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Progress and challenges in making productivity gains in cotton production by smallholders in Sub-Saharan Africa (SSA)

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ABSTRACT

Countries in Sub-Saharan Africa (SSA) alone only contribute to a limited share of world cotton production, but when added to production from Francophone Africa Countries (FAC) their share of world exports is very significant, globally ranking second after the USA with 15% of the exported volume. Existing figures, albeit incomplete, provide evidence that FAC's cotton is among the most competitive in the world. This achievement is further noteworthy since the FAC's production does not benefit from any subsidy, while positive socio and economic impacts associated with cotton production have been emphasized by numerous academic works. The maintenance of, if not increasing, subsidy support to cotton production in many cotton-producing countries is challenging the sustainability of cotton in SSA. Correction of this current iniquitous situation needs to be contemplated through international negotiations the outcomes of which remain uncertain. In addition internal efforts must be implemented with a view of further increases in productivity and competitiveness. This paper explores progress and challenges in making productivity gains at the field level based on data obtained from surveys implemented in Mali, Benin and Mozambique, representing countries with different backgrounds in cotton crop intensification. Compared to World average, yields currently achieved in SSA countries rank from above average to low and this range of the yield distribution is related to input use, the level of which is often far below the one encountered in many other cotton producing countries. However yields obtained by the best farmers can be far above the World average and may be close to the best ones under rainfed conditions. The gap between the best farmer yield level and the average yields in SSA countries is an indicator of the potential margins within which progress could be made in making productivity gains under the existing production techniques. Significant productivity gain is possible from existing techniques, as well as with provision of adapted complementary practices. It is nevertheless hard to associate the observed yield gap with particular cultural practices or to prioritize the practices to correct this gap. The notion of managing yield expectations in connection with the management of technical patterns is introduced. Reasons and constraints to non-optimal implementation of technical practices like plant population, thinning, timely use of fertilizers and accurate spread of chemicals are identified. ¨Prospects of conventional or new technologies in alleviating constraints to help move forward further productivity gains are outlined. Under the different institutional frames of SSA cotton sectors, the extent research implementation can play in helping to increase productivity is discussed.

Introduction

Countries in Sub-Saharan Africa (SSA) only contribute to a limited share of the world cotton production, but their share in world exports are significant, when added to Francophone Africa Countries (FAC) which globally rank second after the USA and account for 15% of the exported volume (Figure 1). Existing figures, albeit incomplete, provide evidence that FAC's cotton is among the most competitive in the world. This achievement is further noteworthy since the FAC production does not benefit from any subsidy, while positive socio-economic impacts associated with cotton production have been emphasized by numerous analyses.

Cotton in SSA is produced from essentially manual farming by countries belonging to the least developed in the World with low GDP/capita and high rates of illiteracy (Table 1). In FAC, around 16 million people have their incomes dependent on cotton, therefore any significant change in the cotton production impacts directly on the poverty alleviation or accentuation in the related areas. Such fluctuations occurred recently for various reasons. Climatic trends towards reduced rainfall (volume and number of rain days) have been evident. Biotic factors also contributed to make cotton production more uncertain. In the FAC, some level of resistance of *Helicoverpa armigera* to some pyrethroids has been documented during recent seasons. In austral Africa, very severe outbreaks of new physiological disorders were reported: in Mozambique, since 1999, severe disorders which seemed to be related to psylles could reduce yield to zero. But institutional factors may have very strong negative impacts on production: in Mali, a disagreement between the cotton stakeholders decreased cotton production by 50% in 2000/01 while similar impacts were also observed in Mozambique.

The continued evolution of cotton production is uncertain in many SSA countries, in particular the crop's future in FAC is under serious threat. Persisting if not increasing support to cotton production in many developed cotton-producing countries is threatening the fate of cotton in SSA. Correction of the current inequitable situation must be contemplated through international negotiations the outcomes of which are uncertain. Consequently, internal efforts must be made with the view of further increasing productivity and competitiveness.

This paper explores progress made with margins in productivity gain at the field level based on data obtained from surveys implemented in Mali, Benin and Mozambique, representing countries with different backgrounds in cotton crop intensification.

Basic information on the surveys and the surveyed farms

The survey in Mali was implemented jointly by Cirad and the Malian research organisation (Institut d'Economie Rurale) in the 1998/99 cropping season. It encompassed 85 farms in six villages of Southern Mali (under the influence of the cotton company Compagnie Malienne de Développement des Textiles, CMDT). Of these farms 10 did not grow cotton and of those which did, many grew a number of plots of cotton. The survey recorded the farms structural features (population, equipment, animals etc.), cropping systems and a special follow-up of the farmers' technical practices was implemented on the plots of the main crops (namely cotton and cereal crops). The survey in Benin was carried out jointly by Cirad and the Unité de Recherche Coton et Fiber (URCF) of the Institut National de recherche Agronomique du Benin (INRAB) during the 2000/01 cropping season. The survey sample was composed of 150 farms in six villages of the Central North of the country, around 20% of the farms did not grow cotton. A survey procedure similar to Mali was carried out to acertain the farm structures and the farmers technical practices on cotton plots.

In Mozambique, two surveys were conducted in the Northern Province of Cabo Delgado, in the area under the influence of the cotton company Lomaco Ltd. at an extensive scale, which allowed them to deal with samples of around one thousand farms for each survey, at least to capture the farm structural features. The first survey carried out during the 1998/99 season was intended to address the general features of the farming systems while the second one was conducted in the 1999/2000 to assess the farmers' practices in controlling pests especially after the outbreak of the physiological disorder mentioned above. Owing to the collaboration of the cotton company there, yields were recorded per cotton farm for around 300 farms, from the statistics of the cotton company which traded the farmers' production and which provided insecticide inputs on credit. Examination of the data provided showed that some farmers experienced total production collapse (zero yield) which could be sometimes be attributed to very severe occurrences of a physiological disorder (suspected to be related to the outbreak of psylles) but which may also reveal some farmers' attempts to cheat the cotton company in order to escape from reimbursing the input credit (these farmers transferred totally their production to others who demonstrated then a very high yield level). Such a phenomenon does not modify the average yield but amplifies the extent of yield variation: for this reason, yield distribution is not further analyzed in the Mozambican case.

The extent of the follow-up of the farmers' cultural practices during the growing season varied between countries, according to the skills of the staff directly involved. It was quite intense in the case of Mali where a specific survey team was involved, intermediate in Benin, and rather extensive in Mozambique.

Agricultural production is dominated by family farming, exclusively in Mali and Benin (where commercial farms never existed) and even in Mozambique where commercial farms have played a decreasing role for many years. Family size varies greatly, in relation to the cultures and recent histories of each country (Table 2). In Mozambique, families are nuclear ones, with a small size (less than four people per farm), which means also a great labor constraint. The opposite is evident in Mali where farm holdings pertain to enlarged families where polygamy dominates. On average, families are composed of more than 14 people, implying that family labor is available but this is also a constraint due to the need to devote much of this labor to maintain food needs. The situation in Benin is intermediate with around eight people per farm.

It is noteworthy that Mali is an African exception in terms of the degree of animal-drawn agriculture in the cotton growing areas (around 85% of the farms). In Benin, agriculture remains essentially manual while it is exclusively the case in Mozambique. In spite of its high total cotton production, the cotton share in the cropping system remains around 30% in Mali. The survey data gave a figure, which is a little bit higher in Benin and in Mozambique.

Levels of productivities and costs

Low Productivities and incomes in spite of respectable outcomes/ha

With reference to productivity and incomes, Benin and Mali demonstrate outcomes, which are very similar (Table 3). Farmers have on average 3.2 to 3.6 ha of cotton respectively in Benin and Mali, but owing to the smaller farm size in Benin, the extent of the cotton specialization in this country is higher. The average lint yield (deducted from the conversion of the seedcotton yield by applying a ginning outturn of 42%) varied from 550 to 564 kg/ha. In comparison, the figure obtained for Mozambique is low (less than 100 kg/ha), in spite of the fact that it is a more favorable climate for cotton, indicates the yield gap, which is common between eastern-austral African countries in comparison to the western African ones. The mean cotton area (0.8 ha) is also very small, illustrating the reliance on manual farming. Cotton cultivation provides farmers with an average gross income of around US $350/ha in Benin or Mali, or around US $1200 per cotton farm. After deduction of the cash expenses for chemical inputs (fertilizers and insecticides exclusively, seeds were free), net income reaches a little more than US $250/ha or US $900 to US $1100 per farm.

Due to the high demand on staff to record the labor actually invested in cotton growing, calculation of the productivity (labor productivity) was not possible. Consequently, a proxy of this was made by estimating the gross income per family worker number. This method does not take into account the family workers who do not work only in the cotton fields.

Taking into account the cotton growers family sizes, cotton cultivation contributed US $193 and US $147 of gross income per family worker respectively in Benin and Mali, or respectively US $180 and US $127 of net income. Regarding the profitability of the cash expenses engaged on chemical inputs, the output/input ratio is 3.8 and 3.7 for Benin and Mali, which is higher than the 2.5 to 3.0 threshold which is commonly considered to justify such costs. In a nutshell, cotton growing appears to be financially sound in Benin and Mali.

Because cotton has a relatively secure outlet on the World marketplace, the figures emphasized above are indications of the cash income that farmers can generally rely on. Although this guaranteed part is not the total cash income that cotton farmers obtain, it is a proxy to appraise the farmers' poverty situation relative to the general level in their respective countries. In absolute terms, incomes derived from cotton cultivation are still low: this is an indication that there is scope to improve them through productivity gain. In relative terms, there is some evidence cotton producers are not necessary the poorest among the poor. GDP per capita is reported to be US $368 and 242 in Benin and Mali, our figures of net income per family worker which are also net of expenses for housing and food, indicate that cotton farmers may be better off than many other inhabitants in their countries. This assumption is a matter of consideration in the poverty alleviation schemes to be promoted in the developing countries where agricultural promotion could make sense. In other words, this assumption highlights the negative impact in terms of poverty alleviation if cotton production is disrupted for some reason.

In Mozambique, the situation is far less positive. Yields and gross incomes are very low (US $25 per farm), and net income is very limited and not always positive. Gross income per capita is only US $4.90: therefore cotton cultivation is unlikely to contribute much to alleviate poverty under the cultivation techniques measured here.

A matter of extensive to low-intensive production

In Benin and Mali, sound yields are achieved at relatively low cost, with an average cost of US $/ha 94 and 82 respectively (Table 4), far lower than what is required in developed countries for similar yield level: in the USA, seeds and pesticides alone total US $347/ha not mentioning many other expenses that African growers do not encounter (total cash expenses amount to US $746/ha in the Mississippi Region).

The total cost in Benin and Mali encompasses US $56 to US $58 for fertilizers and US $25-39 for insecticides. It is noteworthy that, for both countries fertilizer cost is far higher than the cost for chemical pest control: this is opposite to what is encountered in the USA where pesticides account for US $213/ha and fertilizers for US $86/ha.

It is noteworthy that chemical pest control in Mali, with a comparable number of insecticide applications, is significantly less expensive in spite being a landlocked country, which normally means higher prices for imported goods. Actually farmers in Benin do not benefit from lower prices in insecticides after their provision was liberalized which contradicts the assumption that guided the liberalization move.

Cotton production in Benin and Mali remains little intensified in terms of chemical use. Fertilizer dosage amounts to 200 kg/ha while chemical insecticides are applied five times with a total dosage of 4.9 to 6.4 l/ha in our survey samples.

Occurrence of some level of pest resistance of *Helicoverpa armigera* to pyrethroids is now evident in recent seasons in West Africa, this is an indication that introduction of Bt cotton could be relevant. Data from our surveys clarify the financial constraints that such an introduction would face, with reference to information from South Africa where the adoption of Bt cotton by smallholders is under way. For recent seasons, Bt seed is sold at R 387/ha with an additional technology fee of R 350, totaling R 737/ha or around US $82/ha, which is the level of current total cash expenses that farmers have to pay currently in Mali. Such a financial gap appears hardly acceptable before considering the "revolution" farmers would have to accept in paying for seed when they are used to obtaining it for free. Without any change in the conditions and costs attached to the dissemination of Genetically Modified varieties in the developing countries, successful introduction of such varieties in SSA appears to be unlikely at present.

Cotton production in Mozambique is totally extensive with nearly no recourse at all to chemicals. Chemical insecticides were applied with an average three applications during the survey season (which were very unfavorable climatically and were associated with a severe outbreaks of physiological disorders). Although the introduction of Bt cotton is advocated by some people in Mozambique, no pest resistance to insecticides used there has been reported so far, therefore, the value of its implementation at the smallholders' level would appear to be uncertain.

Generally speaking, productivity and income are low in spite of some of the quite sound indicators mentioned above on a per hectare basis. Due to these relatively low input costs, significant gains cannot be expected from their reduction. Similarly the use of genetically modified cotton (GMC) is unlikely to provide a significant reduction in the cost of pest control, which is already very low. Instead, productivity gains could derive from more optimal use of the limited inputs used and there are signs that there is room for such a gains to be made.

Prospects for productivity gain

In appraising the prospects for productivity gain, it is necessary to identify farmers' groups whose performance can be assessed and to clarify and measure what factors impact negatively on their performance. In the following discussion, we focus mainly on results coming from Mali and Benin.

Difficulties distinguishing distinct performing groups and consequences

We favor using descriptive statistics to clarify whether farmers' groups are distinct in their performance or their input use. Since histograms are very sensitive to the class limits one selects, they are not suitable for showing bimodal distributions. Examination of the curve of cumulative frequencies is more useful, but it does not readily detect existence of two or more modes when these modes are rather close. Gaussian transformation of the X-axis values of the cumulative frequencies curve in the Q_Q plots (for Quantile_Quantile), and compared to the values of a true Gaussian distribution (with similar mean and variance) enables easier identification of multiple modes. Figure 2 represents a case of clear deviation from the normal distribution and indicates two modes with concentration around of the mode of lower value (this figure was obtained from the XLstat software and has axis inversed as compared to Q_Q_Plots established by SAS software).

Analysis of the Q_Q plots obtained from the surveys in Mali and Benin do not clearly identify the existence of more than one group of farmers based on their production performance or in their production costs. Even though a second mode is indicated, the size of the related second group of farmers is small (Table 5).

In view of improving the average level of the productivity in one country, either the leading group or the lagging group could be selected for the targeted actions. Our analysis of the performance distribution shows that the leading group is by far the smaller one and that addressing the larger lagging group would have more impact. Assembling the means to boost the productivity will not be effective without proper targeting of the right issues: consequently, it makes sense to firstly identify the key factors that impact negatively on current performance.

Factors impacting on the current productivity

Many variable factors involved

In addition to the intensification level of chemical use, which is analyzed above, several other factors impact on the yield achieved. Sowing date is acknowledged to be of particular importance, and optimal sowing period has been clarified by previous research, which has led to technical recommendations encouraging farmers to comply with this period at sowing. At the research station level, experiments specified the yield loss per day of delay with reference to the optimal planting period. A range of agronomic practices is also of acknowledged importance including: periods of thinning, of weeding, of spreading fertilizers or of application of insecticides. In African countries where the use of herbicides remains limited, except in some cotton zones like in Mali or Cameroon, competition from weeds could have significant impact on yield expectations. The same occurs with late thinning, since manual sowing and free seeds lead farmers to sow many seeds within the same hole, increasing then the competition between cotton plants.

Table 6 indicates that, for the survey year in Mali, sowing complied with the recommended period, thanks to timing of the rains. However, the plant density actually achieved was lower than the recommended density of 80,000 plants/ha in spite of the fact that the plant density at emergence was sufficient to ensure the recommended density. The reduction observed to plant density occurred at the thinning stage when more plants were removed than necessary. Although plant compensation for below optimum density can normally be expected to reduce negative impacts on yield, thinning can be initiated too late for maximum compensation to occur.

For many agronomic inputs, delays in the recommended timing of implementation of critical operations or variations from recommended dosages of chemicals are common. For instance, thinning and first weeding occur late in around 50% of the cotton plots. Figure 3 gives another illustration of the importance of such delays. The same occurs with the period of application of fertilizers: many farmers spread fertilizer compounds and urea at the same time, but this is commonly later than recommended (Figure 4).

Farmers' practices in implementing chemical protection against pests vary considerably. They commonly wait a constant the number of days after sowing before implementing the first chemical spray even if earlier spraying may be justified (Figure 5). At the other end of the season many farmers cease chemical control earlier than recommended which is consistent with the lower yields achieved (Figure 6). These observations demonstrate that farmers do not manage chemical control optimally.

Similar delays and mistimings are observed in Benin for each of the agronomic practices we analyzed in Mali. In Mozambique, interviews of the sample of 1000 farmers revealed that nearly 70% of the farmers destroy their cotton crop residues less that two months before sowing for the new season (Table 7): this is a practice that may explain the high level of jassid infestation that can occur early in season.

All the deviations from recommended practice we observed are indications that farmers are either not sufficiently aware of the negative impacts of these deviations may have, or that they are facing constraints in implementing them on time, or they are not convinced by the soundness of the technical recommendations they obtain. Since that most of these recommendations were made through a technical optimization approach and not an economic optimization process, it would not be wise to conclude that farmers are necessarily wrong (from a technician perspective), nor that they are necessarily right (from a pro-farmer perspective). A comprehensive economic analysis of the farmers' practices is needed as a means of identifying the proper actions to undergo in order to improve productivity. Nevertheless, such an analysis is not a simple one because it is quite difficult to relate farmers' performance (yield) to a single factor.

The outcome of a cotton crop depends on how optimal was the implementation of the various cultural practices. We observed that there is some variation in the implementation of these practices, therefore identifying any practice that accounts for most of the yields achieved becomes an important issue.

Regression analysis shows that it is not possible to claim that all the agronomic practices acknowledged to be critical in seedcotton production actually demonstrate significant effects (Table 8). Although most of the signs (but not all) of the correlations are consistent with knowledge derived from previous research work at station level, only a few of them are statistically significant, and they are not common to both of the countries considered. Furthermore, individual coefficients of determination of the significant practice are low, indicating that each one contributes only to a limited extent in the yield achieved.

Multiple regressions do not improve the analysis substantially. The broad effect of the combination of several variables being considered (from sowing period till the duration of the chemical pest control) is significant, but it enables only explains 42% to 70% of the yield variation obtained (Table 9). Only a limited number of the variables showed a significant effect in Mali: sowing period, dosage of compound fertilizer, delay in implementing the first insecticide spray and the number of insecticide sprays. In Benin, only two variables are statistically significant, and they are different from those encountered in Mali: delay in the first weeding and in spreading the compound fertilizer.

These results seem to contradict some research results at station level. For example it has been found that within some limits, the earlier the sowing, better the yield. Similar results were obtained with regard to weeding, fertilizing and pest control. However, all these results were conducted through experimental approaches under which the effect of one factor was varied and all the other factors were kept unchanged and conducted in the optimal way. At the farmers' level, especially when smallholders with limited means are considered, the assumption that all the cultural operations are conducted optimally is not a realistic one, for this reason, it is not surprising that some results achieved with specific agronomic practices in research cannot be confirmed at the farmers' level.

The apparent contradiction that our results point out does not mean that the research results were not correct, nor that they are not relevant. It only suggests that we should remain cautious when extrapolating the expectation that research results will all apply at the farmers' level. With regard to achieving productivity gain, our results show that this is unlikely to be derived from the improvement of a specific practice. In other words, achieving significant productivity gain is likely to be far more challenging that one may think.

The challenge of the management of technical patterns along with yield expectations

Our analysis suggests that it would be difficult, at the farmers' level to assess the impact of a specific factor (cultural practice) in isolation from others. To succeed such an assessment should take into account what occurred prior to the execution of the specific cultural practice analyzed, and what may happen after. Sequences of cultural practices differ between farmers, they are not all optimal, and a specific practice may perform positively within some sequences and rather poorly within others.

In order to appraise the impact of a specific cultural practice, or to clarify how to decide on the implementation of such a practice, we consider the notion of how the quality of the management input can affect the yield (or profitability) expectation at any stage of the crop (Figure 7). In a given location and year, this expectation is the highest before sowing (if not before soil preparation), but it can only be maintained if all the cultural practices are implemented optimally and if no adverse biotic or abiotic events occur (Figure 7, scenario 1).

During each stage of the cropping season the way in which cultural practices are implemented will maintain the yield expectation (but not necessarily the profitability expectation) or reduce it. From stage to stage, if reduction occurs, it is usually cumulative. By poorly implementing practices, a farmer may still achieve a disappointing yield in spite of having sown his cotton early enough. Conversely, by implementing practices in an optimal way, another farmer could maintain the expected yield expectation he had at sowing time (Figure 1, scenario 2). Conversely, if he sowed later and had a lower initial yield expectation, with good management his final yield could be effectively maintained (Figure 1, scenario 3).

This approach in considering yield expectation can also be used to address profitability. Managing inputs to maintain expected yield, does not guarantee that profitability will be maintained because the costs of the inputs needs to be considered.

Models could be helpful in formalizing this notion of management of yield or profitability expectation but they would not be easy apply in the context of African agriculture and therefore of limited use. Moving towards such modeling is not our aim here, our point is mainly to emphasize the need for flexibility in considering the implementation of various inputs and practices at a more empirical level. For example, ploughing before sowing probably impacts positively on yield but not if it will further delay sowing time. Or spreading fertilizer at recommended rates does make sense if the sowing period is correct and weeds effectively controlled, otherwise fertilizer rates should be reduced. Many other examples could be considered to illustrate how flexibility could be guided.

The surveys we implemented show that farmers are already expressing some of this flexibility, according to their own experience, and more or less successfully. The challenge to face in making productivity gains will depend on feeding in sound information and knowledge to help farmers' decision-making. We doubt that such a "feeding in" will only result from conducting experiments at research stations alone or from just organizing opportunities for exchanges of experiences between farmers. We think that both must be combined. Experiments at research stations are helpful in acquiring basic knowledge and understanding the physiological and biotic phenomena that impact on yield. This knowledge will enable better understanding of the results farmers obtain through their experience and the interaction will assist them in commanding improved management decisions.

Reasons underneath the observed practices and consequences in R&D

It is beyond the scope of this paper to clarify the farmers' reasons for all the practices observed. We limit ourselves to analyzing a specific practice in order to point out that several reasons could be considered, not necessarily all relevant, and that the technical implications (if not institutional ones), in terms of research orientation and service provision to farmers, will differ according to the reasons one favors.

In the case of Mali where dissemination of technical messages to farmers dates back several decades, it is quite interesting to observe that basic practices like thinning and weeding are so poorly implemented as we pointed out above. This observation is not consistent with some views, prevailing in Mali, that Malian cotton farmers are competent with basic techniques and that they no longer need conventional dissemination of basic technical messages. If these views prevail, they could be detrimental for future cotton productivity in Mali.

Several reasons could be considered to explain the implementation distortions identified. One is to consider that distortion resulted from lack of continuity between the dissemination of technical information and a portion of the farmers who grow cotton nowadays, the youngest ones, especially those who separated themselves from their fathers' farms, may not have benefited from message diffusion earlier. If this reason is correct, the issue could be resolved by properly resuming technical message diffusion.

Another reason is that although many farmers know how and when to implement thinning and weeding, the matter is that they lack the labor to do so, since food crops have to be looked after as well and this may be in preference to their cotton. If this reason is the correct one, the issue could be resolved by saving labor from thinning and weeding. This could occur by reducing the need to thin, a situation that could result from new methods in sowing and from more consistent quality of the seeds the farmers obtain. Labor saving in weeding could derive from a more general use of herbicides. The use of herbicides is already somewhat significant in cotton zones in Francophone Africa, but their relative high cost is the major impediment to scaling up. We suspect another impediment is related to the perception of some people with regard to herbicides. For those people involved in extension, herbicides have been, and still are in some extent, considered as an input, which would encourage "farmers' laziness". For external observers who imagine that Africa does not suffer from lack of labor, weeding is not regarded as a constraint. Finally for observers sensitive to environment protection, the less farmers use chemicals, the better. In a nutshell, to successfully address the issue of thinning and weeding will demand technical, institutional as well as perceptional change.

A third reason more related to the social evolution in the cotton zones must be considered as well. In this scenario farmers do know how and when to implement thinning and weeding. They have enough labor to implement it, but their family labor force has lost the capacity to function in a coordinated manner. Intergeneration conflicts have become real in significant number of cotton farms, in every country where this production has been promoted for a long time. These conflicts are fed by the feeling about the inequitable distribution of the cash generated by cotton cultivation. If the youngsters observe that cash is mainly captured by the farm heads, as it is very common, they may consider that cotton is only a cash crop for their fathers but not for themselves and they may find less reason in working hard to generate more cash. This situation is the basis of the phenomenon of farms splitting apart. Scientists cannot address directly such a social issue, but their role is to anticipate what consequences could come out of it and prepare technical solutions to help alleviate the possible negative consequences. A direct consequence is a reduction of the farm size with reduced labor for each farm. This phenomenon will therefore increase the labor constraint and dictates the need for more investment in new techniques to enable labor savings.

Balanced conditions to achieve productivity gain

The challenge of increasing productivity depends upon the promotion of new techniques more adapted to the farmers' constraints, among which labor constraint and lack of financial resources are of paramount importance.

On the one hand, the current situation is positive. Several new techniques are available or are under proposals for large scale testing in various countries. They pertain to the Genetically Modified varieties (that could potentially save insecticide use or enable weed control with reduced labor) or non-conventional farming (that may be more environment friendly in addition to ensuring better input use efficiency).

On the other hand, adaptation of these new techniques requires increased research programs combining experiments at station level and interaction with farmers' experiences. Unfortunately, most of the research teams have suffered from stagnation if not reduction in trained staff during the last two decades. There is little sign that this situation will be reversed in the short term.

In addition, it is one thing to carry out testing with newly adapted techniques to enhance productivity, but it is another to have them adopted in practice, this is particularly true for techniques that require cash expenses. Farmers need at least two conditions to adopt techniques that require cash expenses. One is financial incentive to take the financial risk of cash expenditure. Incentives such as a secure outlet for their cotton production are required, as well as an attractive pre-announced price which is honored at the trading stage. The other condition is access to the required inputs at reasonable prices and credit conditions. All the cotton sectors in Sub-Saharan Africa are being influenced by institutional changes, which have not yet settled down. There are signs that farmers have not become necessarily better off by these changes. For the first time, farmers were paid at lower prices than were announced before sowing and some farmers in Benin and Côte d'Ivoire have not been paid for the production they sold. These current negative outcomes could be corrected through adjustment of the institutional frameworks but this is time and resource demanding. Owing to the bearish world market, distorted by subsidies in developed countries, it is difficult to expect that the SSA cotton sectors with their decreasing financial means will be able to overcome the current shortfalls. External funding is taking place in some countries to complement the national efforts, but we doubt that they are focusing on the issue of productivity gain or addressing this issue properly.

Conclusion

We processed data obtained from several surveys at farmers' level in Mali, Benin and Mozambique in order to assess the current level of productivity, to explore productivity gain and to understand the distance between what farmers achieve and what technical research would predict. We observe a great gap between what Mozambique achieves and what Benin and Mali obtain. For low-productivity countries like Mozambique, as those located in eastern and austral Africa, Benin and Mali set up productivity milestones that could inspire them.

For countries like Benin and Mali, productivity and income performance achieved at the hectare basis are quite comparable to those developed countries can obtain, but at the farm scale, they are still low because of limited farm size and labor constraints. Nevertheless, incomes induced by cotton cultivation net of cash expenses and expenses to cover lodging and food needs indicate that cotton farmers are not the poorest among the poor in their countries. In other words, cotton does contribute to poverty alleviation in rural areas, there it would be very dramatic social consequences if cotton production was disrupted.

Farmers in Benin and Mali achieved sound performance at very low production costs. This observation implies that productivity gain is unlikely to derive from further cost reduction and that cost reduction experienced nowadays by some other cotton countries may not easily be extrapolated to African countries. More precisely, we observe that fertilizers cost far more than insecticides, this is quite the opposite situation to many other cotton countries like the USA. The use of GM varieties helps mitigate the insecticide costs in several countries but it would not be necessary the case in the African countries.

Productivity gain should result more from the improvement of the efficiency in the input use, where inputs are at the lower levels because African farmers are unable to afford higher levels. This improvement requires a better understanding of who farmers are and how they perform. Our data demonstrate that they are rather homogenous in the way they grow cotton. Even though one may assume that a distinct group of better-performing farmers may exist, this group is of limited size. A significant increase of the whole productivity in the related countries would not derive from the improvement by the farmers of this group but by the large number of farmers belonging to the other group. A practical consequence is that relevant means must be engaged to push this large number to move forward. In other words, it is unreasonable to expect a general productivity gain through limited investment targeted at a limited number of farmers.

Investment in promoting productivity gain would not be automatically effective if it is not properly targeted. It requires an understanding of what are the factors which impact on the yields farmers achieve. Our analysis points out that there is great variation in the way farmers implement the various technical practices in cultivating cotton, some with notable distance to technical recommendations. Furthermore, we observed that critical techniques like thinning and weeding may be implemented with too much delay and this may impact very negatively on yield. This is an indication of poor technical information continuity even in a cotton zone where technical dissemination dates back for a long time and which also contradicts the conclusion of several recent studies.

It is unreasonable to expect a close relationship between yield and specific cultivation techniques as the latter have come from experiments at the research station level. This is not due to a dismissal of the knowledge supplied by research experiments, but rather an objection against a too simplistic extrapolation of the results at research station level to the farmers' level. The basic reason lies in the fact that it is not possible for farmers to implement all the technical practices in an optimal way. We introduced the notion of the management of yield expectation (or at a more complex dimension of profitability expectation) in order to understand why yield varies so much and why it is difficult to relate yield closely to a limited number of specific cultivation techniques. As a consequence, actual productivity gain will not result from targeting actions on the improvement in just a few technical practices. The issue is therefore to assist farmers in their decision-making while managing their profitability expectations. Such a process will require more exchange with farmers and continuation of experimentation at research station level to gain more knowledge needed in interacting efficiently with farmers. Both types of activities would involve scientists in a re-launch of research activities. However, we observe that the current institutional framework is not very favorable to such a re-launch.

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Table 1. *Some macro-economic feature of cotton production in FAC.*

	Total population (10^3 in 2001)	Rural population (10^3 in 2000)	Rural population w/cotton (10^3 in 2000)	GDP/capita income US $ (2001)	Adult literacy rate (% in 2001)	% Manual farms
Benin	6 446	5 207	2 500	368	37,4	60
Burkina Faso	11 856	8 320	3 000	196	23,9	60
Cameroon	15 200	9 640	1 300	644	75,8	70
Central Africa	3 782	2 037	900	247	46,7	
Côte d'Ivoire	16 349	8 562	1 600	563	46,8	70
Mali	11 677	8 642	2 000	242	41,5	15
Senegal	9 662	5 635	500	477	37,3	50
Chad	8 135	5 415	3 000	183	42,6	
Togo	4 657	2 723	1 200	266	57,1	85
Total/average	87 764	56 181	16 000	354	45,5	58,6

Table 2. *Demography and cotton share in cropping system.*

	Mali	Bénin	Mozambique
	1998/99	2000/01	1999/00
Inhabitants per farm	14,4	8,2	3,5
Total Family farm workers, Equivalent man.worker	8,7	5,3	1,9
Male Family farm workers, Equivalent man.worker	4,2	2,8	0,5
Female farm workers, Equivalent man.worker	4,5	2,5	1,4
Total cultivated area (ha)	9,5	5,5	2,2
Cotton area (ha)	3,6	2,9	0,8
Cotton share in cultivated areas (%)	29,5%	36,9%	40,2%

Table 3. *Incomes from cotton cultivation.*

			Lint yield	Acreage	Cotton gross income		Cotton net income		G. inc./worker
			(kg/ha)	(ha)	$/ha	$/farm	$/ha	$/farm	($)
Benin	2000/01	Average	564	3,2	345	1187	252	887	193
		St. D.	121	2,5	74	1042	74	816	167
Mali	1998/99	Average	550	3,6	346	1278	253	1107	147
		St. D.	194	2,8	122	1157	203	1142	136
Mozambique	1999/2000	Average	94	0,8	31	25	19	17	18
		St. D.	143	0,6	48	48	42	43	40

NB. Averages per hectares derived from calculations made on individual plots, while averages per farm are computerized from data of individual farms, which may encompass various numbers of cotton plots. Incomes per farm cannot be deducted in this table from multiplying the figures at the hectare basis by the number of hectares.

Table 4. Comparative intensification and costs.

	Mali		Mozambique		Benin		USA, 1999
	Average	St. D.	Average	St. D.	Average	St. D.	Mississippi Portal Region
Urea use (kg/ha)	51	34	0		28	31	
Compound fertilizer use (kg/ha)	146	57	0		177	55	
Total fertilizer use (kg/ha)	200	69	0		205	59	
No. Insecticide application	5,2	0,9	3,0	2,0	5,0	1,2	
Insecticide use (l/ha)	4,9	1,7	3,2	2,0	6,4	1,9	
Total cash input cost ($/ha)	82	24	12	8	94	20	
Fertilizer cost ($/ha)	58	20	0		56	16	86
Pesticide cost ($/ha)	25	8	12	8	39	12	213

Table 5. Synthesis from QQ_plots examiniation.

	Mali			Benin		
	Distortion to normal distribution	More than one mode?	Concentration around the lower mode?	Distortion to normal distribution	More than one mode?	Concentration around the lower mode?
Plant density	-	-	+	+++	+++	+++
Cotton acreage per farm	+++	+++	++	+++	++	+
Seedcotton yield	+	+	++	+	+	++
Total input cost	++	++	++	+	+	+
Fertilizer cost	+++	++	++	++	+	+
Insecticide cost	+++	++	+++	++	+	+
Compound fertilizer dosage	+++	+++	+++	++	+	-
Urea dosage	++	++	++	+++	+	+
Insecticide dosage	+++	++	++	++	+	+
No. insecticide sprays	++	-	-	+++	-	-
Delay for 1st insecticide spray	+	-	-	+	+	+
Delay for compound fertilizer spray	+	+	++	+	+	+
Delay for urea spread	-	-	-	++	+	++
Delay for thinning	++	++	+	+++	+++	++
Delay for 1st weeding	+	++	+	+++	+++	+
Gross income per ha	++	++	++	++	++	++
Gross income per farm	+++	+++	+++	+++	+++	++
Income net of input cost, per ha	++	++	++	+	++	+
Gross income per family worker	++	++	++	++	+	++

+++ Very clearly; ++ probable; + suspected; - No

Table 6. Distribution of technical practices on cotton plots in Mali and Benin.

	Mali			Benin		
	First quartile	Median	Third quartile	First quartile	Median	Third quartile
Sowing date	May 29th	June 3rd	June 10th	June 1st	June 10th	June 20th
Plant density/ha	38500	47100	52500	30200	33900	39900
Compound fertilizer dosage (kg/ha)	112	140	169	150	200	200
Urea dosage (kg/ha)	37	50	66	0	17	50
Insecticide dosage (l/ha)	3.9	4.6	5.5	5.5	7.0	8.0
No. of insecticide sprays	5.0	5.0	6.0	4.0	5.0	6.0
Delay for 1st insecticide spray, DAS[1]	46	52	56	47	53	59
Ending period of insecticide sprays, DAS	103	110	117	107	117	128
Delay for compound fertilizer spray, DAS	22	29	37	31	41	52
Delay for urea spread, DAS	35	46	54	48	62	71
Delay for thinning, DAS	19	25	49	20	30	46
Delay for 1st weeding, DAS	18	23	30	19	25	35
Seedcotton yield (kg/ha)	947	1285	1614	1130	1290	1565

[1] DAS – days after sowing

Table 7. Periods of destruction of crop residues in Mozambique.

Period of crop residues destruction	Percentage of farms concerned
July	16,1
August	16,9
September	24,2
October	23,4
Beyond October	19,5

Table 8. Differentiated degrees of the impacts of various critical technical practices.

	Mali		Benin	
	Parameter	R^2	Parameter	R^2
Sowing period	-0,461	15,4%	-0,408	
Delay in thinning	-0,131		0,372	
Plant densities at harvest	-0,006		-0,223	
Delay in First weeding	-0,170		-0,424	1,9%
Delay in spreading compound	-0,101		0,517	5,5%
Delay in spreading urea	0,048		-0,003	
Total compound dosage	0,203	4,7%	0,049	
Urea dosage	0,231	5,1%	0,114	
No. Of fertilizer spreads	0,122			
Delay in 1st insecticide spray	-0,213	1,3%	-0,025	
No. Insecticide sprays	0,505	18,5%	-0,167	
Insecticide dosage	0,350	8,2%	-0,320	
Duration of chemical control	0,250	13,4%	-0,171	

In bold, correlations are significant at 5%, bilateral test.

Table 9. Multiple linear regressions for Mali and Benin.

Parameter	Mali			Benin		
	Coefficient of determination = 0,425			Coefficient of determination = 0,698		
	Value	t of Student	Pr > t	Value	t of Student	Pr > t
Constant	1065,646	1,888	0,062	1606,726	2,765	0,022
Sowing period	-115,763	-2,677	0,009	65,953	0,810	0,439
Delay in thinning	-1,418	-0,319	0,751	-16,637	-2,072	0,068
Plant densities at harvest	-0,001	-0,321	0,749	0,002	0,259	0,802
Delay in 1st weeding	-3,115	-0,618	0,538	-13,778	-2,327	0,045
Delay in compound spread	-0,775	-0,233	0,816	21,944	2,306	0,047
Delay in urea spread	4,281	1,729	0,087	-8,442	-0,913	0,385
Compound dosage	1,763	2,414	0,017	-1,871	-1,172	0,271
Urea dosage	-0,726	-0,439	0,662	-1,113	-0,388	0,707
No. Fertilizer spread	-0,181	-0,003	0,997			
Delay 1st insecticide spray	-13,861	-1,963	0,052	8,995	1,428	0,187
No. Insecticide sprays	171,653	2,363	0,020	119,990	1,087	0,305
Insecticide dosage	25,815	0,932	0,354	-109,651	-1,833	0,100
Chemical control duration	0,523	0,080	0,937	0,076	0,010	0,992

Figure 1. *Evolution of the cotton production and exportation in the FAC.*

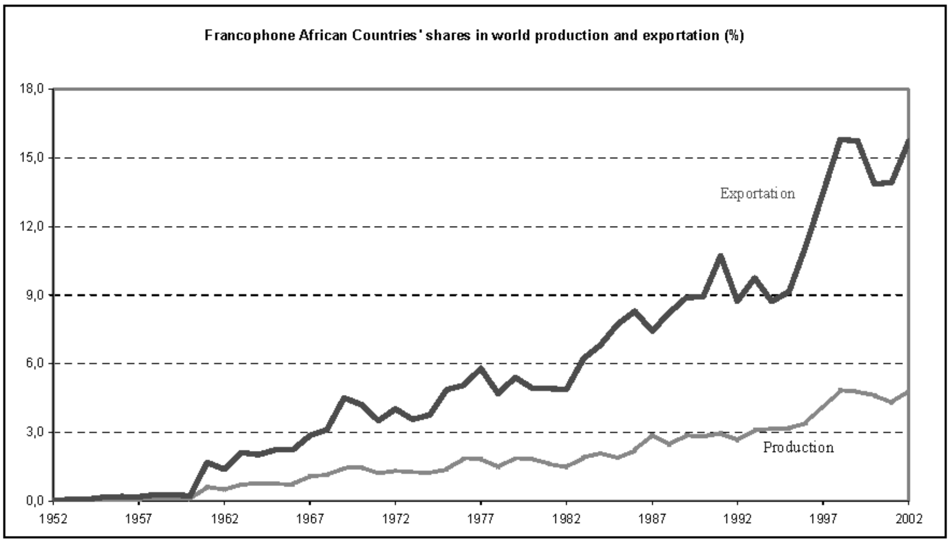

Figure 2. *QQ_Plot, distribution of 75 cotton farms in Mali with regard to their cotton acreage.*

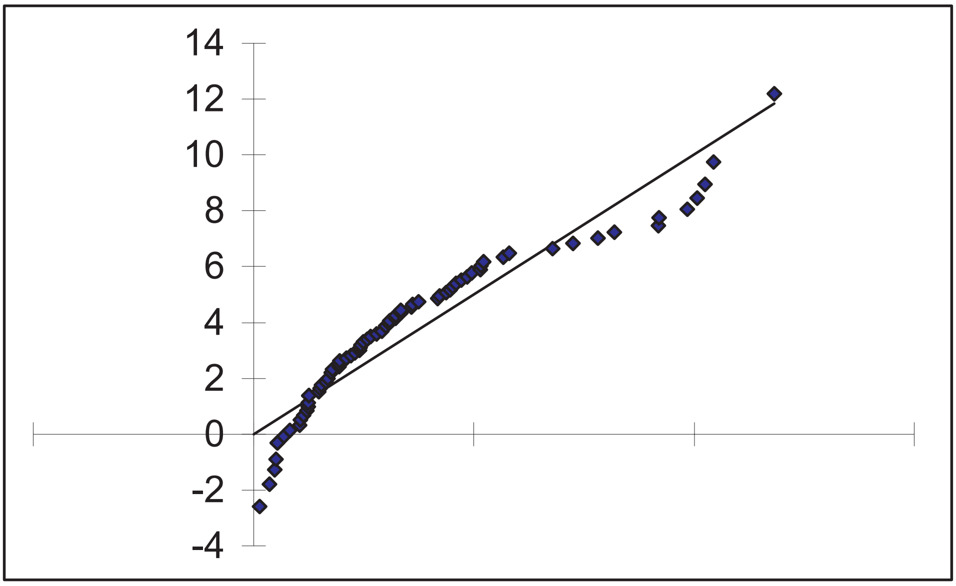

Figure 3. *Late implementation of critical thinning and weeding operations in Mali.*

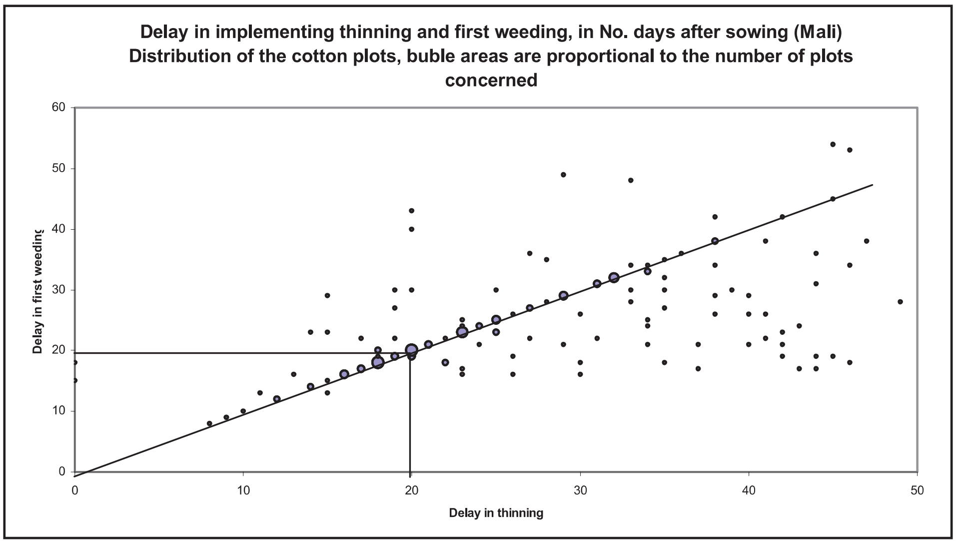

Figure 4. *Farmers' practices in spreading fertilizers on cotton plots in Mali.*

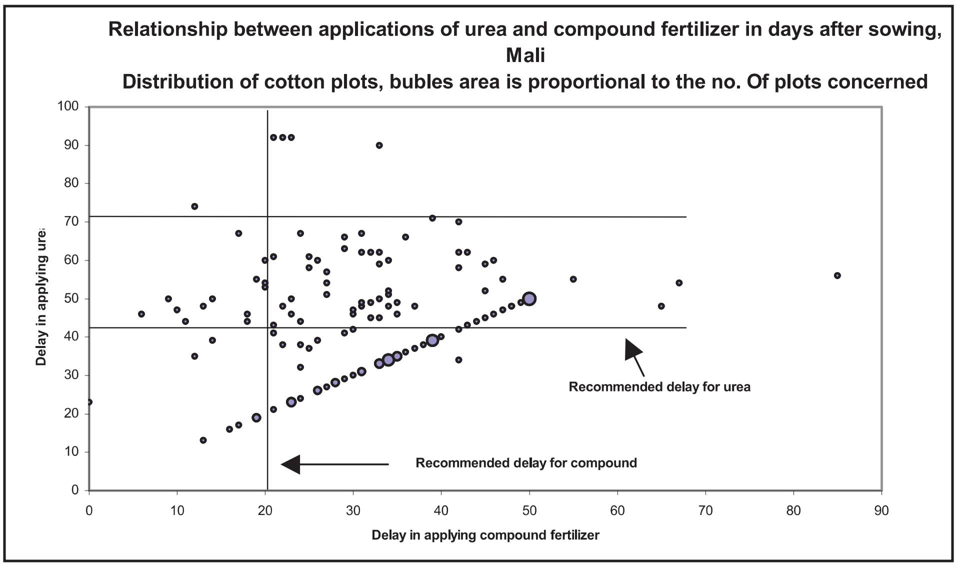

Figure 5. *Constant if not delayed implementation of the first insecticide spray in connection with delayed sowing.*

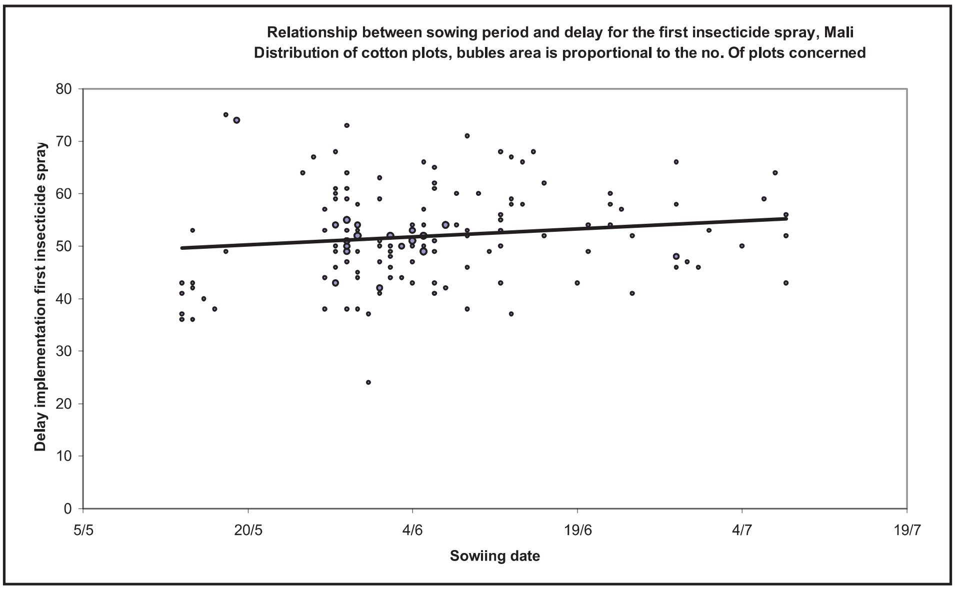

Figure 6. *Adjustment of the length of chemical protection in accordance with the sowing date.*

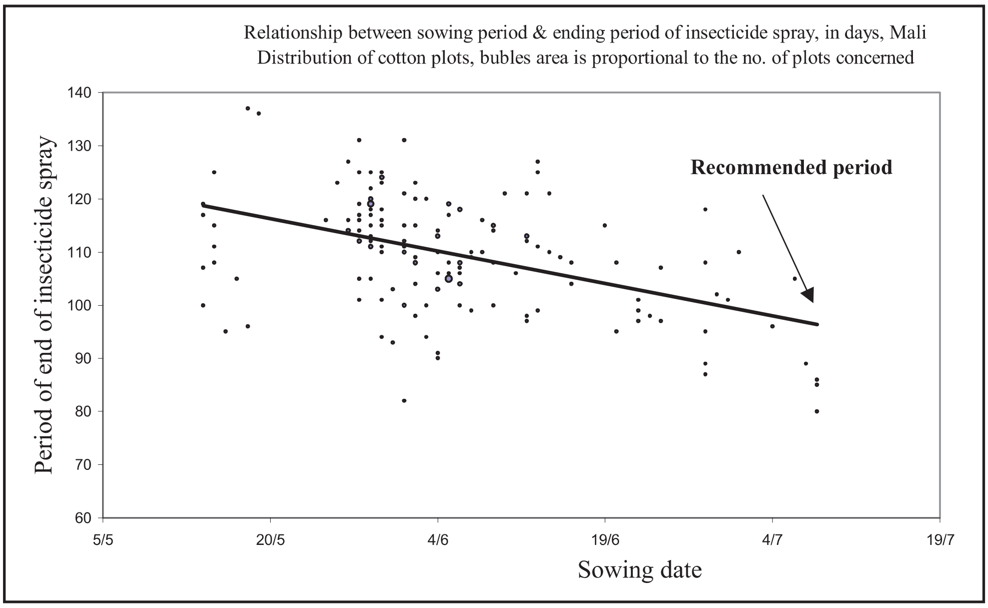

Figure 7. Management of the yield expectation along the cropping season.