, such as Plant Varieties Protection (PVP) for the varieties protection, or releasing new varieties steps. Performance of few cassava elite lines presented in Figure 2 that shows variation in each elite line. Moreover, there are a few elite lines that show good and optimal growth than other lines. The observation on each cassava elite lines done in few growth stages which is on 1 month after planting (MAP), 3 MAP, 6 MAP, and 9 MAP.

The important point for other researchers, especially for cassava breeders, is do not only focus on high yielding characteristics, but also including other characteristics that needed by industries which are high starch content, high amylopectin content, and many other characters. Therefore, any program or concept is needed to deliver cassava research results to the users and followed by stakeholder action to accelerate the cassava improvement program in the future according to industry demand.

Figure 3 presents the concept of the relationship between cassava researchers and other stakeholders. That shows the research team really needs any feedback from stakeholders and make it as the base for further cassava improvement. It seems on a national level, we require a good mapping and good roadmap for cassava development and its added value, which can be implemented by other parties.
Figure 2. Few cassava elite lines performance on 3 MAP (a), 5 MAP (b), 6 MAP (c), and 7 MAP (d). MAP: month after planting.

Figure 3. The concept of stakeholder relations related to the development and increase in cassava added value.

3.2. Mass Propagation: In Vitro Multiplication Study on Several Cassava Genotypes
Cassava development in Indonesia is constrained by limitation on superior varieties, difficulty in providing a large amount and continuous supply of high-quality seedlings, also limited productive area for cassava planting.
area expansion [4]. In vitro propagation is an advance technology that can be used for the rapid and mass propagation of cassava seedlings, as well as to assist the cassava breeding program for high yielding and abiotic stress tolerance traits.

In vitro technique is not only used for cassava mutant mass propagation, but also for cassava germplasm preservation. In vitro cassava plantlets seedlings propagation can accelerate the supply of high-quality seedlings that are free from virus and true to type. The IPB cassava multiplication protocol has obtained a patent register number, now in the process of waiting for granted. Although in vitro cassava multiplication technology has been mastered, the percentage of successful plantlet from the acclimatization stage still become an important challenge to support the superior and high quality of cassava seedlings industry.

3.3. Sustainable Food System and Transdisciplinary Approach to Strengthen Cassava-based Industry in Indonesia

Based on the description above, The catalyst team tried to analyze and propose several important aspects to be focused on, to promote the cassava-based industry in Indonesia (Table 2). On sustainable intensification aspects, the activity started by developing new cassava lines with specific characters (i.e. high yielding, high starch content, and adaptive to abiotic stress specifically to drought and salinity stress, also resistant to specific important pest and diseases. New variety breeding can be done by conventional breeding, mutation breeding, and genetic engineering. Another improvement to increasing yields including enhancement on cultivation techniques, IPM implementation, and planting schedule.

Table 2. Aspects and proposed activities to strengthen the cassava-based industry in Indonesia

| Aspects | Activities |
|---------|------------|
| a. Sustainable intensification program | ○ New varieties development for high yielding, high starch content, abiotic stress tolerance, and pest-disease resistance traits ○ Balanced fertilization (organic and chemical fertilizers application) ○ Development of the main nursery of superior cassava varieties ○ Integrated Pest-Disease Management (IPM) ○ Sustainable cultivation system (i.e. mix cropping, plant rotation, and agroforestry) |
| b. Extensification program | ○ Improvement of planting and harvest area through the utilization of marginal areas |
| c. Added-value of cassava products | ○ Harvest and post-harvest ○ Development of simple processing units in the Community Cassava Estate area |
| d. Strengthen the cassava farmer institution | ○ Development of farmer field school ○ Field management of cassava estate ○ Strengthening the cassava farmer association ○ Farmer affirmative ○ Collaboration quality improvement between cassava-based industry |
| e. Improvement and strengthen the government role | ○ Improvement of farmer capacity through mentoring ○ Improvement of farmer extension services ○ Incentive system ○ Farmer’s protection system: Insurance/compensation for cassava farmers having harvest failure due to force majeure reason ○ Farmers banking empowerment ○ Sustainability program ○ Farmers friendly policy for win-win solution of all cassava stakeholders |
| f. ABGC (Academician - Business - Government - Community) concept | ○ Creating and planning the ABGC concept ○ Implementation of the ABGC concept |

Furthermore, extensification aspects can be done by expanding the cultivation area using sub-marginal land in many regions such as dry land, high salinity land and unproductive land that haven’t fully utilized. Many efforts to increasing cassava added value by minimizing harvest losses and good primary post harvest handling. Moreover, simple equipment infrastructure for primary processing must be provided for Farmers group.
Existence of cassava farmers association and cassava farmers group need an activity to increase the society capability from many aspects, technical knowledge, management, organization, and the ability to initiate a collaboration with another private company. Another important aspect is government support on regulation including sub-district, district, province, and national level. Those activities if implemented well by every stakeholder could easily by creating a good chance in reaching and implementing good collaboration between A-B-C-G (Academic-Business-Consumer-Government).

The transdisciplinary approach is the key to scientific contributions in studies and research related to sustainability. However, it is not only about interdisciplinary because it requires active stakeholder participation and synergy between researchers and the community (Prof. Dr. Kazuhiko Takeuchi from United Nations University Japan) at the 2016 International Sustainability Science Symposium at Padjadjaran University. Furthermore, it was conveyed that transdisciplinary approach various disciplines, while transdisciplinary also combining with non-academic parties. Interdisciplinary develops integration between theory and scientific knowledge, while transdisciplinary develop integration between theory and scientific knowledge also local wisdom in society.

The trans-disciplinary approach thus becomes a necessity in the development of cassava-based industries program, so it can be realized in Indonesia also able to cope with domestic cassava needs. The matrix of involvement on several scientific fields as well as aspects that have potency and opportunity to provide added value to the cassava-based industry is presented in Table 3.

Table 3. Transdisciplinary approach to increase the potency and value of cassava for community life quality.

| Aspect                  | Agronomy                  | Plant Protection | Soil Sciences | Post-harvest | Food Technology | Agribusiness | Social   | Business | Community |
|------------------------|---------------------------|------------------|---------------|--------------|----------------|--------------|----------|----------|-----------|
| Variety development    | Genetic resources, Crop improvement | Characters for selection (plant – pest interaction) | Tolerant to abiotic stress characters, Quick test | Characters for selection, Phase life, Primary product | Information on consumer need | Participation, market driven | Characters, information |          |
| Cultivation            | Propagation SOP and GAP development | Integrated pest management (IPM) | Land suitability and fertility | SOP, mechanization, Fresh storage | Manage ment, Supply - Demand | Capacity building, Institutional | Simple and low cost |          |
| Product development    | Raw materials             | Integrated pest management (IPM) | Land suitability and fertility | Minimize losses Vase life | Product innovation | Business model, SCM | HRD, Capacity building | Branding, marketing strategy, promotion |
| Zero Waste Management   | Organic fertilizer        | Minimize vector and source of pest | Improve soil quality | Minimize losses | Another chemical compound | Alternative input | Improve the environment and social health | Decrease inputs and make Alternative income |

The development of science in harmony with the efforts to realize the vision and mission must be continuously carried out. Science that continues to develop along with existing needs must also be balanced with the ability of universities to adapt. One of the trends in the development of science is the interconnection of one scientific discipline with other scientific disciplines which are then implemented in research activities. Sustainability science which is currently being developed in various universities is a knowledge paradigm that is predicted to be more rapidly develop and become the answer to various development challenges with different approaches.

Another approach carried out by [10] is to develop a framework for Social-Ecological System (SES) analysis which is an interdisciplinary scientific approach in a multilevel system so expected to be able to diagnose specific problems that arise with proper governance in the social-ecological context. Further development of the sustainability science approach was conveyed by [11], which illustrates that sustainability science is an interdisciplinary scientific approach that aims to solve urgent global challenges by linking comprehensive and integrated segmented scientific disciplines with the purpose of building a sustainable global society.
refers to [12] sustainability science is a new perspective in understanding fundamental issues, especially the relationship between nature and society. This understanding becomes important, which includes a whole global process of interaction with reference to social conditions and characteristics that are adjusted to both spatial and sectoral aspects. Therefore, efforts to increase the potential of cassava for improving people's life quality also contribute to Indonesian economy development, still needs a transdisciplinary approach thinking models. The following matrix tries to present the relationship between scientific aspects and related knowledge to realize the potency of cassava for Industry and community life quality.

4. Conclusion
Integrated research and development of cassava and adapting interdisciplinary approach will result in a very useful innovation and have a high potency to be commercialized. A transdisciplinary approach to the cassava-based industry is one of the solutions to supporting a sustainable food system. Implementation of A-B-C-G concept in the cassava-based industry also become a sustainable solution for the cassava-based industry in the future.

Acknowledgement
Authors would express gratitude for Ministry of Research Technology and Higher Education for funding the research through Penelitian Berbasis Kompetensi (PBK) and CPPBT scheme.

References
[1] Nag OS. 2017. Top cassava producing countries in the world. https://www.worldatlas.com/articles/top-cassava-producing-countries-in-the-world.html. (accessed 13 September 2018).
[2] Indonesia Ministry of Agriculture. 2016. Outlook Komoditas Pertanian Tanaman Pangan Ubi Kayu. Jakarta (ID): Indonesia Ministry of Agriculture.
[3] Nugroho CC, Khumaida N and Ardie SW 2016. In Vitro Shoots Growth of Cassava (*Manihot esculenta* Crantz.) Jame-jame Genotype. *J. Agron. Indonesia* 44 (1) : 40 - 46
[4] Yani RH, Khumaida N, Ardie SW, and Syukur M 2018. Analysis of Variance, Heritability, Correlation and Selection Character of M1V3 Generation Cassava (*Manihot esculenta* Crantz) Mutants. *AGRIVITA Journal of Agricultural Science* 40(1): 74-79
[5] Subekti I, Khumaida N, and Ardie SW 2017. Identification of potentially high yielding irradiated cassava ‘Gajah’ genotype with different geographic coordinates. *IOP Conf. Series: Earth and Environmental Science* 54 (2017) 012013
[6] Nguyen, H. 2018. Sustainable food systems: Concept and framework. Food and Agriculture Organization of the United Nations.
[7] The Secretary Geneal’s High Level Task Force on Global Food and Nutrition Security. 2015. All Food Systems Are Sustainable. Compendium Final Report Zero Hunger Challenge Working Groups.
[8] Fukuda WMG, Guevara CL, Kawuki R, Ferguson ME. 2010. *Selected Morphological and Agronomic Descriptors for The Characterization of Cassava*. Ibadan (NG): International Institute of Tropical Agriculture (IITA).
[9] Joseph R, Yeoh HH, Loh CD 2004. Induced mutations in cassava using somatic embryos and the identification of mutant plants with altered starch yield and composition. Plant Cell Rep. 23:91-98
[10] Ostrom, E. 2007. Sustainable social-ecological systems: an impossibility?. http://ssm.com/abstract=997834
[11] MEXT. Proposal to UNESCO on “Sustainability Science”. http://www.mext.go.jp/english/unesco/1323150.htm.
[12] Kates RW 2001. What kind of a science is sustainability science? Proceeding National Academy of the Sciences. 108 (49): 19449-19450