REGIONAL BEAN BREEDING AND SEED SYSTEMS APPROACHES FOR INCREASED IMPACT: EVIDENCE FROM EAST AND CENTRAL AFRICA BEAN RESEARCH NETWORK (ECABREN)

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Bean production in sub-Saharan Africa is largely done by small-scale farmers (less than 2 ha), predominantly by women for both household food security and cash. Bean productivity is limited by biotic and abiotic constraints such as diseases, pests, poor soil fertility and drought (Beebe *et al*., 2012). One of the major interventions being pursued by regional bean research networks to address bean productivity in smallholder systems is enhancing the use of adapted varieties (Buruchara *et al*., 2011). Based on bean agro-ecological adaptions and market demand similarities across several African countries, a regional breeding programme based on regional constraints and variety demand was introduced by the Pan-African Bean Research Alliance (PABRA) in 1996. Through the alliance, national bean research programmes (NBRPs) in partnership with the International Center for Tropical Agriculture (CIAT) have developed a range of farmer-preferred bean varieties with useful adaptation and consumer-preferred traits. Through this alliance, countries share germplasm and variety evaluation data that accelerate the release process, often leading to simultaneous release of a variety in several countries. It is therefore logical that seed systems are developed and implemented to facilitate seed access in each member country, and to promote regional seed business development. This paper describes the PABRA approach and experience in the development of regional seed systems to facilitate access to seed of improved bean varieties by farmers.

KEYWORDS: ADAPTED VARIETIES, REGIONAL SEED SYSTEM

WHY A PAN-AFRICA BEAN RESEARCH PERSPECTIVE?

Based on agro-ecologies (latitude, altitude, available moisture/rainfall regime, soil pH and rainfall regime), Wortmann *et al.* (1998) clustered bean production systems into 14 African bean environments (AFBEs) cutting across several countries (Table 1). These AFBEs determine the types of bean germplasm, cropping systems and uses.

There is regional bean trade with similar bean market classes (grain types) produced and traded across countries (Table 2).

The Pan-Africa Bean Research Alliance (PABRA) is a consortium of African-owned regional bean networks consisting of National Agricultural Research Systems (NARS), other bean value chain actors (including traders, extension service providers and seed producers from 29 countries in sub-Saharan Africa) and the International Center for Tropical Agriculture (CIAT), working to improve productivity, utilisation and commercialisation of the common bean (*Phaseolus vulgaris*) for the benefit of the urban and rural poor. The capacity of National Agricultural Research Systems (NARS) at country level to conduct bean research for development varies from one country to another. They range from a single scientist working on a broad range of legume crops, to multidisciplinary teams of scientists and specialists in crop breeding, plant pathology, entomology, agronomy, nutrition, seed systems, markets

and social science working on a single crop (bean) in other countries. A coordinated regional breeding programme that facilitates information-sharing, technical expertise and germplasm is hence justified. The ultimate goal is to enhance the food security, income generation and health of poor communities in a gender-equitable manner.

Table 1. African bean environments across East and Central Africa Bean Research Network (ECABREN) countries

AFBE	Burundi	DRC	Ethiopia	Kenya	Mada-gascar	Rwanda	Uganda	Tan-zania	Sudan	South Sudan
1	X		X	X		X	X	X		
2	X	X		X		X		X		
3			X					X		
4					X					
5				X				X		
6			X							
7	X	X		X		X	X	X		
8		X								X
9				X		X	X	X		
10			X							
11		X			X					
12					X					
13					X				X	
14	X	X						X		

Table 2. Major bean market classes in ECABREN countries

Market class	Burundi	DRC	Ethiopia	Kenya	Mada-gascar	Rwanda	Tanzania	Uganda
Red mottled	X	X	X	X	X	X	X	X
Browns: yellow, brown, tan	X	X		X	X	X	X	X
Reds: dark red kidney and small red	X	X	X	X		X	X	X
Creams: sugar, carioca and pinto	X	X				X	X	X
Whites, large and small white		X	X	X	X	X	X	X
Blacks		X		X				X

PABRA has three regional bean networks. These are: Eastern and Central Africa Bean Research Network (ECABREN) covering ten countries; Southern Africa Bean Research Network (SABRN), covering nine countries; and the West and Central Africa Bean Research Network (WECABREN), covering ten countries. ECABREN, SABRN and WECABREN are semi-autonomous and respond to priorities defined by corresponding sub-regional organisations, which are the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA); Centre for Agricultural Research and Development for Southern Africa (CARDESA); and West and Central African Council for Agricultural Research and Development (CORAF/WECARD), respectively. All the networks use a uniform log-frame under the

PABRA umbrella. Activities in the PABRA work plan are developed using a bottom-up approach, and are based on the outcome of national programme planning followed by planning at the regional network level. The alliance provides a forum for building and maintaining linkages to multiple partners in areas of bean research and development. These collaborative linkages are maintained and strengthened through joint priority-setting, planning, agreed division of responsibilities, joint implementation of activities, and joint reporting and sharing of experiences. PABRA facilitates collaborative research linkages across different but complementary areas, from breeding to product utilisation, including markets, nutrition and integration of beans in the agro-ecosystems.

PABRA LOGIC MODEL 2009–13

Regional breeding strategies

The PABRA breeding strategy uses a market-led approach as farmers also produce beans both for food and sale. Preferences for bean types differ with markets, countries and regions; no single variety or class of bean can meet the diversity of market and consumer needs. Currently, the breeding programme is focusing on seven market classes (Buchara *et al*., 2011). For each market class, the breeding objectives and methods are well defined and the germplasm requirements to meet their breeding goals are identified. The research priorities are based on both demand (bean market classes and nutrition) and agro-ecological adaptation/constraints that often go beyond national borders and require a regional approach. The main priorities for the breeding programme are:

- yield improvement;
- improvement of resistance to major biotic and abiotic constraints;
- identification, characterisation and utilisation of new and better sources of resistance to major biotic (also targeting new disease races and pest species) and abiotic constraints (e.g., drought, low soil fertility, acidity, low N, low P and salinity);
- cooking and nutritional quality including improvement of iron and zinc content;
- improving canning quality of dry bean for the canning industry and developing new niche market varieties (snap/green beans).

New priorities include tolerance to heat or cold, tolerance to waterlogging/excessive water, and assessment of advanced and fixed lines for productivity in different cropping systems, particularly intercrop and sole cropping systems.

The PABRA members share the breeding responsibility depending on national members' interest and on the comparative advantage of each member. Stronger NARS may handle segregating populations or develop populations themselves, while the weaker NARS start with evaluation of advanced lines and gradually handle segregating materials. In this way, the evaluation is accelerated due to sharing of characterisation and variety performance data. Through this approach, countries or regions without structured bean breeding programmes (e.g., Angola, Burundi, Cameroon, Congo Brazzaville, DRC, Guinea Bissau, Lesotho, Mozambique and Swaziland) have released bean varieties as a result of collaborative evaluation and sharing of germplasm. More than 200 multiple stress-resistant and farmer accepted bean varieties have been released in PABRA, of which 140 have been released in ECABREN since 2009, representing over 65% of the total releases (Table 3). Some of these varieties target niche markets such as snap beans in Rwanda and canning beans in Ethiopia, while others have an added trait of high iron and zinc grain content. The collaborative process has contributed significantly to scaling up and widening of the impact efforts. Bean technologies and approaches have been moved across

countries or networks. For example, most countries have adopted participatory variety selection (PVS) approaches and impact-oriented seed systems.

Table 3. Bean variety releases in ECABREN countries, 2009–14

Country	Marketable varieties*	Niche market varieties	Micronutrient-rich	Total	Percentage release by country
Burundi	8	0		8	5.7
DRC†	19	7	15	41	29.3
Rwanda	16	4	10	30	21.4
Uganda	13	0	0	13	9.3
Ethiopia	22	0	0	22	15.7
Madagascar	12	0	0	12	8.8
Kenya	11	0	3	15	10.0
Total	**101**	**11**	**28**	**140**	**100**

*Marketable dry bean varieties with multiple stress tolerance.
†Varieties released in eastern and western DRC.

Variety development

In the period 2009–14, 140 releases were made in seven ECABREN countries (Table 3). Most progress has been made in the dry bean multiple stress-tolerant variety category, which accounted for more than 72% of the releases (Table 3). This is mainly because dry bean has been prioritised in these countries. Similarly substantial progress was made in the development of micronutrient-rich beans based on the PABRA target of 13 releases. Twenty-eight high-iron and -zinc varieties were released in ECABREN, with iron levels ranging between 75 and 95 ppm and zinc levels ranging between 31 and 37 ppm. Most of the varieties were released in only three out of the ten ECABREN countries, indicating the need for other countries to prioritise this trait in their breeding programmes. However, only a few of the released varieties reached the new PABRA target of >90 ppm iron, indicating the need to increase efforts to achieve this target. A similar pattern was observed for releases of niche market varieties. Only two ECABREN countries (DRC and Rwanda) released 11 niche market varieties. Most of the varieties are in the dry bean market class (DRC) and snap bean in Rwanda.

Most varieties released in Ethiopia (small whites and small reds) and in Madagascar (large whites) target the niche canning market, although they were classified as multiple stress-tolerant varieties (Table 3). Income earned from niche markets allows farmers to diversify their diets and have more purchasing power to acquire essential household items and hence improve their livelihoods. However, these niche market products are faced with a number of challenges. The most fundamental bottleneck for snap bean production in the region is the lack of locally adapted varieties combining high pod yield, pest and disease resistance, and market-demanded pod characteristics. This is because the varieties grown in the region are imported from temperate regions, have a narrow genetic range and are vulnerable to major pests and diseases (Silbernagel *et al*., 1991; Kimani, 2004). Seed is costly as it is imported; it cannot be recycled as in some instances reproduction has been constrained (PABRA, 2012). Similarly, great potential exists for canning beans as a niche market product. However, existing bean processing

industries rely on a very small number of canning bean varieties. In spite of its susceptibility to diseases such as rust, MEX 142 is still the most popular variety because it meets canning industry specifications.

Regional and multiple variety releases

As a result of the collaborative regional breeding and variety evaluation, several varieties have been released in several countries. These regional efforts hastened the release process and/or allowed countries with limited breeding capacities to target desirable varieties and carry out minimum additional evaluation. Table 4 lists varieties released in more than one country in the ECABREN (ASARECA) region.

Table 4. Bean varieties released in more than one country and year of release in the ECABREN region

Variety	Burundi	DRC	Ethiopia	Kenya	Rwanda	Tanzania	Uganda
AFR 708		2007		2008			
CAB 19					2004	2006	
Flora de Mayo	1987			1996	1991	2006	
G 2333		1990		1996	1991		1999
G 685	1993	2004		1966	1991		1999
KAT B1	2008		2013	1998			
KAT 56	2008		2013	1998			
KAT B9	2008		2013	1998			
KAT 69	2009			1998			
G 5621				2008		1990	
Gasilida	2011				2010		
CAL 96	1999	2008	2012				1994
GLP 2	2011		2011	1984			1970

Linking regional breeding to seed systems

In order to accelerate the use and facilitate the dissemination of seed of new bean varieties to the wider farming community, NBRPs in collaboration with CIAT and seed value chain actors have evaluated various approaches. These include aligning seed systems activities to respond to the bean value chain seed quality requirement, e.g., navy beans in Ethiopia (Teshale *et al*., 2006); pluralistic seed systems with multiple seed actors and complementary roles (Rubyogo *et al*., 2010; Table 5); and use of small, affordable packs (TL II, 2012). Stemming from these interactions and functional partnerships, an integrated seed systems approach was adopted for wider impact. The approach encourages partnership among local seed producers, entrepreneurs, local extension service providers and NBRPs in seed production and marketing. This complements the centralised formal seed system that usually provides 2–6% of the seed requirements in many countries (Rubyogo *et al*., 2010).

The integrated seed systems approach has very significantly increased seed availability to farmers especially for new varieties, and reduced the lag period between variety release and use (Rubyogo *et al*., in press). In addition, several seed training and resource manuals developed in one country have been adapted or translated from English into local languages (Table 6). A small and affordable seed packs approach, initiated in Rwanda and validated in Kenya and Ethiopia with the private sector, has spread to other ECABREN countries such as Burundi, DRC, Madagascar and Uganda (PABRA, 2014a,b).

Table 5. Integrated seed systems actors and their complementary roles

Actors	Roles and responsibilities
NARS	Variety development Production of breeder/foundation seed Provision of information on new varieties Support for seed production skills enhancement
Seed parastatals/ seed companies	Facilitation of variety testing Seed multiplication of preferred and released variety Marketing of certified seed of popular varieties Provision of business opportunities and capacity building for contracting farming (outgrowers) Provision of initial seed for bulking
Local extension services (GOs/NGOs/CBOs/FOs)	Decentralised testing of varieties Decentralised seed production Popularisation of preferred varieties Community mobilisation Local skill building (e.g., in enhancing seed quality) Information development: variety promotional materials Development and/or translation of training manuals in relevant languages
Farmers (seed producers/entrepreneurs)	Carrying out local seed production and supply/marketing of locally preferred genotypes Farmer (customer) awareness creation Popularisation of preferred varieties Training of other farmers in bean agronomy and post-harvest management (farmer implements)
Farmers (individuals/groups)	Testing and providing feed about potential genotypes Grain production which pulls the seed supply
Local grain traders	Linking local seed producers with wider bean seed markets and moving varieties beyond local zones Provision of grain market intelligence
CIAT/ECABREN	Provision of potential promising germplasm to NARS Co-research key bottleneck areas Support for skills enhancement in seed/business skills Support for monitoring and evaluation

Source: adapted from Rubyogo et al*. (2010)*

Table 6. Examples of seed training/resource manuals translated into local languages							
Title	**Language**						
	Swahili	**Amharic**	**Kirundi**	**Malagasy**	**Luo**	**Luganda**	**Runyakore**
Bean seed production	X	X	X	X	X	X	X
Bean seed business	X	X		x	X		X
Bean pest and disease management	X	X	X		X		X

Posters, brochures and flyers developed in one country have been adapted and used in other network countries.

IMPACTS

Between 2009 and 2013, an estimated 22,459.3 t of bean seed was produced and made available to farmers in ECABREN countries (Table 7) using the supportive interventions described above (Table 5). This quantity of seed is enough to plant about 312,374.2 ha (at an average rate of 70 kg/ha).

Table 7. Amount of seed supplied to farmers in ECABREN region between 2009 and 2013					
Country	**Amount of seed supplied and estimated total areas under new varieties 2009–13**				
	Seed directly supplied to farmers by seed producers (t)				**Estimated area (ha) under new varieties**
	2009	**2010**	**2011**	**2012–13**	**2009–2012/13**
Burundi	116.7	249.7	220.0	192.9	9,704.8
DRC-East	2,076.8	2,610.5	1,402.0	77.2	88,093.9
DRC-West	52.1	160.4	7.8	4.3	3,035.7
Ethiopia	922.2	1,111.3	1,430.0	1,932.1	77,080.0
Kenya	242.0	237.8	321.0	1,030.0	26,154.3
Madagascar	33.2	56.5	165.0	102.8	5,107.1
Rwanda	230.0	345.7	1,35.0	985.9	35,495.1
Tanzania (N)	66.1	87.0	45.0	97.2	4,219.3
Uganda	917.7	1,101.0	1,367.0	1,103.2	64,126.7
Total	**4,656.9**	**5,959.9**	**6,317.0**	**5,526.0**	**312,374.2**
*Estimated area (ha) under new varieties 2009–2012/13 (seed rate 70 kg/ha)					

Seed access

Using the integrated seed systems approach, it is estimated that during 2003–08, PABRA reached 7.5 million households with seed of improved bean varieties, impacting about 35 million people with bean-based technologies (Rubyogo *et al.*, 2010). Between 2009 and 2013, another 6,816,365 households in the ECABREN region, of which 56.9% were women, had access to quality seed of improved varieties (Table 8).

Table 8. Number of farmers who accessed seed of improved bean varieties in the ECABREN region between 2009 and 2012

Country	Seed access (number of households)											
	2009		2010		2011		2012		2013		Total	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Burundi	104,900	80,649	134,208	112,982	115,900	95,350	67,511	28,933	39,744	15,456	462,263	333,370
DRC-East	357,689	139,204	258,645	155,470	220,450	167,030	38,500	16,500	10,890	5,648	886,714	483,852
DRC-West	24,165	11,750	46,800	14,250	5460	2340	1,506	645	450	358	78,381	29,343
Ethiopia	46,249	107,914	42,713	128,140	47,900	145,490	28,950	164,050	106,089	247,541	271,901	793,135
Kenya	155,861	104,998	213,425	168,635	120,900	146,900	141,625	115,875	177,789	142,211	809,600	678,619
Madagascar	24,293	15,338	27,859	7,373	45,890	28,800	33,410	17,990	121,390	77,610	252,842	147,111
Rwanda	94,900	73,590	202,692	90,150	252,450	187,900	367,486	157,494	71,799	31,533	989,327	540,667
Tanzania (Northern Zone)	21,600	10,090	25,990	13,073	12,900	6,709	15,273	12,496	7,459	6,061	83,222	48,429
Uganda	78,309	95,709	82,921	101,348	265,565	145,670	154,444	66,190	210,518	99,067	791,757	507,984
Total	**907,966**	**639,242**	**1,035,253**	**791,421**	**1,087,415**	**926,189**	**848,705**	**580,174**	**748,128**	**625,485**	**4,625,467**	**3,562,511**

Source: PABRA (2014a)

INCREASED BEAN PRODUCTION AND PRODUCTIVITY

Significant bean yield increases have been recorded from the use of improved varieties coupled with complementary integrated crop management practices in areas where PABRA operates. On average, a 48% increase in on-farm yield attributed to improved bean varieties was made since 2009, based on data from ten countries drawn from the three networks (PABRA, 2013). Changes in on-farm bean yield levels were observed in several countries across PABRA. The target sought to increase yield from as low as 0.6 t/ha in some countries in 2009 to as high as 2 t/ha by 2013. To date, several PABRA countries have doubled the on-farm bean yield levels, while all countries have seen a positive change in on-farm bean yields (PABRA, 2013). Three factors seem to drive dramatic upward shifts in on-farm bean yield levels:

- adoption of climbing bean varieties where these were widely promoted, e.g., Rwanda;
- better access to markets and associated commercialisation of bean production, which stimulates farmers to invest in intensive bean production and post-harvest management, e.g., Ethiopia (IFPRI, 2010);
- localised high-intensification production systems such as production using irrigation or residual moisture, e.g., Madagascar (PABRA, 2014a).

Table 9. Levels of on-farm bean yields across some PABRA countries

Country	Bean yield (t/ha)		
	2009	2012	Desired
Kenya	0.3	0.45	0.8
Ethiopia	0.75	1.4	2.5
Rwanda (climbing beans)	1.0	2.5	3.5
Zambia	0.72	0.9	1.5
DRC East (bush beans)	0.45	0.6	0.8
DRC East (climbing beans	0.9	1.5	2.5
Madagascar (residual moisture)	0.6	1.5	2.7

Source: PABRA (2014a)

However, there is still a huge yield gap between on-station and on-farm productivity. For example, Ethiopia reported a yield potential of up to 3 t/ha for bush beans on-station and 1.5 t/ha on-farm (PABRA, 2013). The average yield potential of climbing beans in experimental plots in Rwanda was 4 t/ha, compared with the national average of 1.3 t/ha (PABRA, 2013). The situation may worsen as a result of the impacts of climate change on bean production. For instance in areas where a 4°C temperature rise has been predicted, losses are likely to be severe, diminishing the options available to most smallholders (Beebe *et al*., 2011). Current crop varieties and agricultural practices will often be inadequate, and food security will be more difficult to achieve because of commodity price increases and local production shortfalls. Even where adaptation strategies already exist, considerable institutional and policy support, such as a better organised and more profitable bean market, is needed to develop a sustainable bean sub-sector at the required scale. The profitability of the bean value chain incentivises farmers to invest in high-yielding production systems (use of quality seed and complementary improved agronomic practices) and post-harvest management, including marketable products (PABRA, 2014b).

CONCLUSION

The regional approach has proven its efficiency in breeding and seed delivery at both regional and national levels. However, despite multiple variety release across ECABREN countries and an increasing regional bean trade based on specific bean market classes, cross-border seed movement is still limited to breeder seed and informal seed exchange across common borders. With the harmonisation of seed rules and regulations in the ASARECA region through the East African Community (EAC) and Common Market for East and Southern Africa (COMESA) region, PABRA member countries should take advantage of multiple releases to increase access to quality bean seed by farmers through the cross-border seed business.

REFERENCES

Beebe, S., Ramirez J., Jarvis, A., Rao, I.M., Mosquera, G., Bueno, J.M. and Blair, M. 2011. 'Genetic improvement of common beans and the challenges of climate change.' *In* Yadav, S.S., Redden, R.J., Hatfield, J.L., Lotze-Campen, H. and Hall, A.E. (eds) *Crop Adaptation to Climate Change.* John Wiley, New York.

Beebe, S., Rao, I., Mukankusi, C. and Buruchara, R. 2012. 'Improving resource use efficiency and reducing risk of common bean production in Africa, Latin America, and the Caribbean.' *In Eco-Efficiency: From Vision to Reality.* http://ciat.cgiar.org/wp-content/uploads/2012/12/chapter_8_eco_efficiency.pdf

Buruchara, R., Chirwa, R., Sperling, L., Mukankusi, C., Rubyogo, J.C., Muthoni, R. and Abang, M.M. 2011. 'Development and delivery of bean varieties in Africa. The Pan-Africa Bean Research Alliance (PABRA) model.' *African Crop Science Journal* 19: 227–245.

IFPRI. 2010. *Pulses Value Chain in Ethiopia: Constraints and Opportunities for Enhancing Exports.* International Food Policy Research Institute, Washington, DC.

Kimani, P. 2004. 'Breeding snap bean for smallholder production in East and Central Africa.' *In Annual Report 2004.* CIAT, Cali, Colombia.

PABRA. 2012. *Annual Report 2012.* Pan-Africa Bean Research Alliance, Kampala, Uganda.

PABRA. 2013. *Annual Report 2013.* Pan-Africa Bean Research Alliance, Kampala, Uganda.

PABRA. 2014a. 'PABRA program planning document 2014–2019.' Pan-Africa Bean Research Alliance, Kampala, Uganda.

PABRA. 2014b. *Five Year Report 2009–2013.* Pan-Africa Bean Research Alliance, Kampala, Uganda.

Rubyogo, J.C., Sperling, L., Muthoni, R. and Buruchara, R. 2010. 'Bean seed delivery for small farmers in sub-Saharan Africa: The power of partnerships.' *Society and Natural Resources* 23(4): 1–18.

Rubyogo, J.C., Magreta, R., Kambewa, D., Chirwa, R., Mazuma, E. and Andrews, M. In press. 'Using subsidized seed to catalyze demand-driven bean seed systems in Malawi.'

Silbernagel, M.J., Janssen, W., Davis, J.H.C. and Gustavco, M.O. 1991. 'Snap bean production in the tropics: Implications for genetic improvement.' *In* Schoonhoven, A. and van Voysest, O. (eds) *Common Beans: Research for Crop Improvement.* Centro Internacional de Agricultura Tropical (CIAT)/Redwood Press, Melksham, UK.

Teshale, A., Rubyogo, J.C., Sperling, L., Amsalu, B., Abate, T., Deressa, A., Reda, F., Kirkby, R. and Buruchara, R. 2006. 'Creating partnership for enhanced impact: Bean variety delivery in Ethiopia.' *Journal of Crop Science Society of Ethiopia* 12: 27–30.

TL II. 2012. *Tropical Legumes II: Annual Report.* ICRISAT, Hyderabad, India.

Wortmann, C.S., Kirkby, A.R., Eledu, C.A. and Allen, D.J. 1998. *Atlas of Common Bean (*Phaseolus vulgaris *L.) Production in Africa.* Publication No. 297. CIAT, Cali, Colombia.