Le programme Génoplante, programme mobilisateur en génomique végétale

Feature: Genomics and the Oilseed Sector The Genoplante programme: a mobilizing programme in plant genomics

Oléagineux, Corps Gras, Lipides. Volume 9, Numéro 2, 124-9, Mars - Juin 2002, Dossier : Génomique et filière oléagineuse - Journées Chevreul de l' AFECG, Paris, 21-22 novembre 2001

Auteur(s) : Michel CABOCHE, Michel BOUCLY, Unité de recherche en génomique végétale, Inra, 2, rue Gaston-Crémieux, CP 5708, 91007 Évry Cedex.

Author(s) : Michel CABOCHE, Michel BOUCLY

Résumé : Les enjeux de la génomique végétale sont immenses pour le secteur de la création variétale et concernent de multiples objectifs, allant de la réduction d'intrants à l'amélioration de la qualité des produits récoltés ou transformés. Une situation d'oligopole se met en place au niveau mondial avec quelques firmes provenant du secteur de la chimie, principalement aux États-Unis avec de très forts soutiens publics. En 1998, l'Inra, le CNRS, le Cirad, l'IRD pour le secteur public et Biogemma, Aventis Crop Ssciences et Bioplante pour le secteur privé s'engagent dans le programme Génoplante, acté, en février 1999, par le ministère de la Recherche, qui y apporte son soutien, pour une première période de cinq ans, afin de permettre à nos recherches, fondamentale et appliquée en biologie végétale, de rester compétitives. Le programme Génoplante comprend d'abord des programmes génériques : analyse fonctionnelle du génome d'Arabidopsis, génomique du riz, nouveaux outils d'analyse des génomes, bio-informatique, cibles importantes dans le génome des plantes cultivées. L'évaluation des projets soumis dans ce cadre est réalisée par des experts internationaux indépendants. Globalement, plus de 300 chercheurs sont impliqués dans ces projets. Il comprend aussi des programmes par espèces (blé, maïs, colza, tournesol, pois) ayant chacun une partie générique (cartographie physique, banques génomiques, etc.) et des projets concernant des caractères agronomiques, des stratégies de résistance aux maladies, ou des objectifs de caractérisation et d'amélioration de la qualité des produits.

Summary : Plant genomics issues are vast for plant breeding and apply to multiple objectives, from input reduction to improvement of harvested or transformed products. A situation of oligopoly is currently being set up worldwide with some companies from the chemical industry sector, essentially in the United States, where they enjoy a very important public support. In 1998, the Inra, CNRS, Cirad, IRD for the public sector and Biogemma, Aventis Crop Sciences and Bioplante for the private sector, became involved in the Genoplante programme which was formally recorded in February 1999 by the French Ministry of Research which sustained it for a first 5-year period in order to allow our fundamental and applied research sectors to remain competitive. The Genoplante programme firstly comprises generic programmes: functional analysis of the Arabidopsis genome, rice genomics, new tools in genome analysis, bioinformatics, important targets in the genome of crop plants. The appraisal of submitted projects in this framework is carried out by a panel of independent international experts. As a whole, more than 300 researchers are involved in these projects. It also comprises species-based programmes (corn, pea, rapeseed, sunflower, wheat), each of which being composed of a generic part (physical mapping, genomic library, etc.) and of projects concerning agronomic characters, strategies for disease resistance and characterisation and improvement of the quality of products.

Mots-clés : génomique végétale, amélioration des plantes, Arabidopsis, blé, colza, maïs, pois, tournesol.

Keywords : plant genomics, plant breeding, Arabidopsis, corn, pea, rapeseed, sunflower, wheat.

ARTICLE

Since the mid-1980s, the World Bank has been backing the liberalisation of cotton sectors in most African producing countries. The results of an analysis conducted by this institution indicated that a proper institutional framework - with less public involvement - could turn cotton countries in West and Central Africa (WCA) into a "cotton superpower". This belief in a feasible "cotton superpower" was strongly expressed during the Cotton Symposium that took place in Ouagadougou in June 2000. However, for these prospects to become reality, the current institutional shift towards a more liberalised function will require complementary actions aimed at enhancing service and provision. Adapting cultivation techniques through efficient research implementation is hence critical and this was part of the rationale of the workshop attended by some cotton sector stakeholders [2].

The liberalisation process is nevertheless producing more mitigated effects than expected. A study is currently under way to assess the outcomes and shortfalls of the process in four countries (Côte d'Ivoire, Burkina Faso, Ghana, and Zimbabwe) in order to tap the benefits of this past experience if the liberalisation process is to be continued.

Like every cotton producing country in the world, francophone countries in WCA [3] are facing a serious decline in financial resources derived from cotton production (as a consequence of the sharp drop in the world market prices [4]), thus threatening the future of this activity. Owing to this threat, an international campaign has been launched by African cotton producers to remonstrate against the unfairness of subsidy policies implemented by various leading cotton countries like USA, China, and also the European Union. This concern has been taken into account in Europe. The threat of a total collapse of cotton production, in spite of various positive economic and social trends, has been debated in the French Parliament [5]. Although the inequity of international trade is a well founded issue, we feel that the current protest will not be sufficient [6] to ensure a future for WCA cotton, and that only an active move towards enhancing productivity and competitiveness could help protect against the probable occurrence of a new crisis in the world market.

This paper analyses the specific question of enhancing productivity and competitiveness with respect to seedcotton production and processing. It firstly emphasizes the need to jointly tackle technical and institutional innovations. It provides a balanced view on the expectations from new technologies. It underlines the assets and constraints to be taken into account in assessing the technical prospects of productivity gain. It offers a preliminary analysis of technical innovation along with institutional innovations. Finally, the implications are assessed in terms of research implementation conditions.

The need to link technical innovations to adapted institutional innovations

Reality of technical innovation backed by adapted institutional framework

There is evidence that technical innovation is just one of many ways of enhancing productivity and the success of such technology transfer depends on the extent to which requested socioeconomic conditions are being met [1]. While identifying possible new technical innovations, my chief concern here was to assess how new techniques could actually be implemented so that a potential "technology future" becomes real. A clear distinction should be made between technical novelty, technical innovation and institutional innovation. A technical novelty is basically a new combination of production factors generally proposed by researchers. Technical innovation has a more socially-oriented meaning as it deals with new technical practices for farmers. In other words, technical novelty is a technical proposal while technical innovation is a technical adoption. Technical innovation could encompass a technical novelty proposed by scientists, while also integrating a proven technique derived from research conducted nationally or elsewhere in the world. What induces farmers to adopt a previously overlooked existing technique? Basically, changes in the socioeconomic production framework will facilitate adoption. This is what we call institutional innovation, which means any new responsibility sharing or role distribution arrangement among stakeholders within a production sector.

Most technical innovations adopted in WCA cotton countries could be analysed with respect to concomitantly implemented institutional innovations [2]. The extension of ox-drawn agriculture in Mali was basically linked with the promotion of village ironsmiths. The widespread adoption of organic manure in the same country was associated with the dissemination and funding of animal-drawn carts. Chemical fertilizer use became widespread at a time when national and external stakeholders decided to promote this strategy through funding incentives, thus making this input affordable for farmers. It is very likely that technical novelties that are not promoted along with institutional adjustment will not be sustainable - as occurred with the time-limited launching of glandless cotton varieties in WCA cotton countries [7]. This could also be the case with the current resistance management program which is based on alternated use of two types of insecticides. If this alternated use is not properly respected, there is a risk that the cotton bollworm will become resistant to both insecticides. Insecticide sales to farmers should thus be very carefully coordinated in order to avoid this threat.

It is hence critical to jointly examine technical novelties that could lead to productivity gain and new role sharing between cotton sector stakeholders that would promote new technical adoptions. New institutional arrangements are not always feasible. Consequently, efforts to promote new techniques must be prioritised according to the feasibility of their implementation by farmers. When a potential technique meets farmers' actual expectations and constraints there is more chance that a new institutional arrangement will effectively promote adoption of the technique.

Our proposed analysis is twofold. First, under current production conditions in WCA, the questions we are tackling are: What technical innovations would be needed? What technical knowledge do we have that would help achieve the desired technical innovations? and What institutional arrangements are needed? Second, with prospects for a new cotton sector framework, would it be favourable for the needed institutional innovations and how could these innovations be promoted when they are not set up naturally?

This analysis is focused specifically on the cotton crop instead of the whole cotton cropping system. This is debatable since any cotton productivity gain will have an impact on other crops in the system and, inversely, any productivity gain for the other crops will have an impact on factor allocation to cotton plots. The analysis presented here should thus be completed to take these interactions into consideration.

New technologies: not the only answer

Research on new technologies is often presented as the best strategy to enhance productivity. Yield stagnation, or even regression, is interpreted as a signal of the limitations of existing techniques, a situation that could only be overcome through the adoption of new technologies. This is, however, only true for economically developed cotton countries where actually achieved yields are very close to potential yields, while in most developing countries actual yields lag far behind potential yields with existing techniques [3]. This fundamental point has two direct implications. First, the relevance of new technologies adopted and implemented in developed countries should not be directly extrapolated to developing countries. Second, the starting point in analysing future technologies for developing countries must be to understand the production constraints involved.

In short, enhancing productivity in the field through technical novelties could be achieved by adapting existing techniques to local conditions, or by introducing new technologies that have been successfully implemented abroad. A complementary issue is to set priorities for implementing technical novelties, while making sure that they comply with farmers' actual production constraints.

Assets, constraints and technical prospects in cotton production

It is obviously not ideal to deal with WCA as a homogenous unit, since there are major differences between countries, between cotton zones within a given country and between cotton farmers within the same zone. Nevertheless, there are some common features that could be underlined.

Satisfactory production potential with natural advantages and disadvantages

It is seldom mentioned that tropical conditions have natural advantages for producing cotton, owing to high temperatures that sustain plant growth and sunny conditions that favour boll maturing and opening. This advantage is offset by poor and fragile soils, which limit yield potential and sustainability, and the reduced rainfall trend that has been documented in Sahelian and humid savannah regions [4, 5].

Existing production techniques ensure a quite satisfactory yield potential provided that sowing is carried out at the right time and poor soil fertility is compensated by sufficient mineral and/or organic fertilizer inputs. Some farms in WCA still achieve high yields despite the global trend towards reduction. These farms, however, are in minority and there is need to pinpoint the factors underlying this contradiction.

Perception of uncertainty and risk as a limiting factor

Predictable increase in perception of uncertainty and risk

Any perception of uncertainty or risk leads to less than optimal production investment, which is particularly true in the case of smallholders with limited resources. This perception could be derived from natural factors such as increasingly erratic rainfall patterns. This can induce farmers to react by applying fertilizers at less than recommended dosages or by adopting staggered sowing dates. This perception could be linked to income becoming harder to accurately anticipate, due to a lack of price stabilisation, of crop insurance devices or liquidity constraints (e.g., constraints that force farmers to sell their production when market prices are low).

A crucial point to clarify is how the perception of uncertainty and risk could evolve if cotton sectors function in a more liberalised way.

I foresee that purchase prices for seedcotton will become more uncertain in the mid-term after a possible short-term positive trend. Ensured outlets should help to bolster the positive trend, e.g., for farmers located close to transportation and ginning infrastructures, but not for farmers in remote areas. Competition between input providers should theoretically lead to input cost reduction. However, the lack of infrastructures in WCA is responsible for high transaction costs, thus limiting the extent of competition. Consequently, costs related to inputs will grow at the expense of the expansion of their use [6, 7]. There is little evidence that liquidity constraints are loosened by effective credit markets wherever liberalisation is implemented: the imperfection of credit markets in WCA is associated with structural factors which cannot naturally reverse without appropriate corrective actions. The inverse effect has also been documented [8].

My general assumption is that WCA farmers' perception of risk and uncertainty will rise, implying increased reluctance in using cash-paid inputs or a demand for more risk-proof techniques.

Adapt new production techniques accordingly

The increase in the perception of risk and uncertainty induces farmers to prefer techniques requiring less cash investment, and based on improved efficiency of input use or on improved security of the effects of the inputs involved. Farmers' adherence to organic manure production is a typical example of their reaction to invest more in family labour during the dry season in order to occasionally reduce mineral fertilizer use requiring cash outlays. This phenomenon implies that the extension of biotechnology output use could be limited if cash expenses were to significantly increase, as observed with respect to current costs associated with the use of genetically modified varieties (GMV) in many countries [8]. However, it is not possible to clearly assess the prospects of the GMV market represented by cotton smallholdings in WCA. Smallholders have shown an interest in adopting GMV, as reported in South Africa [9]. Deeper insight into this issue could be gained by conducting specific studies based on actual costs and efficiencies since price policies may vary between countries or between types of growers within the same country [9]. Besides, the future of GMV depends on the extent to which they actually comply with farmers' constraints. The prospects of GMV use will be assessed further in the analysis of farmers' reactions according to various types of inputs we identified.

Going beyond uniform technical messages

A uniform technical message would be unsuitable owing to ecological diversity within a given cotton country, and to socioeconomic diversity between cotton growers within a given cotton zone [11]. If farmers have to adapt to uniform production techniques, the economic outcome would be the failure of cotton production in some zones because the unique existing techniques ensures only natural advantages to some zones and not to others. This retreat of cotton production might not be politically acceptable, so researchers may be required to tailor production techniques to conditions in specific zones in order to make cotton production feasible and safe under short rainy season or erratic rainfall conditions for instance.

Consequently, new specifically adapted techniques should be developed that take perceptions of higher risk and uncertainty, as well as ecological and socioeconomic diversities into consideration.

Examples of adapted techniques to assess

Solutions to the evolution of natural factors

Cotton production must remain feasible under reduced and more erratic rainfall conditions since the long-term trend indicates a reduction in rainfall (in terms of number of rainy days and rainfall volume). A technical answer would be to improve soil water retention in order to prevent/limit the effects of drought. This could mean abandoning conventional cultivation techniques, based on soil preparation, which might also be advantageous for non-equipped farms [12].

Although some extent of pest resistance to insecticides has occurred, the negative trend in pest dynamics should not be overstated. Pest control is still feasible through a sound combination of control techniques (a more practical way of dealing with IPM). In the short run, chemical control should still be implemented, while enhancing its effectiveness and reducing potential negative impacts on the environment. This objective could be reached by adopting control programs based on scouting techniques implemented by properly trained farmers backed by agricultural warning systems. The results achieved by a significant number of farmers in Mali demonstrates that this objective is feasible [13].

Biological control offers exciting prospects, but this strategy is hard to adopt on a large scale, at least in terms of the production and distribution of efficient biological agents. Certain technical practices require some cash outlay and may be efficient. Two examples are: installing trap plants to divert part of the pest pressure away from the cotton plants; and topping cotton plants at the maturing stage in order to prevent/limit damage from picking and sucking pests, which can be detrimental to cotton quality (lint stickiness).

Genetic solutions have proven to be less costly and more sustainable. There is still room to achieve such solutions through classical varieties, but most stakeholders have turned away from this strategy and are focusing their attention on GMV which have come yet to a large extent of use. Some features mitigate optimism related to the pest control prospects of the existing GMV in WCA. The sustainability of the *Bt* GMV is debated [14] and the potential development of pest resistance is still being discussed. The gene base that is being tapped is quite narrow, so it will be hard to develop varieties resistant to the broad range of pest complexes in WCA. Adaptation of existing GMV may require high investment while the current lack of intellectual property protection does not ensure a full return on this investment. Once again, further targeted studies would be required assess this question.

Solutions adapted to the evolution of cotton farming systems

Cotton remains the dominant and sometimes only cash crop in WCA and therefore cotton acreage within cropping systems has increased significantly. Labour requirements for growing cotton has consequently increased and failure to meet these requirements has a greater economic impact. Meanwhile, social evolution within farmholdings has led to a partial loss of control of family labour. We have visited cotton plots where technical practices are not properly mastered because the farm heads have little power over the farm hands. As reported in several WCA countries, many large traditional farmholdings have split into a new type of farms of smaller demographic size [15]. This is an expression of some inter-generation conflicts that were also encountered in most developed countries. A direct consequence of this social phenomenon is an implicit demand for less labour intensive techniques for cotton growing.

The critical challenge of reducing labour investment concerns the different cotton cropping stages. No-tillage techniques could be a solution at the soil preparation stage. Farmers may, however, be reluctant to try such techniques when they have been accustomed to ploughing. Peasants farming without any mechanization should be more open to this alternative solution. Moreover, no-tillage techniques which enable labour savings for controlling weeds should be the most promising, e.g. cropping systems with mulch cover which are to be tested in several WCA countries [12]. A wide range of selective or non-selective herbicides are now available, many of which are inexpensive generic formulas that could help achieve successful weed control.

Weed population dynamics are quite slow (as compared to insect populations) but should not be disregarded [16, 17]. GMV that are resistant to some herbicides deserve special attention [18] in order to enhance weed control solutions. Actual adoption to these GWV will depend on their relative cost and the price of associated herbicides.

There are also some prospects for controlling weeds without additional cost through appropriate cultivation techniques. We found that high cotton plant densities could complement pre-emergence weed control and sidestep the need for additional weeding [19].

Little has been done to address the labour intensive harvesting stage in WCA. We believe that harvest labour requirements represent the main impediment to further cotton acreage extension. It seems that little could be done in the near future to overcome this bottleneck. Some harvesting machines are more adapted to family-size cotton cropping systems, e.g., in China, but such machines would not last long if operated on rough earth tracks. The challenge is to design a new type of machines adapted to operations on poor road networks, while being cost-effective and reducing labour needs.

Solutions adapted to farmers' input use behaviour

There is a implicit temptation to associate future technologies with low input consumption technologies owing to the well known financial resource limitations of WCA smallholders. This could be poor strategy. Of course, there is some room for maintaining yield levels with less input use through a more sustainable approach. The prospects are, however, limited since the current input use level is still very low as compared to most cotton countries. We believe that stakeholders should not be left to expect results solely from new technologies based on less input use - the main issue is to achieve better and more secure productivity through more efficient and risk-proof use of inputs. To clearly identify these new technologies, it should be kept in mind that farmers react differently to different types of inputs.

A classical well established distinction concerns cash expense criteria. Financial resource poor farmers favour using inputs requiring less cash outlay through substitution of cash-expense input by labour intensive input. This substitution is however only valid when the labour opportunity cost is low, *i.e*. during the dry season but not necessarily during the cropping season. From this viewpoint, we do not consider that the preference for non-cash expense input is always valid.

Another classical criterion is linked with the possibility of partitioning the amount of input used, e.g.*,* for mineral fertilizers but not for the seeds required to sow one hectare. This is a phenomenon that may impede the use of costly GMV seeds.

We suggest an additional criterion to distinguish input types with respect to their effects on achieving yield expectations. We distinguish a first type of input that helps to increase the yield expectation by the time of its use but whose fulfilment is dependant on various uncontrolled factors, like natural conditions. Mineral fertilizers belong to this first category. The second type of input helps to achieve the yield expectations provided by the cultivation practices or the other inputs being used. Chemical herbicides belong to this second category as they have no effect on increasing the yield expectation, while they limit yield loss due to weed competition. Insecticides also belong to this second category. There may be a third type of input which helps both to increase the yield expectation level and to fulfil this expectation at harvest.

Having distinguished these three types of inputs, we suggest that farmers are more open to using inputs of the second or third categories. We observed that farmers have actually adopted herbicides despite the fact that they are seldom subsidized [20, 21]. We also noted that, in many countries, when insecticides are accessible farmers seldom abandon their use, nor do they reduce insecticide applications to less than four times a season. Conversely, we have found that farmers tend more to reduce mineral fertilizer dosages and to postpone the period of their spray.

My conclusion is that new technologies should rely more upon using the second or third types of inputs, provided that their costs are reasonable and that farmers are properly trained in using them. During the last cropping seasons, experiments have been launched to assess the use of plant growth regulators - which we consider to be an input of the third category. It is somewhat amazing that WCA is the only cotton producing region where plant growth regulator use has been overlooked. Ongoing experiments in Benin, Cameroon and Mozambique seem to confirm that growth regulation associated with higher plant densities leads to a higher yield potential, while the enhancement of boll retention, insecticide penetration through reduced vegetative growth and improved earliness help achieve the expected yield. Moreover, this earliness gain - whereby boll maturing is grouped - implies that single harvests could be possible (instead of 2 to 3 harvests), thus leading to significant labour (and financial) savings at the harvest stage.

Technological prospects in processing cotton products

There is little to be said about the technological progress margin in processing cotton products.

In the area of seedcotton ginning, saw ginning is more widespread than roller ginning. There is also a new ginning technology which is still in the experimental stage. Spinners are advocating roller ginning as it is not very damaging to cotton lint. So far this is like preaching in the desert since most ginners - to be cost competitive - are geared to economies of scale. In WCA countries, the economies of scale issue could, however, be of a different nature than in other cotton producing countries. There has been very little analysis of the ginning alternative involving more dispersed ginning facilities with reduced capacities, which is the pattern observed in XinJiang province [10], China. Some positive economic and social impacts could be expected from dispersed and labour intensive ginning technologies. This type of dispersed network could be a starting point for some industrialisation in bush regions of WCA. Roller ginning is more adapted to limited scale production, but some saw gins are also designed for reduced capacities. In Brazil, limited capacity ginning stands are already being marketed for small village scale processing. Of course, this alternative will be hard to achieve in WCA due to the lack of decentralised energy provision. Finally, although saw ginning is an American technology that no longer protected by property right, it is somewhat striking that ginneries in WCA are exclusively USA made, while Indian and Chinese stakeholders also master this technology, which they could provide at a cheaper cost.

Local cotton lint processing is not very developed in WCA countries. As is commonly the case, start up cotton textile industries are not very demanding in terms of lint quality. Such textile industries could, to some extent, be an ensured outlet for low quality cotton lint, with top grade lint reserved for the world market.

In spite of the existence of an export market for cottonseed, there is evidence of the limited scale of this market which should be very price-elastic to any significant increase of the cottonseed supply. In this context, cottonseed should continue to be crushed locally [22]. There are likely many possibilities for increasing the productivity of this industrial activity. We noted, however, that cottonseed oil content has seldom been a key criterion for selecting cotton varieties. In WCA, oil extraction ratio is now slightly less than 18%, which could be enhanced by benefiting from genetic variability in oil contents (Table 1) [12].

Analysing specific cases of technical and institutional innovation interaction

Progress could obviously be achieved through the adoption of identified high-performance techniques. However, the adoption of technical innovations is seldom automatic unless concomitant relevant institutional innovations that set a clear framework for new responsibilities and role sharing between stakeholders are also adopted. As an illustration, below we discuss that some technical prospects which we have pointed out could remain virtual without considering the institutional innovations required.

Increasing cottonseed oil content

This is a case of technical and institutional interaction that would seem easy to achieve. A higher cottonseed oil content is favourable for the seed crushing industry, but high oil content seeds are produced by seedcotton varieties which are seldom selected since oil content is not considered to be an important criterion. Producing varieties that may also meet the needs of the seed crushing industry implies additional research work at the variety screening stage - assessment of this complementary feature requires costly specific chemical analyses. Besides, some WCA countries may lack specialised laboratory facilities required to implement the chemical analyses. Consequently, the crushing industry would have to cover the specific marginal costs for research geared to enhancing cottonseed oil content. This is an institutional innovation involving a stakeholder contribution to research funding.

In practice, there may be delicate issues to deal with when implementing such innovations. A trade-off is needed between the financial contribution and the extent of oil content increase. Should selection for oil content be secondary to selection for seedcotton yield and cotton lint characteristics? If so, there would be minimal additional costs but the expected gain in oil content could also be limited. How to prioritise breeding criteria with respect to cotton crop performance, lint quality and oil content is an issue which could hardly be overlooked and let un-clarified between the various contributors in financing research.

Lint quality management

Lint quality inevitably regresses from the sowing to the sale stages. The choice of variety to sow determines the lint quality potential in given growing conditions. Adapting pest control, managing the boll maturing process, e.g. using growth regulators or topping cotton plants, are technical practices that could help preserve the lint potential until the harvest stage. We have seen that institutional innovations are required to enhance the availability and affordability of these technical practices, thus broadening the scope of their application. Preserving lint quality after harvest depends basically on institutional arrangements. Early seedcotton purchase, associated with early payment, effectively reduces lint quality degradation after boll opening. In contrast, intra-annual price variations - with prices frequently peaking during periods far from boll opening - often prompt farmers to delay their harvests, thus submitting opened bolls to various types of biological and abiological damage. Such intra-annual price variations are commonly encountered in a liberalised seedcotton market setting. It has been documented that quality is generally overlooked in favour of quantity when ginners compete in seedcotton purchase, with the aim of boosting the ginning capacity use ratio and thus reduce the unit fixed cost [23, 24]. Actually, when ginners demand higher quality seedcotton, farmers generally decide to sell to their competitors, which leads to a general decline in quality as observed recently in Mozambique [25]. Non-monopolistic measures are required that will encourage farmers to enhance lint quality under a liberalised purchase scheme. We have no knowledge of any alternative measures that are currently being implemented. Ginners could set up a system to grade seedcotton themselves before ginning (case of Zimbabwe), *i.e.* the solution is for ginners to cover the costs associated with seedcotton quality preservation.

Beyond any reference to the seedcotton marketing system, compliance with the world market lint quality requirements implies to catch up with the lint classification standards. There are signs that such standards will be connected to HVI classification for which not any WCA country is actually being prepared to, while spinners are advocating it to an increasing extent [26]. Catching up forthcoming enhanced quality standards will necessitate serious new institutional arrangements since this process requires considerable financial investment to change habits acquired in manual grading.

The seed industry

Genetic progress has had a marked impact in WCA, and seeds have been an efficient vehicle for widespread dissemination of this progress. Variety changes for cotton are close to rates noted for major crops in developed countries *(Table 2)*.

There is, however, still considerable room for enhancing sustainable productivity through the seed vehicle. In WCA, there is no real seed industry devoted to cotton production although there is an actual seed production program. There is no real seed policy as seed prices are not set according to their cost and economic impact. Seed providers are thus not very accountable for seed germination. Seeds are not used properly, which leads to some wastage through excessive seed dosage, since seed prices are out of line with the actual economic value of this product. The negative economic impact is more harmful than the visible seed wastage. High seed dosage means higher competition between plantlets of the same hole, leading to a reduced yield potential, as also occurs with competition from weeds [27]. Then there is an economic cost for thinning, which is often implemented late [28], thus reducing the yield potential even further. The absence of an actual seed industry also means that genetic progress is not enhanced by specific "seed services", e.g. seed treatments against insect or disease attacks, or seed calibration to ensure a proper plant density in case of mechanical sowing.

A seed industry will only become reality if seed certification and control are organised and transparently implemented, which is a clear example of an institutional innovation. This is the first step towards collectively building confidence in using and paying for certified seeds. Such a building process is time consuming and cannot be obtained overnight. Of course, seed costs must be acceptable for farmers, while seed prices have to be attractive so that investors will commit themselves to this startup industry.

The particularity of GMV seeds raises the issue of how to coordinate the setting up of a seed industry with the introduction of GMV. There are two contrasting positions: one is to consider GMV introduction as an opportunity to set up an efficient seed industry, and the other is to install the seed industry first, which could keep operating irrespective of GMV usage patterns. This GMV versus seed industry launching issue is very illustrative of the inter-connection of technical and institutional innovations.

Conditions and implications in moving towards a technology future

Specific long-term research investment would be needed to actually benefit from the productivity gain we pointed out above. Since the market for technology provision will remain small in the short run, it would be hard to rely only upon private contributions or cotton sector stakeholders. A self-financing mechanism involving cotton sector stakeholders would increase the risk of over-emphasizing short-term targets. Meshing limited resources with research efficiency objectives implies prioritisation and new research implementation conditions.

A narrow market for the expansion of technology provision

In the light of my analysis of farmers' perception of risk and uncertainty and the evolution of this perception in a liberalised cotton sector, the market for technology provision should be limited in the short term. It could hardly involve stakeholders expecting quick returns. The issue of delayed returns means that technology providers must have diversified activities to offset the lack of short-term benefits, but there is a risk of activity diversification through insufficient focus on technology provision to the detriment of provision efficiency. More explicitly, the specificity of high transaction costs (e.g., due to distributing services to dispersed farmers with small-scale demands) could force technology providers to limit the costs they can control, probably by providing uniform services non-adaptated to diversified needs. Reducing transaction costs within the technology provision framework is a crucial challenge. Adapting technical dissemination systems should contribute positively, e.g. through rural broadcasting program channels.

Long-term investment in implementing adapted technologies

Time is needed to implement an adapted technology and have it actually adopted. Even in the simplest case of adopting an existing variety, showing obvious gains under a new set of growing conditions, it can take more than 4 years (e.g.*,* adoption of cultivar CA 324 in Mozambique). Obviously, even more time is required to test and adapt new cultivation techniques.

The time requirement raises the issue of a developing a sustainable financing mechanism for research implementation, or more precisely of setting up a financing mechanism in tune with efficient responsibility sharing between cotton sector stakeholders. Administrative processes that sustain research funding while research implementation is public financed is a thing of the past. Direct financing by the cotton sector is more positive, provided that decision-making is transparent and collective, which is not often the case in WCA countries. Alternative financing procedures are being implemented in USA, Australia and Israel that could serve as a model for more efficient and adapted new financing mechanisms.

There is a threat of over-emphasizing short-term issues when the financing process is too dependent on the end-users of research outputs. Achieving a trade-off between short- and long-term issues to be tackled by research scientists would be another institutional innovation, complementing that related to financing mechanisms. Seeking alternative sources of research funding (internal or external, private or public) - with obligatory transparent and controllable fund management - could be an effective way to achieve this tradeoff.

Clarifying research guidelines

Research guidelines are based on former analyses of farmers' input use behaviour. In summary, research projects should be partially oriented towards:

- enhancing the feasibility and cost-effectiveness of new production techniques based on combinations that favour inexpensive factors and reduce costly factors;

- favouring factors that farmers could actually afford;

- using a new input if it could help save more scarce factors;

- using a new input if it could help secure the reimbursement of still invested production factors.

Conditions for developing adapted technologies

Research scientists must comply with certain conditions when targeting new adapted technologies:

- the need to think differently, by efficiently managing the way a cotton plant should grow under specific natural conditions. This is illustrated by the prospect of enhancing the cotton plant canopy through rational use of growth regulators;

- a demanding open-mind, which could lead to questioning existing techniques that have been previously promoted;

- ensuring that research scientists are properly informed through documentation, attendance at international meetings and visits to major cotton growing countries;

- provision of opportunities for the research scientists to update their knowledge, e.g. in the areas of physiology, biotechnology, modelling, etc;

- greater focus on research implementation and social implications;

- some accountability of research scientists to the end-users who finance research activities. This implies taking farmers' expectations into greater consideration in research projects;

- a communication approach, by informing farmers about research outputs and integrating them into cultivation sequences so as to efficiently assess their relevance with regards to farmers' constraints.

Requirements for enhancing technology implementation

New adapted technologies do not require fewer inputs nor are they less demanding with respect to farmers. Research implementation towards a technology future will lead to enlarge the production technology choice, encompassing occasionally new types of inputs. Mastering new technologies implies a better understanding of how cotton plants react to natural conditions and how these reactions could be modified or regulated. Farmers will need to be more and better informed and trained, while research scientists will have to become better communicators and able to take full advantage of advanced message disseminating tools.

More choice possibilities may be confusing. Farmers must be assisted in their decision-making to prevent them from becoming discouraged. This means that research scientists will have to integrate their new outputs into decision-making sequences - based on the assumption that they have a comprehensive view of farmers' cotton cropping conditions - according to an interdisciplinary approach that takes socio-economic constraints into account.

How to adapt research implementation

The challenge ahead in implementing new adapted technologies goes beyond the financial and technical resources of any individual WCA country. There is some rationale in promoting a regional cotton research program that complements national initiatives. This is in line with some current thinking about a global cotton research program within CGIAR structures and should facilitate intervention of international research bodies. Such a regional program is an exciting but delicate institutional innovation as it poses the issues of making it compatible with national program contents and implementation modalities as well as implementation incentives. How to make a regional research program or national program accountable to national cotton sector stakeholders is also an issue that should be addressed in order to enhance the impact of these programs in each WCA country.

Integrating a cotton research program within a comprehensive research organisation, as is the case in most of WCA countries, comes with the risk that the bureaucracy of the embedding body could impede research dynamism. Moving towards a specific technical institute could help overcome this shortfall, but could also be viewed as moving back into a system that prevailed in colonial times. More must be learnt from existing and modern sector research organisations worldwide.

Notes :

* A first version of this article was presented as a communication within the framework of an internal workshop [1] of the World Bank in May 2001.

[1] The World Bank explorary Workshop: "The road to a Regional Cotton superpower in West and Central Africa", Washington DC, May 31, 2001.

[2] "Rôle et place de la recherche pour le développement des filières cotonnières en évolution en Afrique" Séminaire Cirad, Montpellier, Sept. 1-2, 1999.

[3] This geographic entity encompasses Mali, Benin, Senegal, Côte d'Ivoire, Burkina Faso, Cameroon, Chad, Togo, Guinea. Niger and Gambia could be included as well but their cotton production has dropped to insignificant levels.

[4] The world price is generally indicated in the Liverpool Cotton Outlook A index for specific types of cotton lint.

[5] The French Parliament organised a seminar entitled "Développement des pays du Sud et commerce international, le cas du coton". Paris, Feb. 27, 2002.

[6] "Préserver un futur au coton africain : la revendication légitime d'équité dans les échanges mondiaux ne sera pas suffisante" : forthcoming.

[7] In 1995, close to 400,000 ha of glandless cotton were sown in WCA, which could be considered as the widest experience in the world in adopting a new type of cotton varieties whose seeds could be used by monogastric animals.

[8] Taking into account a seed price of US $ 2/kg and 20 kg/ha of seeds, the seed cost amounts to US $ 40, which is, for instance, slightly more expensive than the current cost of the insecticide application program. In some countries, additional technology fees of US $ 50-100 have been requested.

[9] In South Africa, GMV seed cost is estimated at around US $ 35/ha for communal farmers as compared to US $ 80/ha for commercial ones [10].

[10] This province is producing one third of the production in the first cotton producing country in the world.

REFERENCES

1. FOK M (1995). Le coton en Afrique francophone : Révolution verte ou évolution institutionnelle ? In: Cirad, ed. *Succès et limites des révolutions vertes* Montpellier, 6 septembre 1995. Montpellier: Cirad: 80-92.

2. FOK M (1999). Histoire du développement de la filière cotonnière au Mali. Rôle et place des innovations institutionnelles. In: *Rôle et place de la recherche pour le développement des filières cotonnières en évolution en Afrique,* Montpellier, sept. 1-2, 1999. Montpellier: Cirad: 19-26.

3. FOK M (1998). Cotton yield stagnation: addressing a common effect of various causes. In: *World Cotton Research Conference 2,* Athens, sept. 5-11, 1998.

4. SERVAT E, JEAN-EMMANUEL P, LUBES-NIEL H, KOUAMÉ B, MASSON JM (1996). *Variabilité des régimes pluviométriques en Afrique de l'Ouest et centrale non sahélienne*, t. 324, série II a, pp. 835-8.

5. PATUREL JE, SERVAT E, LUBES-NIEL H, DELATTRE MO (1997). *Variabilité climatique et analyse de séries pluviométriques de longue durée en Afrique de l'Ouest et centrale non sahélienne*, pp. 779-782.

6. FOK M (2000). *Privatization of cotton sectors in Sub-Saharan Africa: impacts are still short and worrisome*. Montpellier: Cirad.

7. UPTON M (1992). Privatization of agricultural input delivery systems. In: *29^e^ séminaire AEEA Hohenheim 21-25/09/1992*, University of Hohenheim, Centre for Tropical Agriculture: 83-95.

8. ARAUJO BONJEAN C, COMBES JL (2001). *Modes d'organisation des filières et lutte contre la pauvreté : les cas du coton et du cacao*. Paris: Ministère des Affaires étrangères.

9. MENNESSIER M (2001). Dans les champs de coton OGM d'Afrique du Sud. In: *Le Figaro*, Paris, 14 mai 2001: 14.

10. VAISSAYRE M (2001). *Conséquences de l'introduction du cotonnier génétiquement transformé pour la résistance aux chenilles de la capsule (*Bt *Cotton) sur le parasitisme et les pratiques phytosanitaires des petits producteurs de la région des Makhatini Flats*. Montpellier: Cirad: 10.

11. FOK M (1999). Relancer le rôle économique de la production cotonnière dans un marché défavorable : quel appui de la recherche ? *Agriculture et développement*, 22: 4-17.

12. FOK M, SÉGUY L, ROLLIN D (1999). *Increasing cotton oil production in développing countries. Prospects from new technical practices in cotton growing. OCL,* 6: 123-30.

13. MICHEL B (2000). La lutte contre les ravageurs du cotonnier au Mali : problématique et évolution récente. *Cahier d'agricultures*, 9: 109-15.

14. PEREZ M (1999). Les insectes pourraient résister aux plantes transgéniques. In: *Le Figaro*, Paris, 7 août 1999.

15. CMDT (1991). *Étude des nouvelles exploitations selon leur origine : éclatement et migration*. Bamako: CMDT: 7.

16. DERUERE S (1998). Les mauvaises herbes ne veulent pas mourir. In: *Le Figaro*, Paris, 19 Juin 1998.

17. GOLDBURG R, RISSLER J, SHAND H (1991). Biotechnology's bitter harvest: herbicide tolerant crops and the threat to sustainable agriculture. *FPH*, 4: 2-3.

18. CULPEPPER AS, YORK AC (1998). Weed management in Glyphosate-tolerant cotton. *The Journal of Cotton Science,* 4: 174-85.

19. FADEGNON B, TOMAVO J, FAYALO G, GÉRARDEAUX E (2001). Influence de la densité de cotonnier sur l'enherbement. Communication personnelle. En cours de publication.

20. BASSETT TJ (1988). Breaking up the bottlenecks in the food crop and cotton cultivation in northern Côte d'Ivoire. *Africa,* 58: 147-73.

21. DUGUÉ P, GUYOTTE K (1996). Semis direct et désherbage chimique en zone cotonnière du Cameroun. *Agriculture et Développement*, 11: 3-15.

22. FOK M (2001). Portée et limites du marché mondial pour les sous-produits du coton en Afrique francophone. *OCL,* 8: 239-45.

23. GIBBON P (1998). *King cotton under market sovereignty: the private Marketing chain for cotton in Western Tanzania, 1997/98*. Copenhagen: CDR: 75.

24. GIBBON P (1999). Free competitition without sustainable development? Tanzanian cotton sector liberalization, 1994/95 to 1997/98. In: *La libéralisation et la privatisation des filières agricoles en Afrique sub-saharienne,* Montpellier, 09/09/1999.

25. LEMAITRE P, FOK M, JEJE J (2001). *Cotton sub-sector assessment*. Paris: PLC: 159.

26. ITMF (2001). *ITMF Travel report. Zambia, Zimbabwe, South Africa* Zurich: TMF: 13.

27. FADOEGNON B, GABOREL C (1995). Le désherbage chimique du cotonnier et du maïs au Bénin. In:

ANPP-Seizième conférence du Columa. Journées internationales sur la lutte contre les mauvaises herbes Reims, 6 au 8 décembre 1995: 1333-40.

28. FOK M, KONÉ M, DJOUARA H, BALLO D (1999). Diversité des pratiques paysannes en zones cotonnières du Mali : portée et limites des gestions d'itinéraires techniques observées. In: *Rôle et place de la recherche pour le développement des filières cotonnières en évolution en Afrique,* Montpellier, sept. 1-2, 1999. Montpellier: Cirad: 137-59.

Illustrations

Table 1. *Genetic diversity in cottonseed oil contents (source: Fok, 1999).*

	Oil contents of dried and delinted cottonseed			
	16.0-19.9%	20.0-23.9%	24.0-27.9%	28.0-31.9%
% cultivars	33.0	29.1	62.2	5.6
Number of cultivars	35	332	709	64
Total number of cultivars	1,140			

Table 2. *Adoption rate of new cotton varieties from 1955 to 1993 [1].*

	No. varieties adopted	No. varieties adopted at large scale	Average lifespan var. adopted at large scale
Senegal	7	6	6.7
Mali	10	9	4.4
Burkina Faso	14	9	4.4
Côte-d'ivoire	12	12	3.3
Togo	8	7	5.7
Benin	11	8	5.0
Cameroon	15	12	3.3
Chad	14	9	4.4
RCA	14	9	4.4