Demand-Driven Plant Variety Design

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Securing maximum possible adoption of fit-for-purpose improved varieties

Customer demand is a proven vital ingredient for all successful and self-sustaining businesses offering products and services, and it underpins market creation across the world from telecommunications companies using the most advanced mobile phone technology to smallholder farmers growing fresh vegetables for their local market. There are many case studies on development failures that demonstrate how critical it is to focus investment on products that meet customer needs and expectations.

Demand-driven approaches are highly applicable to new variety development in an agricultural setting. This is not new, especially in developed country markets. Focusing on demand to drive successful public crop breeding programs for smallholder farmers in developing and emerging markets *is* new. It is a critical component of scaling seed systems. Securing the maximum possible adoption of fit-for-purpose improved varieties is important now and has an even greater imperative over the next 10 years to meet the huge and growing challenge of food security.

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Customers are at the front and center of the R & D process

How are new crop varieties currently designed?

Clearly, public sector plant breeding programs aim to improve varieties to meet smallholder farmers' needs. They usually include targets such as improving yield, sustainable crop productivity, reduced inputs and labor that together can lead to socio-economic benefits, improved livelihoods and food security. Progressive programs involve farmers. This is often on an informal basis or more formally as part of "participatory breeding programs" where farmers provide advice on key crop characteristics. In these programs farmers are involved with growing, testing and selecting with the breeder the best performing lines for progression and scale-up.

Funders of public plant breeding programs influence the priorities and approach taken to design new varieties. Usually international development funds supporting R&D programs in developing countries are framed to support one or more of the following: the Millennium Development goals, national government policies and the challenges in their agricultural science agendas such as climate change, yield improvement and nutrition. Typically, donors set priorities and allocate funding for projects to address specific objectives within these goals. An example could be improving drought tolerance in staple food crops for smallholder farmers in sub-Saharan Africa.

Working toward particular goals, donors may fund discovery of or access to specific genes, research to understand their function, regulatory control and interactions between genotype and environment, and breeding programs to incorporate the key genes or traits into the best performing local varieties. Current approaches are frequently technology-driven and designed to support professionals in developing countries having access to and using the best known science, often through collaborations with leading international research institutions. Many involve elements of capacity building so that scientists and breeders can learn new methods, use the best tools and develop their own home institutional ability to discover and utilize solutions.

What is different about using customer-demand to create new varieties?

"Demand-driven" or "customer-focused" plant breeding represents a way of designing new improved crop varieties that puts customers at the front and center of the R&D process. It involves customers right at the beginning of an investment decision and before any science has started. Like farmer participatory breeding it includes "prototype testing and selection". But not just with farmers. Also with stakeholders along the value chain that can influence the key buying and selling decisions of the crop as a food, as a raw material for the processing, or as seed for production and sale. Demand-driven crop design can significantly increase the likelihood of farmer use, instead of seed remaining as inventory in public seed supplies, with distributors or just being remembered in the National approved list of crop varieties.

Clearly, high adoption by smallholder farmers is not just due to the intrinsic benefits of improved newer varieties over older alternatives. It is highly dependent on a range of other drivers and particularly the availability of sufficient, quality, cost-effective, affordable seed that is accessible to farmers for crop and food production. Varieties that deliver the key attributes wanted by customers are an imperative, not just for farmers but also for the emergence of successful seed production and distribution businesses and market creation. Seed organizations can only reach scale when they have a portfolio of highly sought after varieties that contain profit for all. This ensures longevity of seed supply to farmers and availability of quality food for consumers and all customers in the value chain.

What does a customer-driven new variety design look like?

A customer-driven new variety design is a profile that has been designed taking into account the opinions, preferences and needs of key stakeholders and customers in the value chain. It includes a specification of key technical, production and commercial factors that drive success. An example of the types of factors that may be included is shown in table 1 (next page).

Different names are used in the private sector for these designs such as "variety ideotype", "variety specification" or "product profile," but essentially these are parallels and are comprised of similar characteristic features. These product profiles are highly specific and tailored to an individual crop, value chain and set of customers. Creation of the designs have required significant gathering of market information and consultation with stakeholders to understand their needs and test assumptions. Usually market research has been conducted, involving farmers, foundation seed companies, processors, consumers and others to rank the many possible attributes of varieties for their relative importance. Technical feasibility of delivery will have been reviewed, trade-offs made and the ideal variety ideotype validated for acceptance by customers at an early stage of the program and definitely before major investment has taken place. In addition, how the market place and customers' needs could change over a 10 year + period is taken into consideration. Key drivers are assessed such as government policies on production, subsidies and trade, crop variety protection legislation, food safety requirements and entrance of new paradigm-shifting plant science technologies.

You may be asking why so much importance is placed by some of the private sector on this approach. Visioning and validation of new product designs are required because of the lengthy R&D timelines to develop and register new varieties. Just considering customer needs now is not enough. Foresight and testing of assumptions is undertaken to reduce risk. This is done to ensure that a new variety will not just be approved by variety registration authorities, but will be sought after by customers and achieve the high market shares and profitability needed to underpin ongoing investments, as well as building customer loyalty and company reputation. New variety ideotypes tightly reflect the core strategies of seed and agribusiness companies and their future product ranges and so usually are considered highly proprietary and confidential.

The variety ideotype is validated by customers before major investment has taken place

Table 1: Customer-driven design. Examples of characteristics quantified, benchmarked and ranked against leading varieties to form an ideal product profile

Consumers	Agronomic Performance
• Taste • Flavor • Form and shape • Color • Texture • Cooking qualities • Shelf or storage-life • Nutritional qualities • Safety	• Yield in range of agro-ecological climates • Yield in nutrient poor soils • Resistance to abiotic stresses – drought, heat, flooding, rain, wind and lodging • Responsiveness to fertilizer or low inputs • Responsiveness to crop protection inputs • Resistance to priority list of pests and disease, genetic diversity and resilience • Water usage • Performance to crop rotation • Germination time and length of growth cycle • Plant architecture and space • Ease of harvesting • Postharvest storage life • Genetic diversity and durability to varying biotic and abiotic stresses • Quality and yield of plant biomass as animal fodder
Crop and food processing	**Seed production**
• Resilience to transport • Suitability as raw materials • Speed of process • Quality of end consumer product • Storage of end product	• Fertility • Germination rates • Propagation and production • Resistance to seed borne viruses, bacteria and fungi • Costs of seed production • Speed of scaling
Seed channel	
• Defined benefits and differentiation from existing varieties • Pricing and profitability • Freedom to operate – access to germplasm and royalty payments • Intellectual property and plant protection rights • Certification systems • Seed production systems operational or capacity building required • Costs of distribution	

A critical success factor is the ability of researchers and breeders to access reliable market knowledge and translate market research information into their science programs

How can customer-driven design be used in public plant breeding

The fundamental requirements that are important within the private sector for gaining high variety adoption are generally applicable in public sector programs that support crop and productivity improvements in developing countries. For customer-demand design approaches to be successfully integrated into public sector breeding programs the enabling environment must be conducive. Specifically, support is required at a government, international donor and institutional management level to encourage change and to stimulate greater involvement of customers and stakeholders into the design of new varieties before and during crop improvement programs. At an operational level a critical success factor is the ability of researchers and breeders to access reliable market knowledge and translate market research information into their science programs. A quantitative specification for each varietal attribute is needed that can be measured with meaningful assays and testing regimes. When these attributes go beyond crop parameters that can be assessed in farmer participatory breeding programs, access to specialist tests and partnerships within the value chain will be required. Capacity building and involvement of private sector expertise is essential where line-selection or *de novo* breeding programs do not exist, or do not have the skills or networks of experts to do customer-driven design. There are additional policy considerations for integrating demand-led approaches into plant breeding programs to support scaling seed systems. For example, some national variety registration committees may have strict yield performance criteria. This means that characteristics sought after by consumers, such as crop quality, taste or cooking convenience may not be sufficient to achieve variety registration unless they are also linked with yield improvements.

Many challenges

There are many challenges to successful product design to meet the needs of customers. Some key challenges for public sector breeders and SMEs are:

Customer-focus. This is easy to say but harder to define. For each crop improvement program the lead breeder needs to decide: Who are his/her customers? Who will use the new varieties? How many potential customers are there? Where are they and how do they get new seeds or crops? How can breeders seek customers' opinions on the importance of different varietal attributes? There are usually many people to consider in value chains unless they are subsistence farmers eating their own crops and saving seed each year, or are only selling their produce to neighbors. It is essential to decide before work starts who are the critical customers that the variety improvement is being designed for? Is it the smallholder farmer, the wholesaler, the seed producer, the processor or the consumer? All have inputs but who should have dominant influence when trade-offs on varietal attributes need to be made? Typically, farmers and processors should have the greatest role in variety design for staple food crops when eating and cooking qualities are unaffected. This is because

Demand-driven plant variety design sets the targets for measuring success

generally they have undifferentiated consumer features and are often bulked as commodities for uniformity. Yield, productivity and production costs are key drivers for design. Whereas the consumer is the prime decider on purchasing higher value fresh fruits and vegetables especially in urban situations where there is choice, and therefore, consumers should have a greater involvement in determining the product design at an early stage.

Value-chain. How can breeders engage with the value chain? Is the enabling environment conducive to be able to hold constructive dialogue, particularly if there is a dysfunctional or non-existent public or private seed system in their territories?

Interdisciplinary approaches and project management. The width of ideal attributes of new varieties necessitates the involvement of a range of experts that would not usually be involved throughout the life-cycle of development of new varieties. Seed producers and distributors might be contacted as the seed registration process is approached, but history has shown many examples where there has been a lack of earlier involvement and cost of production or other issues that result at the phase of seed scale-up have not been taken into account. If higher adoption rates are to be achieved a mind-set change is required and a willingness to seek inputs from non-scientists. A broader involvement of customers and experts is essential for success but this increases complexity. Skillful project management to support breeders is likely to be required to optimize outputs from the programs.

Public-private partnerships. Customer-driven design offers fertile ground for public and private partnerships whereby the skills and resources from both parties can create paradigm shifts in the creation and reach of fit-for-purpose improved varieties for/to smallholder farmers. Management support and jointly owned vision between the parties is required.

Breeding for success. Creating the ideal design that has ownership and support from customers is just the start of the discovery and breeding program. It sets the targets for measuring success and creates focus for the interdisciplinary team. The ideal is not always found and understanding the range of acceptable quantified metrics enables good decision-making within the project team. Unlike the approach of registering varieties with small enhancements that ultimately may not attract support and use, customer-led design requires the fortitude to stick to what has been decided in the requirements for line progression, with confidence that this rigorous standard setting will result in farmer adoption at commercialization. Clearly novel features may be discovered that may modify the target variety profile, however, the challenge is not to reduce the customer requirements for line progression when technical difficulties arrive. Only in cases where new information or market research indicates this will not be detrimental to variety adoption.

As evidenced in the private sector seed industry, when demand-driven product design is introduced into productive plant breeding programs, and combined with excellent science and technology, development rigor and appropriate awareness campaigns with farmers and customers, significant gains in adoption rates can be made. The greatest challenge is finding a cost-effective way to integrate and tailor these methods and success criteria into public sector and small seed company plant breeding programs in developing countries. Specifically to be able to harness the skills and cooperation in the private sector and crop value chains, and for public and private sector experts to share knowledge and problem solve together. In this way vibrant seed systems can be encouraged that support smallholder farmers to have access to improved, cost-effective, fit-for-purpose, quality seed. Consequently, demand-driven variety design should be encouraged to play a greater role in priority setting for investment in R&D and crop genetic improvement in parallel with strengthening seed delivery systems.

Key Lessons Learned for Scaling Seed Systems

1. ***Customer-designed varieties.*** Scaling seed systems in Africa is highly dependent on the effectiveness and productivity of African plant breeders creating varieties that meet customers' needs. To achieve scale, seed organizations require portfolios of differentiated varieties that serve the range of requirements of farmers and their customers in different localities. An ongoing pipeline of varieties offering advantages for customers is vital for business competitiveness, growth, and renewal.

2. ***Multi-disciplinary inputs***. Design of demand-driven varieties requires a broad range of multidisciplinary inputs from stakeholders in the value chain. Agronomic features such as drought tolerance and resistance to pests and diseases are important imperatives for farmers to improve their yields. But to achieve maximum potential for seed scaling and impact in Africa there is a range of additional considerations that need to be fully incorporated into the design and criteria for line progression, such as: taste and quality for consumers; transportability, storage and processing for food companies; parameters including cost-effectiveness of seed production and freedom to operate for seed companies.

3. ***Scaling seed production***. Breeding strategies to enable ease and cost-effective large-scale seed production require early consideration in variety design. Difficult or costly seed production can mean that good varieties can never reach scale.

4. ***Public-private partnerships***. PPPs offer an ideal way to catalyze seed scaling. Partnerships enable African public plant breeders to access information on markets, customers' needs, and production drivers to guide breeding targets and priorities. They may also enable access to useful germplasm and a route to increase farmer uptake. Partnerships enable the private sector to access testing capability and tailor new varieties to strengthen their seed businesses until they have the knowledge and commercial profitability to fully support their own breeding programs.

5. ***Public breeding capacity and investment***. Many countries in sub-Saharan Africa have insufficient numbers of breeders and the associated scientific capacity in their National Agriculture System to run *de-novo* demand-driven breeding programs for their key crops. Resources may only permit accessing germplasm from other NARS and International Genetic Resource Centers to select the best adapted lines for local use. Opportunities for investment in African NARS plant breeding programs need to be identified as an important enabler for supporting seed scaling.

6. ***Enabling environment***. For African National public sector breeding programs to operationally deliver their full potential to support seed scaling, the enabling environment needs to be conducive. Government regulation and institutional policies need to encourage public-private partnerships, movement of germplasm between parties at a national and international level, and condone communication and connectivity within value chains. This may require governments and institutions to reflect further on their existing policies and operations. For example National variety registration mechanisms need to be able to approve new varieties on the basis of customer-driven characteristics such as quality, taste, storage etc. and not just on meeting yield criteria.

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