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What determines the stakeholders' participation in plant breeding programs? Case studies in the South

Jacques LANÇON, Benoît BERTRAND, André CLÉMENT-DEMANGE, Henri HOCDÉ, Bruno NOUY, Gilles TROUCHE

Cirad, Montpellier, France

Abstract — What determines stakeholders' participation in plant breeding programs? Case studies in the South. Most plant breeding (PB) approaches rely upon participatory mechanisms that are not necessarily identified and qualified as such. Breeders' experiments with coffee (Costa Rica), cotton (Benin and Cameroon), oil palm (Benin and Indonesia), rubber (Côte d'Ivoire and Thailand) and sorghum (Burkina Faso) have been analyzed to identify aspects of breeder-stakeholder relationships that enhance the PB impact. A breeder's strategy is largely controlled by numerous factors, such as: (i) plant biology; (ii) the existence of specific producer, processor or consumer knowledge or know-how, which is not easy to identify or reproduce in research stations, and; (iii) above all, by the way stakeholders are organized and their specific interests represented when negotiating joint decisions. Stakeholder involvement varies considerably according to their status in the programs, their ability to clearly express a demand and the financial or political means they can mobilize to influence research programs. In most cases, stakeholder participation is limited to the identification of preferences (criteria), and to the evaluation and dissemination of improved genetic material. This rarely occurs in the other steps, i.e. creating genetic variability or early selection. Lastly, stakeholder participation in plant breeding programs tends to increase the chances of extension for breeding products. Consequently, breeders have to reconsider PB strategies, especially: (i) when stakeholder interests are difficult to characterize (number, diversity) or contradictory, and; (ii) when institutional changes occur in pre-existing organizations, relations and representations. Breeders have to professionalize their intuitive approach to participation and reinforce it with structuring tools developed by other sciences, i.e. technical or social. These tools should help to appraise demand, identify relevant stakeholders and evaluate the efficiency of participatory processes.

Résumé — Qu'est-ce qui détermine l'implication des acteurs dans les programmes de sélection ? Etudes de cas au Sud. La plupart des approches de sélection intègrent des dispositifs participatifs qui ne sont pas toujours identifiés ou qualifiés comme tels. Cinq sélectionneurs, spécialistes de l'amélioration du café, du coton, de l'hévéa, du palmier et du sorgho, se sont penché sur les programmes de sélection qu'ils ont eu à conduire au Bénin, au Burkina Faso, au Cameroun, au Costa Rica, en Côte d'Ivoire, en Indonésie et en Thaïlande. Cet article est une synthèse de leur analyse et des leçons qu'ils tirent pour raisonner la participation des non sélectionneurs. La stratégie participative du sélectionneur est induite par des facteurs biologiques et sociaux : (i) la biologie de la plante ; (ii) l'existence, chez les producteurs, les transformateurs ou les consommateurs, de connaissances ou de savoir-faire qui ne sont pas faciles à identifier et à reproduire sur station et par dessus tout ; (iii) la manière dont les acteurs sont organisés et dont leurs intérêts particuliers sont représentés lors des prises de décision collectives. Les acteurs qui s'impliquent le plus dans les programmes de sélection sont ceux qui ont des intérêts directs à faire valoir, qui sont capables d'exprimer une demande claire et qui peuvent mobiliser des moyens, financiers ou politiques, pour peser sur les orientations de la recherche. Les sélectionneurs font le plus souvent appel à eux pour connaître leurs préférences et leurs critères, pour évaluer du matériel génétique ou pour le diffuser. Ces acteurs contribuent rarement à la création de variabilité génétique ou à la sélection dans du matériel en ségrégation. En général, la participation des acteurs dans les programmes de sélection est un élément favorable à la diffusion des résultats de la sélection. En conséquence, les sélectionneurs doivent s'interroger sur l'intérêt de stratégies plus participatives en particulier (i) lorsque les intérêts des acteurs sont difficiles à caractériser (nombre ou diversité) ou contradictoires et (ii) lorsque des changements institutionnels remettent en cause les organisations, les relations et les représentations existantes. Pour cela, ils doivent disposer d'outils d'analyse développés par les autres sciences, techniques ou humaines.

Introduction

The participation of smallholders in food crop breeding has been well documented (Sperling *et al.,* 2001; Cleveland and Soleri, 2002). Several experiences, including Ceccarelli (2001), Sêkloka *et al.* (2001) or Witcombe (2001) show that such farmers in their own fields are able to produce better genetic material than conventional breeders on research stations.

In this paper, we expand the concept of participation to all users of breeding products, including commercial and industrial farmers or processors.

Our purpose is to link explicitly "Conventional" and "Participatory" breeding approaches and to identify appropriate tools and concepts for participation analysis. Most conventional breeders consider the role of users in breeding programs as obvious and necessary. Good breeding relies on relevant objectives and criteria, which can only be fixed in association with growers, processors or consumers. However, in practice, breeding programs differ in the way they associate their beneficiaries. Are the differences related to the results and how? Through an analysis of 9 breeder - user relationships in contrasting situations, we should be able to produce keys for understanding breeders' strategies.

The study was conducted on 9 breeding programs developed with five different tropical plants, *i.e.* cotton, sorghum, oil palm, rubber and coffee. It was intended to test the hypothesis that contextual factors are strongly responsible for determining which actors participate, when and how they participate. It should also enable us to propose a general perception of plant breeding that reconciles conventional and participatory approaches.

Material and methods

Chronicles

Five scientists wrote the chronicle of their own experiences with coffee, cotton, oil palm, rubber and sorghum breeding. They conducted these adaptive research programs in 7 tropical countries at different period of time, with a view to developing these crops. The questionnaire submitted to the authors describes each program from several angles:
– actor participation in these breeding programs; who are the actors? Their role: do they finance or act? Who represents them in the participatory process? How do they participate at each program level? What is their relative weight in the decision making process, in comparison with that of the breeder (dominant, equal or only neutral)?
– explicit and implicit objectives of participation;
– are relations between actors formalized?
– reasons leading to the participation process and actor representation arrangements;
– lastly, specific results and costs due to participation.

To structure the analysis, we considered it relevant to divide each breeding program into 5 phases, i.e. (i) specification setting (objective and criteria); (ii) genetic variability creation; (iii) progeny selection; (iv) evaluation of breeding products; and (v) product dissemination (according to Weltzien, 2001).

Plants described by the breeder

Five species were chosen in order to cover most situations that Cirad plant breeders have faced or are still facing. The corresponding breeding programs differ historically through the way they came about and also intrinsically for biological or contextual reasons: cycle length (perennial *vs* annual), mating system (clones *vs* autogamous *vs* allogamous) dimensions (trees *vs* bushes *vs* herbaceous plants), uses (food vs industry), final destination (self consumption vs international market), production mode (agro industry vs smallholders) and stakeholder organization.

Some of these characteristics are detailed in table I.

Table I. Description of the plants bred.

Plant	Cycle	1st year product.	Plants / ha x 1000	Type	Mating system	Multiplied as	Main product	Other uses
Coffee	Perennial	2-3	3-7	Bush	Autogamous (mainly) Clones	Lines (seeds) or clones	Seed / drink	Unknown
Cotton	Perennial grown as annual	1	30-80	Bush	Autogamous (mainly) or vegetative	Lines	Seed / fibre	Seed / Oil, mill
Palm	Perennial	3-5	0,1-0,2	Tree	Allogamous	Hybrid populations	Fruit / oil – soap	Sap / drink
Sorghum	Annual	1	10-25	Herb	Autogamous (mainly)	Inbred lines or hybrids	Seed / food Seed / bier	Straw / feed Straw / building
Rubber	Perennial	5-7	0,5-0,7	Tree	Vegetative and sexual	Clones	Latex / industry	Wood

According to Charrier *et al.* (1997), Chantereau *et al.* (1997), ClémentDemange *et al.* (1997), Hau *et al,* (1997), Jacquemard *et al.* (1997) and Lançon *et al.* (2002).

These characteristics considerably influence breeders' choices, in terms of designs as well as partners. To achieve a proper evaluation of tree crops, such as rubber or palm, large areas are needed for several years. Breeders therefore tried to organize their experimental design accordingly, i.e. in partnership with estate plantations that were able to evaluate new clones or improved populations in large-scale trials over a long period. Conversely, research stations, which are usually publicly funded specialized in the creation of variability and early generation breeding (10 years) which required less investment in land. This partnership favoured privileged and almost organic links between breeders and the staff in charge of the estates; these links took the form of very numerous and extensive exchanges on objectives, breeding criteria and the new emerging germplasm and they enabled very rapid adoption of genetic progress in those plantations.

Experimenting on annual plants does not require the same level of investments. Breeders have therefore been naturally less driven towards explicit co-operation with other actors, and specialization. To fully understand the relationships between breeders and the users of breeding products, it is necessary to refer to factors that are linked to actor organization and research funding. We will come back to this later.

Key stakeholders for the breeder

Research programs and, more specially, breeding programs, were originally set up through demand from a diversity of actors: coffee producers in Costa Rica, a specific operator among many in the commodity chains for cotton, oil palm and rubber, or a development actor for sorghum (state or financial institution). However, the actors and potential beneficiaries of these programs are generally more numerous than the historical partners. Table II indicates the main stakeholders identified by the breeder in each of the 9 chronicles.

Among the main stakeholders, the breeders mention several kinds of producers differing from each other through their production methods, and processors adding more or less value to the commodity chain, such as cotton ginners, spinners or weavers, coffee roasters, traditional artefact makers and industrial palm oil or palm kernel extractors, soap makers and rubber-products manufacturers. They do not forget staple product buyers of national or international dimension and even financial backers. For sorghum, the major role of the donor for program orientation is worth noting.

Table II. Origin of demand and formalised participation in the 9 breeding programs.

Plant	Origin of the initial demand	Case	Main stakeholders
Coffee	Private growers	Cent.-Amer, Promecafe	SS and C Farmers, Transformers, Traders, Roasters
		C-Rica, Icafe	SS and C Farmers, Transformers, Traders, Roasters
Cotton	Institutional (government)	Cameroun	SS Farmers, Ginners, Spinners, Traders, Donors
		Benin	SS Farmers, Ginners, Spinners, Traders, Donors
Palm	Agro-industry	Benin	SS Farmers, Estates, Mills, Transformers
		Indonesia	Estates, Mills, Transformers
Rubber	Agro-industry	Ivory coast	Estates
Sorghum	Institutional (donors and governments)	Burkina-Faso	SS Farmers, Donors, State agency
		Mali	SS Farmers, Donors, State agency

SS : small scale; C : commercial; Estates or agro-industry
Stake holders identified as dominant are underlined.

Result 1: contextual elements determine who participates

Stakeholders' participation in breeding programs relies on their ability to influence breeders' choices. Those most involved will be the ones who (i) contribute to research, either because they fund it or because they control its funding through an institutional position and (ii) are able to express a clear demand.

Actors who contribute to research funding

In table III, we indicate for the 6 breeding situations, on one hand who funds them and on the other hand the main actors involved in drawing up and implementing the programs.

Table III. Who paid for and who controlled PB in the analyzed cases.

Plant	Cases	Origin of the initial demand	Who paid for research(*) ?	Which actor was significantly involved in the program?
Coffee	Promecafe	Growers	Semi-public	Growers
Cotton	Benin, Cameroon	Institutional (government)	Public / cotton industry	Cotton industry
Oil palm	Benin	Agro-industry (public)	Public / sales	?
	Indonesia	Agro-industry (private)	Pub. / agro-indust. / sales	Agro industry
Rubber	Ivory Coast	Agro-industry	Public / agro industry	Agro industry
Sorghum	B.Faso,	Institutional (donors or governments)	Public	?

(*) : either direct or indirect significant funding.

Operating resources are generally provided by either private or public backers, and, in the case of oil palm, by improved seed and pollen sales. When funds are of public origin, they are managed by an aid agency, by the State or by a parastatal company that is in charge of sector organization (cotton). Private contributions may take the form of direct backing of research activities, the provision of human / material resources necessary for experimental work.

In half of the situations (cotton, oil palm, rubber), public and private funding co-exists and actors who manage the private (oil palm, rubber) or privatised part (cotton) of this research funding are also the ones who influence breeding programs. The cotton company's power relies upon a convergence of interests that may be structural with the State (profit making and taxes) or circumstance-dependent with backers (good management of aid). But when all funding is of public origin (coffee, oil palm in Benin, sorghum), it is difficult to identify actors strongly influencing breeder operations.

These initial results strongly confirm the linkage between those who contribute and those who participate. On the other hand, they also suggest that policy-makers can influence the results of negotiations by modifying the balance of economic or political power between actors. A way has been explored through competitive funding for research introduced by Dutch and German aid agencies in particular.

Actors who are able to formulate a clear demand

Any request to breeders must be expressed in clear and unequivocal terms, so as to be transcribed into a limited number of specification sets. This condition will be more easily fulfilled with groups of actors who share the same interests and who are able to communicate with breeders.

Results show that actors preferentially participated in three situations characterized by specific production organization or crop use: (i) few actors; (ii) actors integrated into a single organization where conflicts and contradictions are internalized; and (iii) final industrial utilization.

We shall not focus on the second point as it depends both on the choice of partners and also on the personality of the breeder, his listening ability and patience in establishing a common language with the partner.

Actors are few

Hevea domestication and rubber production, as well as oil palm estates, were developed in Southeast Asia, in Indonesia or in West Africa from public or private initiatives in relation with large agro-industrial groups. These groups largely contributed to stimulating research through clearly expressed demand and by making available large acreages and experimental facilities. In return, these plantations benefited from quick access to results and genetic progress.

For these perennial crops, breeding programs were devised in collaboration with agro-industry. They were based on cost sharing and complementary means between the private and public sectors, so as to optimize the achievement and dissemination of genetic progress. Designs, and particularly those used in oil palm breeding, were then organized so as to obtain almost universal specifications. They were relied on three assumptions, typical of centralised and non participatory breeding programs:
–growing conditions due to the environment or cropping systems are uniform enough to overlook GxE interactions, except in the case of major biotic or abiotic stress;
– producer constraints are uniform and rather generalized;
– lastly, production quality requirements are strict and constant (few uses).

Actors are part of vertically (rubber, cotton and oil palm) or horizontally integrated systems (cotton)

Some sectors are dominated by public or private bodies, which integrate several functions linked to production or processing: e.g. cotton companies or agro-industrial rubber companies. In most French speaking West African countries, until the late 90s, parastatal cotton companies co-ordinated all commodity chain activities and ensured many of those: extension, input supplies and on-credit sale, seed production and distribution, seed-cotton purchase and forwarding to ginning factories, fiber classifying and marketing, oil and presscake production.

Such companies were equipped with internal negotiation mechanisms between activity representatives and, as a result, they could submit a concise, joint request to the breeder. The breeder attached to this request a weight that was proportional to the importance of the links, especially financial, that tied the company to the research institution. In Cameroon, for example, breeding is mostly co-funded by the State (public funds) and by the cotton company (Sodecoton), based on the sector’s profits or on implemented aid projects. By directly funding research or by controlling its funding, the cotton company is in a favorable position also to control research programs and technical options.

The existence of such institutions considerably simplifies priority setting (step 1) and evaluation (step 4). The breeder remains involved in ascertaining demand from actors outside the company, in setting objectives, and final criteria selection, e.g. cotton growers or spinners, small-scale rubber producers or processors. And this is often considered as optional when these actors have little formal power or contact with the research institution.

The end-product is intended for industry

Demands from industrial oil palm, rubber or even cotton and coffee processors are rather conservative. They mainly focus on product prices and quality standards. Changes in raw material may have potential advantages but they above all entail real technological and commercial constraints, and necessary adjustments to processing and marketing.

In contrast, demand from individual planters or producers leads towards diversification. As local cropping systems and processes diversely affect production conditions, but also because product uses may vary: for industry, oil palm is considered as a source of fatty acids to be processed into various products such as edible oil, soap, detergents, margarine, whereas small-scale operators produce red oil or make palm wine from it. Demand is even more diversified with self-consumption crops such as sorghum, since it has to combine cultural and individual preferences.

Large international or regional markets and industrial users generally lay demands on producers that are narrow, standardized and easy to describe, with many quality criteria. On the other hand, demands linked to local markets and self-consumption are much more diversified.

Result 2: the context also determines participation arrangements

Contextual factors determine (i) the breeding steps in which actors are more frequently involved and (ii) the way this participation is formalized.

When do actors participate?

For six breeding projects and 3 crops displaying successful seed dissemination, table IV sums up the steps in which actors have been heavily involved.

Table IV. Stakeholder involvement in six breeding projects: rubber or oil palm for agro-industry or smallholders in the Ivory Coast, oil palm in Benin and Indonesia and cotton for an integrated commodity chain in Cameroon (ICC) or a more liberal commodity chain in Benin (LCC).

Breeding step	Cotton		Rubber		Oil palm	
	ICC	LCC	Agro-industry	Smallholders	Agro-industry	Smallholders
1	NF	NF	NF		F	NF
2						
3						
4	NF	F	F	F	F	NF
5	NF	F	F	F	F	F

1: Specifications (setting goals); 2: Creating genetic variability; 3: Selection; 4: Testing and evaluating; 5: Variety release and dissemination; NF: not formalized; F: formalized.

Actor participation is always requested for evaluation (step 4) and dissemination (step 5) and it usually takes a formal mode: is this the consequence of user demand or the breeder's wish to be evaluated ex post? Paradoxically, participation is a little less systematic and much less formal for priority setting (step 1).

Steps 2 and 3 are the most technical ones and they correspond to actual breeding work. They generally remain in the breeder's hands. In this study, we only found two series of criteria for which users' participation to the physical aspects of breeding might be worth mentioning, *i.e.* morphology of the rubber tree and organoleptic quality of sorghum. This does not exclude interesting cases of efficient plant breeding by users in the literature.

How is participation formalized?

Breeders seek regular exchanges with the actors in more or less formalized ways, such as annual consultation meetings, trials and plantation field visits. These are necessary for anticipating the needs of all stakeholders, from growers to consumers.

Most commodity chains have no strictly formal place for consultation where all the main actors can meet and solve problems that may be common on a national or regional level. In fact, explanations and contractualization become necessary when breeders have numerous contacts, and when technical or financial decisions are to be officially recognized.

With oil palm, formalization largely takes the form of bilateral contracts, which indicate the rights and duties of each of the stakeholders in the breeding chain (breeders, industrial planters, co-operatives, and nurserymen). This strategy is largely inspired from that followed by private seed producers: it indicates commercial objectives.

In the absence of organized consultation, demonstration or trial plots are the cornerstone of participation. They play an important role in bringing together breeders and users and, as such, they are favourable for exchanging experiences, strengthening links and establishing mutual credibility. They increase the ability to understand and find answers to real questions. In particular, perennial plants remain in the field for long periods, providing many opportunities for breeders and planters to meet in such places.

Result 3: participation has an effect on dissemination

Does actor participation in breeding play a significant role in producing and spreading genetic progress? In other words, might differences be due to the participation of certain categories of actors and, if so, to the way participation has been organized? We shall try to infer a causal connection between participation and dissemination from existing results, though bearing in mind that the number of cases is too small to generalize our conclusions.

Diagnosing actor stakes (coffee breeding in Costa Rica)

Breeders have to take into account the stakes and the influence of all actors when determining breeding program objectives and specifications (step 1). The Central America coffee breeding program experience illustrates the merits of conducting such preliminary analysis.

Until the mid fifties, the varieties grown in coffee plantations originated from a narrow genetic base. They were well adapted to the traditional low input cropping system. They were also familiar to national traders and international roasters who appreciated them (Bertrand *et al.,* 1999). From the early 50s to the late 80s, breeding programs targeted germplasm responding to intensification through increased productivity, but at the expense of quality (Bertrand, 2002). However, regardless of growers' satisfaction, coffee traders stopped disseminating these varieties. Because of this first failure, new breeding programs emphasized quality and included coffee tasting panels that met at the breeder's request: national traders were pleased with the results… but roasters were not and, in turn, they vetoed the release of this new set of varieties.

In this experiment, local actor participation (growers, traders) was not sufficient to guarantee satisfactory dissemination of the germplasm the breeder had created. The breeder gave priority to the local context and the trader's point of view when the final decision could only be taken by the roaster, an international stakeholder invisible at local level.

Table V. Stakeholder participation in coffee breeding in Costa Rica.

Breeding step	Description	80's (Promecafe)	00's (Hybrids)
1	Specifications (setting goals)		F (P + Pr + Tr)
2	Creating genetic variability		
3	Selecting material		
4	Testing and evaluating	NF (P + Tr)	F (P + Pr + Tr)
5	Variety release and dissemination	NF (P + Pr + Tr + Ro)	F (P + Pr + Tr + Ro)

NF: not formalized; F: formalized
P: producer; Pr: processor (from fresh to clean cherries); Tr: traders; Ro: roaster; R: research.

Balances of power between actors influence negotiation results: in another context, the powerful "Federación de cafeteros de Colombia" forced the roasters and the international market to accept a productive variety with a very similar cup quality to varieties created in Costa Rica.

After this second failure, breeders are now convinced of the advantage that objectives ranking and criteria choices can gain from analyzing stakes and the balances of power between actors.

Impacts

Can we simply and directly compare results obtained by several breeding programs? The answer is complex and to simplify it we adopted a private company point of view, i.e.we considered the economic results. We chose, as an indicator, the percentage area grown with one or more varieties bred in that particular program, in comparison with the usual penetration rate of improved varieties in world production for this particular species (table VI).

The indicator shows adoptions varying with species and situations, from almost nil to 100%. Of course, it provides a very simplified image of reality and programs cannot be compared on this basis: contextual situations are highly contrasted, some programs having to deal with competition or to cope with highly complex demand (see further). Moreover, a variety might have significantly contributed to local germplasm renewal through gene flows, though its dissemination may not be easy to record.

The qualitative opinion expressed in table VI (last column) is the result of interpreting the indicator in the light of local and worldwide contexts.

Table VI. Local impact of a program as compared with the worldwide use of improved varieties of the same species.

Plant	Program	% area planted each year with improved material		Estimated impact
		World situation (general)	Local situation (program)	
Coffee	Costa Rica Promecafe	100 %	Traces	Problematic
Cotton	Cameroon (integrated)	100 %	100 %	Satisfactory
	Benin (privatization)		100 %	
Palm	Benin	90-95 %	100 % (a)	Satisfactory
	Indonesia		15 % (b)	
Rubber	Ivory Coast (SS farmers + estates)	Majority	90 %	Rather satisfactory
Sorghum	Burkina –Faso	Small	< 5 %	Problematic

(a) all the explicit demand for improved germplasm is covered by the local breeding program but an unknown share of replanting is also carried out with unimproved material.

(b) in Indonesia, the use of unimproved material for planting does not exceed 5% of total needs.

Dissemination of a new variety depends upon (i) its quality and relevance as a breeding product and (ii) the ability of the program to statisfy the demand it gave rise to. In other words, are users happy with the proposed germplasm and is the seed production system able to satisfy demand?

Breeders can only fulfill the first condition when in a position to identify the factors for specification setting. To do that, oil palm, rubber or cotton breeders tend to maintain close links with agro-industry or parastatal companies, i.e. with a particular actor or with a group of users whose interests are easy to identify and homogeneous. These programs are heavily subjugated to a specific demand (demand-driven).

The second condition is related to the existence of an organized variety dissemination system. This system must satisfy demand at a competitive price, which may be very low if the consumer is not prepared to pay. It must also relie on complex techniques that discourage users from becoming self-sufficient in planting material: hybrid coffee, grafted rubber, industrial conditioning of cotton seeds, genetic sterility in the oil palm etc.. On the other end, simple and localized sorghum dissemination systems (lines or populations) favor user autonomy and limit the impact of conventional breeding programs.

Actor participation seems related to an explicit strategy of genetic progress spreading. Designs are more efficient when breeder - user links are direct or even personal, as is the case with agro-industry, large-scale growers or integrated commodity chain representatives. But personal links may be difficult to establish with some actors or operators, such as oil palm nurserymen, because they are too numerous, or for coffee with roasters because they are far away. In such cases, they benefit from being formalized.

Discussion

Breeding complexity is two-fold

The sorghum example (Burkina Faso)

Conventional sorghum breeding programs have run into serious problems with disseminating new varieties:
– growers have breeding expertise that has not been fully considered by scientists;
– quality standards refer to local traditional or customary uses and they cannot easily be described and regrouped into a limited number of specification sets;
– and, lastly, centralized systems of seed multiplication have not proved to be better than traditional systems using on-farm seed production and exchanges between farmers.

Let us add that breeding ideotypes have been set for growing conditions that are not relevant to the ability of farmers to implement certain practices such as the use of mineral fertilizers or early sowing dates, and that the effect of some adaptive characters encountered in traditional varieties has been underestimated (photoperodism, resistance to drought or to water logging, tolerance to low fertility conditions).

Breeders know how to handle the sorghum reproductive system but they are puzzled by the huge diversity of highly context-dependent demand. On the other hand, dissemination problems also cast doubt on a highly centralized organization of breeding. If breeders want to monitor private or public investments according to impact and economic results, they have to look for solutions for which costs are proportional to the stakes. They might rely upon coordinated consultation procedures or breeding methods and highly decentralized activities: i.e. objectives and specification setting, partnerships and breeding tasks to be negotiated locally.

Intrinsic and contextual complexity

The complexity of breeding situations may depend on intrinsic or context-dependent factors. Intrinsic complexity is largely technical and due to the biology of the plant and its reproductive system. It may induce difficulties for the creation, evaluation and fixing of new genetic variability. Contextual complexity, whether agronomic or social, is due to the diversity of constraints or uses: it requires the breeder to work on a larger number of objectives and specifications. We propose to characterize the complexity of a given breeding situation, at a given time.

For each of the main 5 breeding steps, table VII proposes indicators to describe the intrinsic complexity of a species from the breeder's point of view. At the bottom can be found autogamous species, which are relatively easy to cross and select, such as cotton, sorghum or rice whereas at the top can be found vegetatively reproduced and unstable ploidy crops such as yam or plantain. Between these two groups, species hierarchy is very unlikely and unstable, depending above all on the research efforts of the scientific community and on the level of knowledge that has been acquired at a given time. To validate this characterization, we can use the number of cultivars that have been produced by all international breeding programs, as this number at least partially reflects the difficulties encountered by breeders in creating new germplasm.

Table VII. Biological components of complexity.

Breeding step	Items	Increasing complexity ……………………▶
1		
2	Reproduction regime	Autogamous.……. Allogamous…….. Incompatibility…..… Clones
	Genetic structure	Diploid ...….…. Autopolyploid ….…… Variable degree of ploidy
	Species complex	Large ………………………………………………………… narrow
3	Breeding unit size	Small single plant ..………..…… Single tree ……………….. Plot
4	Time to production	Annual ………. ..…………. Pluriannual ……………..... Perennial
5	Crop renewal	Annual ……….… ..……... Pluriannual ...……………... Perennial

1 : Specifications (setting goals) ; 2 : Creating genetic variability ; 3 : Selection ; 4 : Testing and evaluating ;
5 : Variety release and dissemination

On a contextual level, the most simple situations correspond to programs with perfectly defined objectives in limited numbers (for example, improve the productivity of an agro-industrial oil palm estate), and which can be contained in a limited number of specification sets.

Table VIII. Contextual components of complexity.

Breeding step	Items	Increasing complexity ……………………▶
1	Interest divergences between actors	Between categories ………..…………………… ……...Within categories
	System of representation	Recognized, relevant ………. Accepted, confiscatory ….. …..… Recognized, not relevant ……..… Lacking
	Market	Industrial, standardized.…………Local, specific.……….SelfConsumption
2		
3		
4	Information	Common language..…………..………………….. Lack of understanding
5	Resistance to innovation	New crop……………..…………..……….……………...………Old crop
	Innovator place	Economic or social incentive to innovation………………………..…….
	Multiplication	Technical locks…………….. ……………………..…Seed easy to reproduce

1 : Specifications (setting goals) ; 2 : Creating genetic variability ; 3 : Selection ; 4 : Testing and evaluating ;
5 : Variety release and dissemination

When the actors are numerous, the situation gets confused. The variability of actors and situations increases and consequently the constraints the breeder has to take into account: sector privatisation may reveal and individualize new stakeholders, economic and social policies may modify operational structures towards smaller production or processing units, and lastly, expansion of the crop to new production areas may bring about new constraints. This diversity of actors and situations results in a triple difficulty related to variety specification, evaluation and dissemination (table VIII).

Figure 1 proposes a more complete representation: breeding programs are positioned in a two-axis diagram based on intrinsic and contextual complexities. Species that benefit from breeding programs that are closely linked to producers are also the ones which deal with simple or simplified (cotton, oil palm, rubber) contextual situations. Such cases are tending to become less frequent, either because production conditions and structures are changing, or because of niche marketing strategies resulting in the diversification of demand.

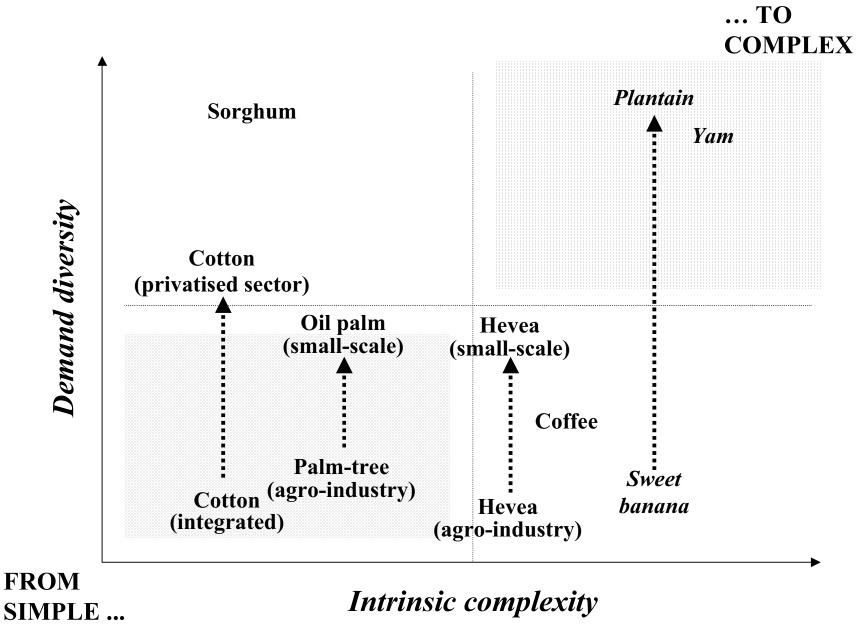

Figure 1. The complexity of breeding is a consequence of intrinsic biological factors (x-axis) or contextual social factors (y-axis).

On the other hand, when it is difficult to describe and group constraints in homogenous sets (food crops), breeding programs are not organically related to production with an explicit dissemination process. It indicates that questions raised by contextual and systemic complexity, and linked to the relations between the plant and its environment, have not been effectively solved.

Managing this double complexity has a cost because, in each case, breeders have to introduce appropriate methods and designs to overcome an obstacle preventing genetic progress from being either achieved or disseminated. In each situation, breeders have to identify the weight of each axis in the research to be developed: which is the most limiting factor when compared to the expected gains?

Breeding programs must adjust to contextual changes

A breeding project lies in the centre of an information and communication system. This system is described by its limits, components and rules. Coffee breeding in Costa Rica clearly illustrates the need for a clear description of what has to be part of the system and what should be considered as external (figure 2).

In Colombia, where the balance of power is more favourable to growers, international roasters are not crucial stakeholders and the system can be simplified. This example also shows that systems must be described with reference to a local context: they are variables in space and change with time.

Production methods are changing (rubber and oil palm)

There can be no doubt that a close partnership with agro-industry has been a powerful incentive for public research in general, and above all for plant breeding. It has helped to produce significant genetic progress. As long as world production has remained dominated by agro-industrial production methods, these programs have been quite well adapted to their objective of adaptive research for development.

However, there is a worldwide tendency towards increased land pressure. This means that large plantations are declining to the benefit of smallholdings, which ensure more competitive production and sometimes processing (oil palm) costs: they already provide 100% of annual crops such as cotton or sorghum, the major share of coffee in Central America, but also over 80% of total natural rubber production and 50% of oil palm. In Benin, for example, small scale palm oil processing meets local and even regional demand for red cooking oil. A niche marketing strategy could justify the development of a traditional product that meets local quality standards.

A large variety of ecosystems and users can also benefit from the germplasm that has been bred in the rather favourable and homogeneous estate environment. But small-scale planters may also express a demand that differs from that of estates. Some constraints are specific to the agronomic, social and economic context of smallholdings and they require smaller sizes, faster growth or better drought tolerance in oil palms, and early production in rubber.

Public breeding programs have to cope with demand for varieties adapted to sets of constraints corresponding to increasingly diverse commodity chains: smallholdings and wood production for rubber, smallholdings, craft industry and red oil, palm wine, dry and more marginal areas for oil palm. Can we reconcile diversification with globalisation? In other words, can breeders work on local specifications but with a significantly sized market? Networking could be the answer by establishing multi-site specifications with representatives of a uniform class of users.

However, with perennial crops, biological inertia is very high. Dependency ties between breeders and planters were woven through rational management of resources and skills. They need to be renewed in the light of contextual changes and new programs need to be reconsidered in relation to emerging stakes, based on well-defined and stable specifications.

Privatization reveals new stakeholders (cotton)

Integrated commodity chains, as described in the West African cotton sectors (figure 2), simplify the stakeholder system and the elaboration of a breeding program. But they also add confusion, because they transfer to some stakeholders the power of representing others. In this relationship, the breeder's favorite partner tends to impose, more or less deliberately, a hierarchy of objectives and criteria that are favorable to its own interests and may be in contradiction with those of the stakeholders it represents. For example, the cotton ginner is often also involved in extension and development projects, and implicitly considered as the growers' spokesman. All the same, the agro-industrial grower, rubber planter, producer as well as rubber processor, is also at least partially considered by the breeder as the spokesman of other planters and transformers. But the criteria hierarchy obtained when questioning him is probably different from what would be obtained through direct planter – processor negotiation.

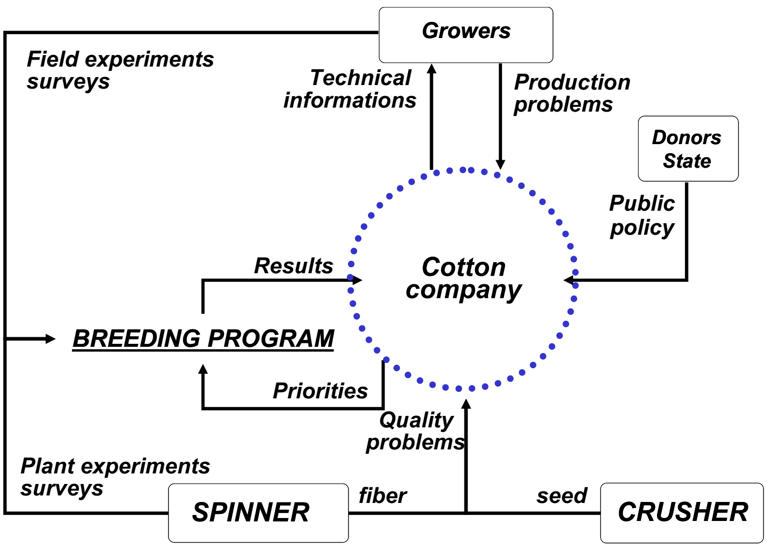

Figure 2. Information flows in the case of an integrated commodity chains.

Institutional as well as structural changes in the sectors re-allocate power cards between actors and, consequently, those linked to the representation of stakes. Planters, extension officers or backers, who used to speak for small-scale growers, users or civil societies in the South gradually lose this privilege. In Benin, the cotton company covered many different crucial activities on behalf of the commodity chain, such as organizing input supplies, fiber classifying, seed cotton marketing and seed multiplication. It mainly concentrates now on ginning and the orther activities are transferred to an interprofessional board that includes growers and ginners (figure 3).

At the same time, farmer organizations become a political force and an institutional partner that is acknowledged by the State and by international backers. On the other hand, State organizations that used to supervise agricultural development have lost the power of representing farmers' interests.

The actors' landscape changes and the breeder has to compromise with it: his ability to detect such changes, to analyse and to integrate them in modified breeding programs becomes a crucial stake for applied research. In Ivory Coast, the demand from small-scale farmers focuses on new breeding objectives and priorities, on producing and disseminating germplasm that reassures planters. Strictly planned and centralized multiplication schemes that are well adapted to large estates must be abandoned for more flexible and decentralized systems. Dissemination is ensured by numerous private nurserymen who produce grafted plants, while research keeps control over budwood distribution.

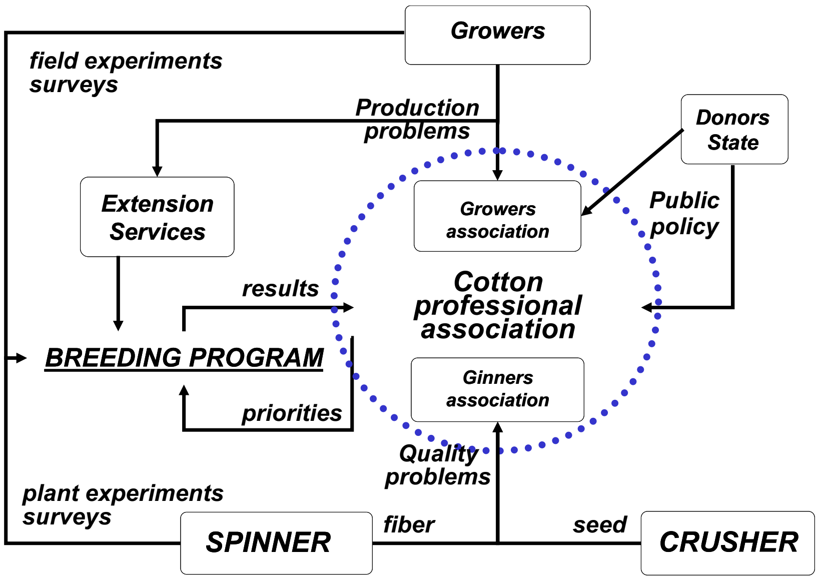

Figure 3. Information flows in the case of a board-co-ordinated commodity chain.

Formalized partnership contributes to faster adaptation

Breeding programs were brought about by actors who were willing and able to fund research. Plant breeding was promoted by a political will to support crop development on a national level in the case of cotton or on a regional level in the case of coffee. Oil palm or rubber breeding was the answer to demand from planters or agro-industry, and sorghum comes from the wish of donors or states to contribute to rural development. The quality and impact of such programs largely depend upon the strong and long-term commitment of backers.

Most long-lasting programs could rely on partnerships between research and usually few, easily identified actors, based on more (oil palm) or less (cotton) contractual relations. The contract could reproduce the contents of "specifications", shared objectives, selection criteria, commitments to resources and results, and control procedures. In addition to the already mentioned (i) formalized relations and; (ii) solid financial commitment, we believe that the success of this partnership was also linked to; (iii) jointly conducted experiments and; (iv) a shared interest in commodity chain organization.

These partnerships have been successful and they can be used as references for building those adapted to more complex demand, arising from social developments. In most commodity chains, the number of stakeholders is increasing and the uses made of agricultural products are tending to diversify.

Prior to drawing up a breeding strategy based on partnerships, breeders should carry out a systemic analysis of the commodity chain: what are the constraints, the economic stakes, the main stakeholders and the discountable financial resources? The choice and ranking of breeding criteria could be based on inquiries and negotiation bodies. But specific skills in social sciences are required when relationships between actors become complex and when stakeholders' interests differ.

Confidence is also a prerequisite for settled partnerships. Our PPB experience in Benin (Sêkloka *et al.,* 2002) confirms the importance of the principles quoted by Roybin *et al.* (2001) for an organization: co-construction, progressiveness and training. Time is required to elaborate a common language, to learn tools and mechanisms, to know each other and to let confidence grow.

Partnerships will have to be founded on control processes. In most of the described situations, breeding is driven by precisely described demand expressed by few stakeholders. Control is based on programming and ex ante evaluation: it is based upon confidence between the breeder and his backer. When the number of stakeholders increases, research is freer to maneuver but, in turn, its credibility must be built on an ex post evaluation of its results, with particular reference to the special features of research directed by partnership and action (Sébillotte, 2001).

Conceptualizing participation in plant breeding

From these considerations, we propose to adopt a general representation of a plant breeding program, in which 5 steps form the backbone: (i) specifications setting; (ii) creating genetic variability; (iii) selection; (iv) testing and evaluation and (v) variety release and dissemination. Systemic analysis of the context should provide the necessary information for choosing the best breeding strategy: which actors and operators should be involved in which prioritary objectives? Each actor's participation in the different steps of the breeding program then has to be discussed in line with the specific added value he may provide.

With this representation, we recognize that participation is not necessarily linked to decentralized breeding designs that characterize most of the acknowledged participatory breeding schemes.

The question of actors being represented by the breeder is now a very challenging one. How can the actors' spokesmen be representative of the variability in demand and their word be faithful to the interests of actors they are meant to represent? Solving this very difficult and burning issue requires the development of very close interactions between local actors, and human and technical science specialists.

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