Progress margins in productivity of cotton production by smallholders in SSA

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Countries in Sub-Saharan Africa (SSA) only contribute to a still limited share in the world cotton production, but their share in world exportations have become very significant, due mainly to Francophone Africa Countries (FAC) which globally rank second after the USA and account for 15% of the exported volume. Existing figures, albeit incomplete, provide evidence that FAC's cotton is among the most competitive ones in the world. This achievement is further noteworthy since the FAC's production benefits of not any subsidy, while positive socio and economic impacts associated with cotton production have been emphasized by numerous academic works.
Persisting if not increasing support to cotton production in many cotton producing countries is questioning the fate of cotton in SSA. Correction of the current iniquity situation must be contemplated through international negotiations whose outcome remains uncertain. Internal efforts must be undergone in view of further increase in productivity and competitiveness. This paper explores progress margins in productivity gain at the field level through data obtained from surveys implemented in Mali, Benin and Mozambique, representing countries with differentiated backgrounds in cotton crop intensification.
Average yields currently achieved rank from correct to low but the extent of the yield distribution is related to the extent of input use whose level is far below the one encountered in many cotton producing countries. Yield obtained by the upper part of the farmers may however be far above the world average and close to the best ones under rainfed conditions. The gap between this yield level with regard to the average yield in the related countries is an indicator of the progress margin in productivity gain under the existing production techniques. Significant productivity gain is expectable from existing techniques, furthermore along with provision of adapted complementary practices. It is nevertheless hard to associate the observed yield gap with a limited number of cultural practices or to prioritise the practices to correct. 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 fertilisers and accurate spread of chemicals are identified. ¨Prospects of conventional or new technologies in alleviating constraints to help move forward productivity gain are outlined. Under the changing institutional frames of SSA cotton sectors, it is discussed in what extent research implementation will be efficient to help increase productivity.

1. Introduction

Countries in Sub-Saharan Africa (SSA) only contribute to a still limited share of the world cotton production, but their share in world exportations have become very significant, due mainly to Francophone Africa Countries (FAC) which globally rank second after the USA and account for 15% of the exported volume (Graphic 1).

Existing figures, albeit incomplete, provide evidence that FAC's cotton is among the most competitive ones in the world . This achievement is further noteworthy since the FAC production benefits of not any subsidy, while positive socio-economic impacts associated with cotton production have been emphasized by numerous analysis .

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 rate of illiteracy (Table 1). With reference to FAC, around 16 millions of people have their incomes depending on cotton, 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 trend towards reduction of rainfalls (volume and number of rain days) has been evidenced . Biotic factors contributed to make cotton production more uncertain. In the FAC, some level of resistance of *Helicoverpa armigera* to some pyrethroids is documented during the last seasons. In austral Africa, very severe outbreaks of new physiologic 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 the campaign 2000/01 while similar impact was observed in Mozambique as well.

The coming evolution of the cotton production is uncertain in many SSA countries, there is a serious threat for the cotton future in FAC in particular . Persisting if not increasing support to cotton production in many developed cotton producing countries is questioning the fate of cotton in SSA. Correction of the current inequitable situation must be contemplated through international negotiations but whose outcome remains nevertheless uncertain. Internal efforts must be undergone in view of further increase in productivity and competitiveness. This paper explores progress margins in productivity gain at the field level through data obtained from surveys implemented in Mali, Benin and Mozambique, representing countries with differentiated backgrounds in cotton crop intensification.

2. Basic information on the surveys and the surveyed farms

The survey in Mali was implemented jointly by Cirad and the Malian research organism (Institut d'Economie Rurale) in the 1998/99 cropping season. It encompassed 85 farms in 6 villages of the Southern Mali (under the influence of the unique cotton company Compagnie Malienne de Développement des Textiles, CMDT). All the farms did not grow cotton (10 actually did not) and those who did may grow cotton on various number of plots. The survey recorded the farms structural features (population, equipment, animal…), 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 Fibre (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 6 villages of the Centre-North of the country, around 20% of the farms did not grow cotton. A survey procedure similar to Mali was carried out in coping with 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 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 cope with the farmers' practices in controlling pests specially 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 inputs (limited only to insecticides) on credit basis. Examination of the provided data leaded to observe that some farmers showed total production collapse (zero yield) which could be attributed in some extent to very severe occurrence of a physiologic disorder (suspected to be related to the outbreak of psylles) but which revealed also some degree of farmers' malpractice to cheat the cotton company in order to escape from reimbursing the input credit (these farmers transferred totally their production to other ones who demonstrated then a very high yield level). Such a phenomenon does not modify the average yield but amplifies the extent of the yield variation: for this reason, yield distribution will not be further analysed 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 play a decreasing role for many years.

Family size varies however greatly, in connection with the related countries cultures and recent histories (Table 2) . In Mozambique, families are nuclear ones, with a small size (less than 4 people per farm) which means also a great labour constraint. In the opposite, in Mali, farm holding pertains to enlarged families where polygamy dominates. On average, families are composed of more than 14 people, implying that family labour is available but also the constraint of devoting this labour to face high food needs. The situation in Benin is intermediate with around 8 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 (concerning around 85% of the farms). In Benin, agriculture remains essentially manual while it is exclusively the case in Mozambique.

In spite of its high level of the cotton production, the cotton share in the cropping system remains sound in Mali, around 30%. The survey data gave a figure which is a little bit higher in Benin and in Mozambique.

3. Levels of productivities and costs

3.1. Low Productivities and incomes in spite of honourable outcomes/ha

With reference to productivity and incomes, Benin and Mali demonstrate outcomes which are very close (Table 3). In both countries, 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 taking account of a ginning outturn of 42%) varied from 550 to 564 kg/ha. In comparison, the figure obtained for Mozambique (less than 100 kg/ha), in spite of the fact that it relates to the cotton zone which was considered to be the most successful, indicates a yield gap which is illustrative of the difference many eastern-austral African countries suffer in comparison to the western African ones. The mean cotton acreage (0,8 ha) is also very small, quite illustrative of a totally manual farming.

Cotton cultivation ensures 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 in using chemical inputs (fertilizers and insecticides exclusively, seeds were free), net income reaches a little more than US $250/ha or US $900-1100 per farm.

Calculation of the productivity (labour productivity) requires that the labour actually invested in cotton growing is recorded which was not the case since it is very demanding in terms of staff and organization. We can only provide a proxy of such a productivity by estimating the gross income per family worker who however does not work only in the cotton fields.

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

Since cotton is the unique crop endowed of secured outlet, the figures emphasized above are indications of the guaranteed cash income that farmers can 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 with regard to the general level in their respective countries. In absolute terms, incomes derived from cotton cultivation are still low: this is an indication that they must be improved in particular 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 points out the negative impact in terms of poverty alleviation if cotton production has to be disrupted.

In Mozambique, the situation is far less positive. yield and gross income are very low US$ 25 per farm), and net income is very limited and not always positive. Gross income per capita is only of US$ 4.9: it is hard to imagine that cotton cultivation could contribute so much to alleviate poverty under the current way of cultivation and outcome.

3.2. A matter of extensive to low-intensive production

In Benin and Mali, the commendable levels of yield are achieved at 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 Portal Region.

The total cost in Benin and Mali encompasses US$ 56-58 for fertilizers and 25-39 for insecticides. It is noteworthy to point out that, for both countries fertilizer cost is far higher than the one engaged for the 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 the chemical pest control in Mali, with a comparable number of insecticide applications, is significantly less expensive in spite being a landlocked country which normally suffers of higher price 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 liberalisation 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 5 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 *Hemicoverpa armigera* to pyrethroids is now evidenced during the last seasons in West Africa, this is an indication that introduction of Bt cotton could be relevant. Data from our surveys clarify the financial constraints to which such an introduction will have to face, with reference to information from South Africa where the adoption of Bt cotton by smallholders is under way. For the last seasons, Bt seed are sold at Rand 387/ha with an additional technology fee of Rand 350, totalling Rand 737/ha or around US 82/ha, which is the level of current total cash expenses that farmers have to pay nowadays in Mali. Such a financial gap appears hardly acceptable not mentioning the "revolution" farmers have to accept in paying seeds they used to get free so far. Without any change in the conditions attached to the dissemination of Genetically Modified varieties in the developing countries, successful introduction of such varieties appears to be very doubtful.

Cotton production in Mozambique is totally extensive with nearly no recourse at all to chemicals. Only chemical insecticides are applied with on average 3 applications during the survey season (which were very unfavourable in climatic terms and suffered from a severe outbreak of physiologic disorder). Although the introduction of BT cotton is already advocated by some people in Mozambique, where no resistance is reported so far (and it could hardly be so owing to the low level of insecticide use), its implementation at the smallholders' level sounds to be very risky.

Globally speaking, productivities and incomes are low in spite of indicators which are quite honourable on hectare basis. Gain cannot be expected from reduction of input costs which are yet very low in comparison to countries with intensive production. Probably the use of Genetically Modified cotton (GMC) will not induce significant reduction of the cost in pest control which remains very low. Productivity gain should derive more from improved efficiency of the input used. There are signs sustaining that there is room for such a gain.

4. Prospects for productivity gain

In view of appraising realistically the prospects for productivity gain, it sounds relevant to firstly identify whether there are farmers' groups distinct in their performance and to make clear what are the factors that impact negatively on their performance. In our contribution to examining these prospects, we focus mainly on results coming from Mali and Benin.

4.1. Non-clear distinct performing groups and consequences

We favour using descriptive statistics to clarify whether farmers' groups are distinct in their performance or their input use. Since Histograms are misguiding in showing bimodal distributions as they are very sensitive to the class limits one selects, examination of the curve of cumulative frequencies would make more sense as it is shielded from such misguidance, but it is neither easy to detect existence of two or more modes when these mode 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. Graphic 2 represents a case of clear deviation from normal distribution and indication of two modes with concentration around of the mode of lower

value (this graphic obtained from the XLstat software has axis inversed as compared to QQ_Plots established by SAS software).
Analysis of the Q_Q plots obtained from the surveys in Mali and Benin do not show very clearly the existence of more than one group of farmers in their production performance nor in their production costs. Even though a second mode can be suspected, the size of the related second group of farmers is limited (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. We observe through our analysis of the performance distribution that the leading group is the far minor one and that addressing the lagging group will impact more. Nevertheless, since this group is far more numerous, the means to invest in boosting such a group in gaining productivity should be of relevant volume. Assembling the needed means will not be sufficient without targeting properly at the right issues to address: it makes sense to identify what are the factors that impact negatively on the current performance.

4.2. Factors impacting on the current productivity

4.2.1. Many factors involved with variation in their expression

In addition to the intensification level in using chemicals and which is analysed above, several other factors impact on the yield achieved. The sowing date is acknowledged to be of particular importance, and optimal sowing period has been clarified by previous research works which leaded technical recommendations to comply with this period at sowing. At the research station level, experiments leaded to specify the yield loss per day of delay with reference to the optimal period. Practices devoted to taking care of the cotton plots are also of acknowledged importance : periods of thinning, of weeding, of spreading fertilizers or 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 be very harmful in decreasing the yield expectation. 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.
The Table 6 indicates that, for the survey year in Mali, sowing complied rather positively with the recommended period, thanks to early instalment of the rains. However, with regard to a recommended density of 80 000 plants/ha, the plant density actually achieved is far lower, in spite of the fact that the plant density at emergence was high and sufficient to ensure the recommended density. The distortion to the recommended density occurred at the thinning stage when more are removed than necessary. Although it is hard to conclude that the density gap is transferred negatively and totally to the yield achieved, because of the well-known compensation effect from cotton plants, some detrimental effect from such a density instalment could neither be rejected, because the compensation effect is somewhat restrained by the late implementation of the operations devoted to protect cotton plants against competition.
Deviation from the recommendations are common for most of the techniques, in terms of delay in the implementation of critical operations or of variation in dosages. For instance, thinning and first weeding occur rather late in around 50% of the cotton plots. The Graphic 3 gives another illustration of the importance of such delays. The same occurs with the period of application of fertilizers: many farmers spread compound and urea at the same time and later than recommended. (Graphic 4).
Farmers' practices in implementing the chemical protection against pests may have impacts of diverging orientation. In spite of delayed sowing, farmers used to maintain constant the number of days after sowing before

implementing the first chemical spray while it may be justified to spray earlier (Graphic 5). In the opposite, farmers do have a chemical control duration decreasing along with the delay in sowing which is consistent with a lower yield expectation (Graphic 6). These observations demonstrate that farmers do have some command in managing chemical control although not totally optimally.

Similar distortions are exactly observed in Benin for every of the technical practices we analysed in Mali. In Mozambique, interviews of the sample of 1000 farmers revealed that nearly 70% of the farmers destroy their cotton crop residues less than 2 months before sowing for the new season (Table 7): this is a practice that may explain the high level of jassid infestation that used to occur early in season.

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

4.2.2. Hard to identify a single main 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, it arises the issue of identifying any practice that accounted the most in the yields achieved.

Regression analysis shows that it is not possible to claim that all the technical practices acknowledged to be critical in the 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 works at station level, only few of them are statistically significant, and they are not common to both of the two countries considered. Furthermore, individual coefficients of determination of the significant practice are low, certifying that each one contributes only to a limited extent in the yield achieved.

Multiple regression does not provide more convincing result. The global 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 to explain 42% to 70% of the yield variation obtained (Table 9). Several factors have significant effect with the right sign, but this is not the case for other factors whose impacts were demonstrated through research experiments. Only a limited number of the variables are showing 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 2 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 what is well-known through many research works at station level. It was evidenced that within some limits, sooner the sowing, better is the yield. Similar results were obtained with regard to weeding, fertilizing, pest control… However, all these results were conducted through experimental approaches under which when the effect of one factor was analysed, all the other factors were kept unchanged and conducted in the optimal way. At the farmers' level, specially when smallholders with limited means are considered, the assumption that all the cultural operations are conducted optimally is a very strong if not unrealistic one, for this reason, it is not so much amazing that some results related to the impact of specific technical practices 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 of no relevance. It only recalls that we should remain cautious when extrapolating the expectation in encountering such results at the farmers' level. With regard to our concern to have productivity gain be achieved, our results show that this could hardly be derived from the improvement of the implementation of a specific technique. In other words, meeting the productivity gain comes out to be far more challenging that one may think.

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

Our analysis leads us to underline that it may be vain, at the farmers' level, to assess the impact of a specific factor (cultural practice) disconnected to the other ones. More precisely, such an assessment must take into account what occurred prior to the execution of the specific cultural practice analysed, and what may happen after. In other words, a cultural practice is embedded within a sequence of technical patterns, its impact is to be assessed within such a sequence. Sequences are different between farmers, they are not all optimal, and a specific cultural 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 in the implementation of such a practice, we suggest to consider the notion of the management of the yield (or profitability) expectation at any time (Graphic 7). In a given location and year, this expectation is the highest before sowing (if not before soil preparation), it could only be maintained if all the cultural practices are implemented optimally and if no biotic or abiotic events occurs (scenario 1). In general, such an expectation before sowing could only decrease along the cropping season.

During the cropping season, at each stage of technical practice, the way of implementing it will maintain the yield expectation (but not necessarily the profitability expectation) or reduce it. From stage to stage, reduction is cumulative. By implementing poorly the various stages of technical practices, a farmers could come to a disappointing yield in spite of having sown his cotton early enough. Conversely, by implementing these stages in an optimal way, another farmer could maintain the yield expectation he had at the sowing time (scenario 2). Even if he sowed later and suffered from an original yield expectation lower, his final yield could be better (scenario 3).

This approach in dealing with yield expectation makes further sense in addressing profitability. However, if maximising techniques will be sufficient in maintaining the level of yield expectation, it is far more difficult to maintain the profitability expectation since it would require that techniques be adjusted by considering the costs of their implementation.

Probably, setting up models could be helpful in formalizing better this notion of management of yield or profitability expectation but it will not be so much easy, and it could be of little use in the context of African agriculture. Moving towards such modelling is not exactly our concern, our point is mainly to emphasize the needed flexibility in considering the implementation of various technical practices. Ploughing before sowing probably impacts positively on yield but it is debatable to maintain it if it will further delay the sowing time. Spreading fertilizer at recommended dosages does make sense if the sowing period has been correct and weeds controlled, otherwise dosages must 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 kind of this flexibility, according to their own experience, more or less successfully. The challenge to face in gaining in productivity will depend on feeding in information and knowledge to help farmers' decision-making. We doubt that such a feeding will only result from conducting experiments at research stations. We doubt that such a feeding will derive only from organizing exchanges of experiences between farmers. We think that both must be combined. Experiments at research station are helpful in acquiring knowledge and understanding the physiologic and biotic phenomena involved, knowledge that will enable to better understand the results farmers obtained through their experience and interact with them to assist them in commanding further better the techniques they apply.

4.4. Reasons underneath the observed practices and consequences in R&D

It is beyond the ambition of this paper to implement the clarification of the farmers' reasons for all the practices observed. We limit ourselves to analysing 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 favours.

In the case of Mali where dissemination of technical messages to farmers dates back to several decades, it is quite amazing to observe that basic practices like thinning and weeding are still so poorly implemented as we pointed out above. This observation is not consistent with some views that Malian cotton farmers are handling perfectly the basic techniques and that what they need is no longer the conventional dissemination of basic technical messages. These views, although not so much founded according to our data, are prevailing in Mali and there is a tendency to alleviate dissemination of technical messages that could be detrimental for the cotton productivity in the next future.

Several reasons could be considered in addressing the amazing implementation distortion we pointed out. One is to consider that distortion resulted from lack of technical command, as a consequence for instance of failure in disseminating technical messages (for various reasons we would not elaborate here). There is at least an objective reason to sustain such a view : part of the farmers who grow cotton nowadays, the youngest ones, specially those who separated themselves from their fathers' farms, are no longer exactly the same who benefited from message diffusion earlier. If this reason is correct, the issue is a matter of resuming properly the message diffusion.

Another reason is that farmers do know how and when to implement properly thinning and weeding, the matter is that they just cannot do that because of lack of labour, since food crops have to be looked after as well, if not preferably. If this reason is the correct one, the issue is a matter of saving labour from thinning and weeding. This could lead to prevent from having to thin, a situation that could only result from new modalities in sowing and from a sound confidence in the quality of the seeds the farmers obtain. Labour 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 which 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 labour, weeding is not regarded as a constraint. Finally for observers sensitive to environment protection, the less farmers use chemicals, the better. In a nutshell, addressing successfully the issue of thinning and weeding will demand technical, institutional if not mental revolution.

A third reason more related to the social evolution in the cotton zones must be considered as well. Farmers do know how and when to implement thinning and weeding. They have enough labour to implement it, but they just cannot have their family labour to work properly. Such an assertion may sound amazing but it is not. Inter-generation 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 at the basis of the phenomenon of farms splitting apart. Scientists cannot address directly such a social issue in enhancing it or in impeding it. Their role is to anticipate what consequences could come out and prepare solutions to help alleviate the possible negative consequences. A direct consequence we can figure out is a reduction of the farm size with reduced labour for each farm. This phenomenon will therefore make the labour constraint further strong and dictates more investment in new techniques enabling to save more labour.

4.5. 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 labour constraint and lack of financial resources are of paramount importance. In one side, the current situation is positive. Several new techniques are available and are under large application in various countries, they pertain to the Genetically Modified varieties (that could potentially save insecticide use or enable weed control) or non-conventional farming (that may be more environment friendly in addition to ensuring better efficiency in input use).

In the other side, 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 suffered from stagnation if not reduction in trained staff during the last two decades. There is little sign showing that this situation will be reversed in the short run.

Besides, one thing is carrying out adapted techniques to enhance productivity, another is to have them be adopted actually, 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 expenses. Such an incentive has taken the shape of secure outlet for the cotton production, at a pre-announced price necessarily respected at the trading stage, and at an attractive level. The other condition is accessibility to the required inputs through reasonable prices and credit conditions. All the cotton sectors in Sub-Saharan Africa are engaged into institutional changes which have not yet settled down. There are signs that farmers have not become necessarily better off. For the first time, farmers were paid at lower prices they were announced before sowing and some farmers in Benin and Côte d'Ivoire have not being paid for the production they sold. These current negative outcomes could be corrected through adjustment of the institutional frameworks which is however time and resource demanding. Owing to the bearish world market distorted by subsidies in developed countries, it is difficult to expect that the related cotton sectors with their decreasing financial means will be able to overcome alone the current shortfalls. External funding is taking place in some countries to complement the national efforts, but we doubt that they are focussing on the issue of productivity gain or addressing this issue properly.

5. 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 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 honourable with regard to what developed countries obtain, but at the farm scale, they are still low because of limited farm size and labour constraint. Nevertheless, incomes induced by cotton cultivation net of cash expenses and expenses to cover housing and food needs point out 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, and it would be very dramatic if cotton production has to be disrupted.

Farmers in Benin and Mali achieved honourable performance at very low production costs. This observation implies that productivity gain could hardly derive from further cost reduction and that cost reduction experienced nowadays by some other cotton countries should not be extrapolated too quickly to African countries. More precisely, we observe that fertilizers cost far more than insecticides, this is quite opposite to the situation in 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, at the low level of this use because African farmers could hardly afford a higher level. 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 sounds vain 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 efficient if it is not properly targeted. It arises the condition of understanding what are the factors which impact actually on the yields farmers reach. Our analysis points out that there is a great variation in the way farmers implement the various technical practices in cultivating cotton, with notable distance with technical recommendations. Furthermore, it is observed that critical techniques like thinning and weeding may be implemented with great delay which may impact very negatively the yield achieved. This is an indication of bad technical command even in a cotton zone where technical dissemination dates back for a long time and which contradicts the opposite assumption of several recent studies.

It is vain to expect finding out a close relationship between yield and specific cultivation techniques as it has come out from experiments at the research station level. This is not a dismissal of the knowledge supplied by research experiment, but only an objection against a too simplistic extrapolation of the results at research station level to the farmers' level. The basic reason lies upon the fact that it is not possible to assume that farmers can 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 yields varies a lot and why it is difficult to relate them 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 implementing some technical practices. The issue is therefore to assist farmers in their decision-making while managing their profitability expectation. Such a process will require more exchange with farmers and continuation of experiment at research station level to gain more knowledge needed in interacting efficiently with farmers. Both types of activities involve scientists within a re-launch of the research activities. However, we observe that the current institutional frame is not very favourable to such a re-launch.

Table 1: Some macroeconomic feature of cotton production in FAC

	Total population (10^3 in 2001)	Rural population (10^3 in 2000)	Rural population w/cotton income (10^3 in 2000)	GDP/capita US $ (2001)	Adult literacy rate (% in 2001)	% manual farms
Benin	6 446	5 207	2 500	368	37,4	60,0%
Burkina Faso	11 856	8 320	3 000	196	23,9	60,0%
Cameroon	15 200	9 640	1 300	644	75,8	70,0%
Central Africa	3 782	2 037	900	247	46,7	
Côte d'Ivoire	16 349	8 562	1 600	563	46,8	70,0%
Mali	11 677	8 642	2 000	242	41,5	15,0%
Senegal	9 662	5 635	500	477	37,3	50,0%
Chad	8 135	5 415	3 000	183	42,6	
Togo	4 657	2 723	1 200	266	57,1	85,0%
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 derive 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			Bénin		
	Distorsion to Normal distribution	More than one mode?	Concentration around the lower mode?	Distorsion 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	+++	++	++	++	+	+
Number 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			Bénin		
	1st Quartile	Median	3rd Quartile	1st Quartile	Median	3rd Quartile
Sowing date	May, 29th	June, 3rd	June, 10	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
Number insecticide sprays	5,0	5,0	6,0	4,0	5,0	6,0
Delay for 1st insecticide spray, days after sowing	46	52	56	47	53	59
Ending period of insecticide spray, days after sowing	103	110	117	107	117	128
Delay for compound fertilizer spray, days after sowing	22	29	37	31	41	52
Delay for urea spread, days after sowing	35	46	54	48	62	71
Delay for thinning, days after sowing	19	25	49	20	30	46
Delay for 1st weeding, days after sowing	18	23	30	19	25	35
Seedcotton yield, Kg/ha	947	1285	1614	1130	1290	1565

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%

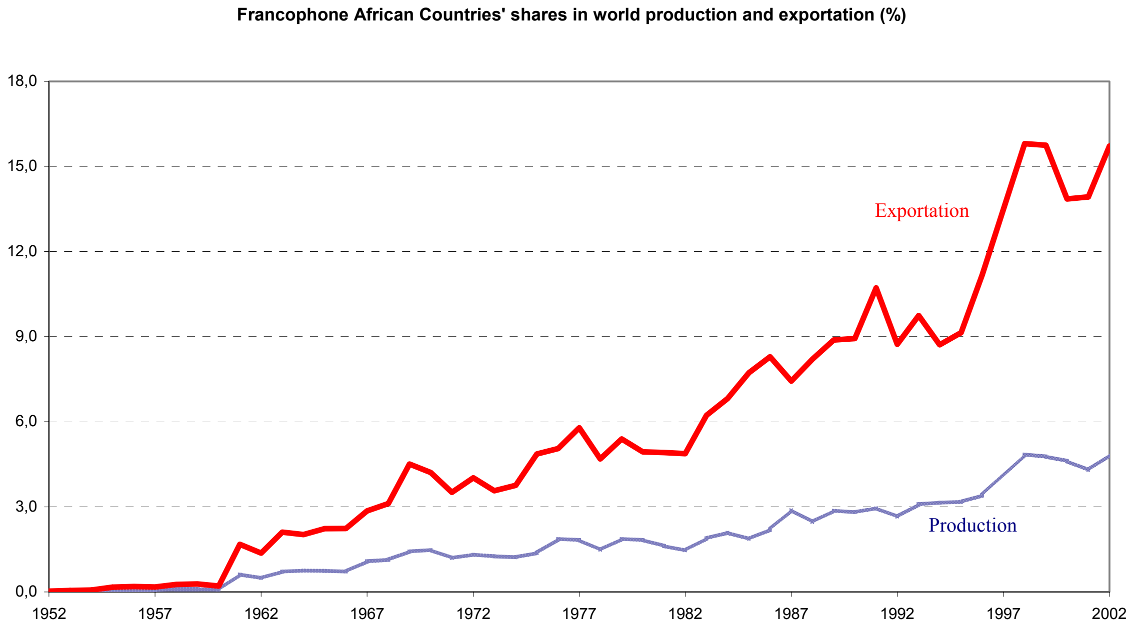
Table 8: Single correlation between seedcotton yield and various critical technical practices

	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	

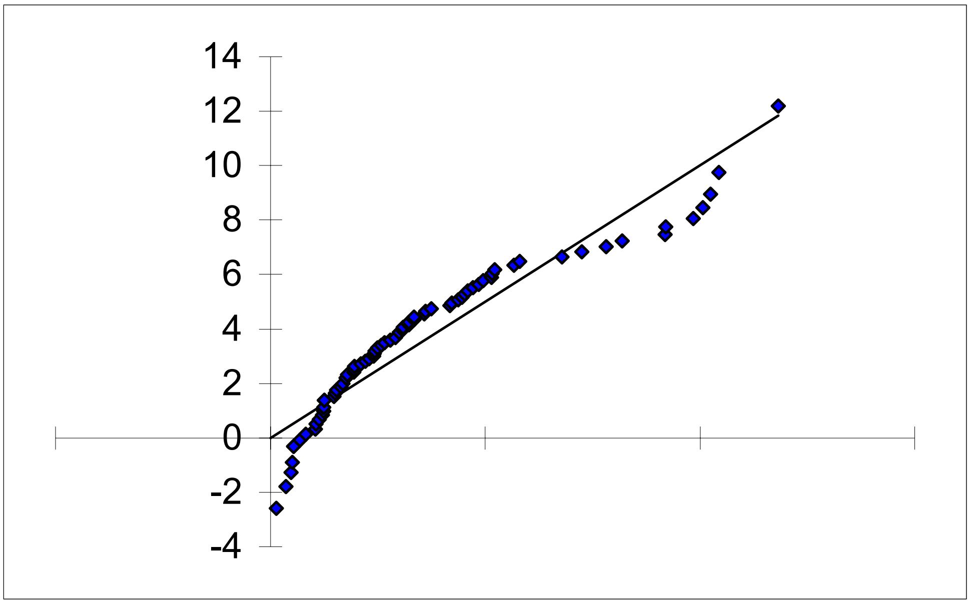
In bold, correlation are significative at 5%, bilateral test

Table 9: Multiple Linear regression between seedcotton yield and various critical technical practices

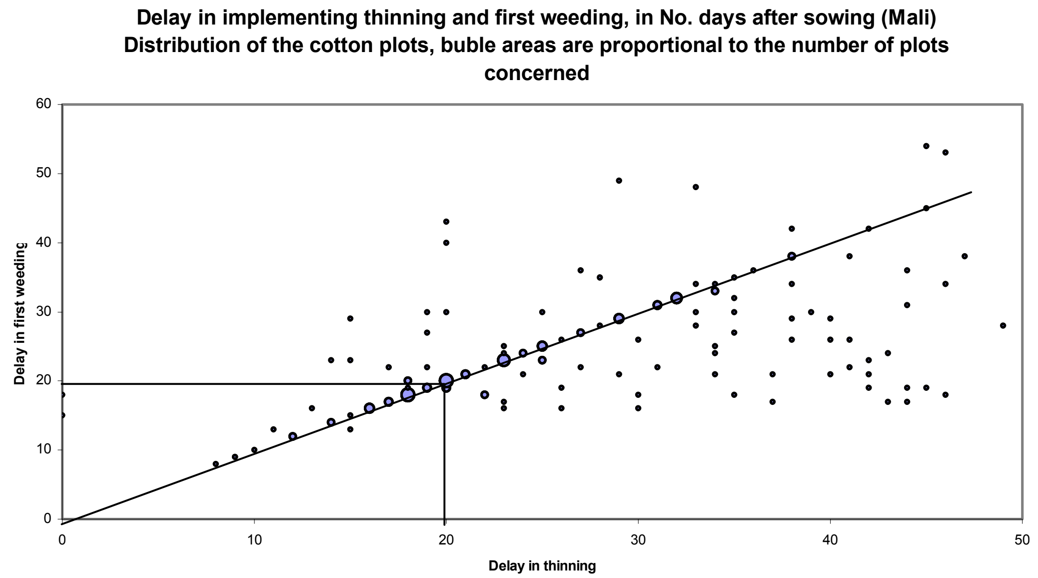
Paramètre	Mali, Coef. Determination = 0,425			Benin, Coef. Determination = 0,698		
	Value	t of Student	Pr > t	Value	t of Student	Pr > t
Constant	1065,646	1,888	0,062	1606,726	2,765	0,022
Sowing period	**-115,763**	-2,677	0,009	65,953	0,810	0,439
Demay in thinning	-1,418	-0,319	0,751	-16,637	-2,072	0,068
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 psread	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



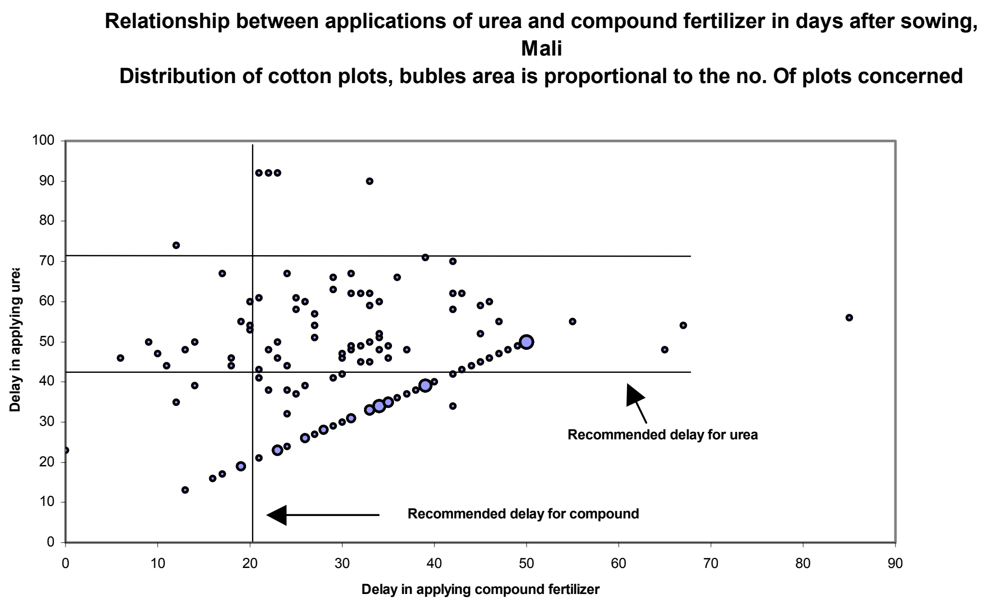
Graphic 1 : Evolution of the cotton production and exportation in the FAC



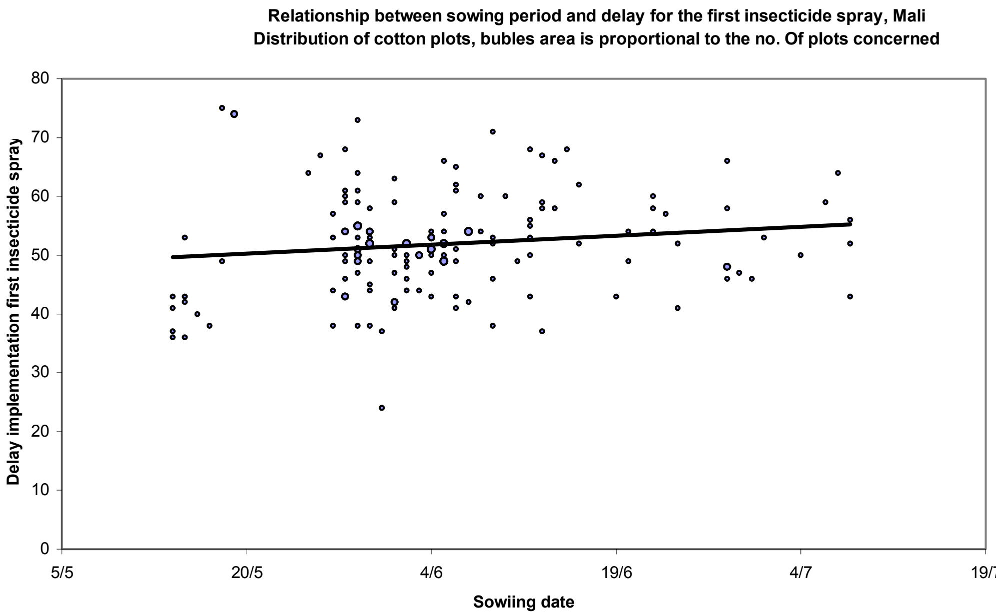
Graphic 2: QQ_Plot, distribution of 75 cotton farms in Mali with regard to their cotton acreage



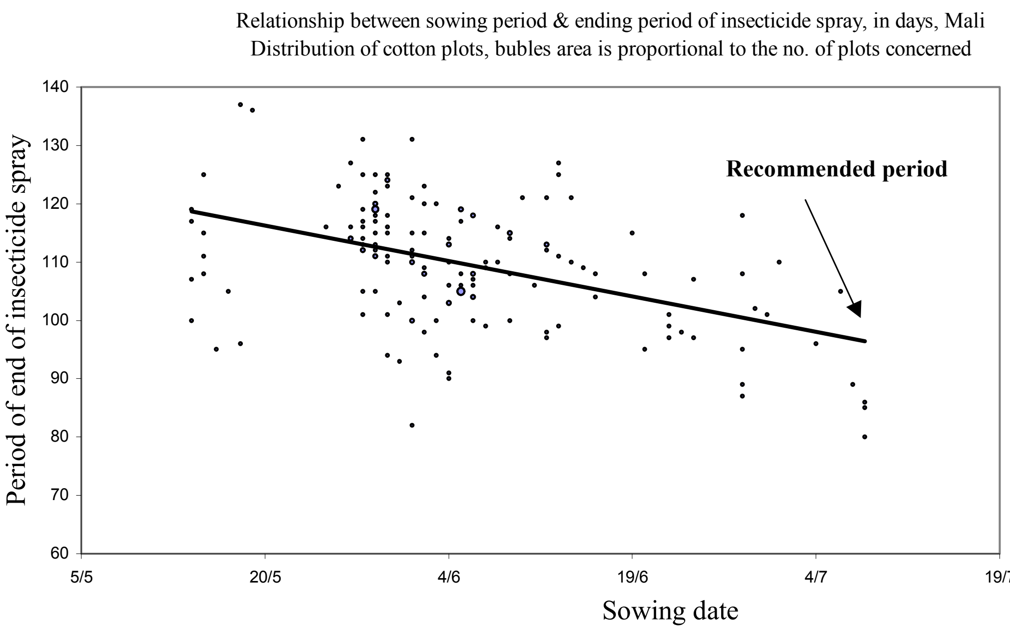
Graphic 3: Late implementation of critical thinning and weeding operations in Mali



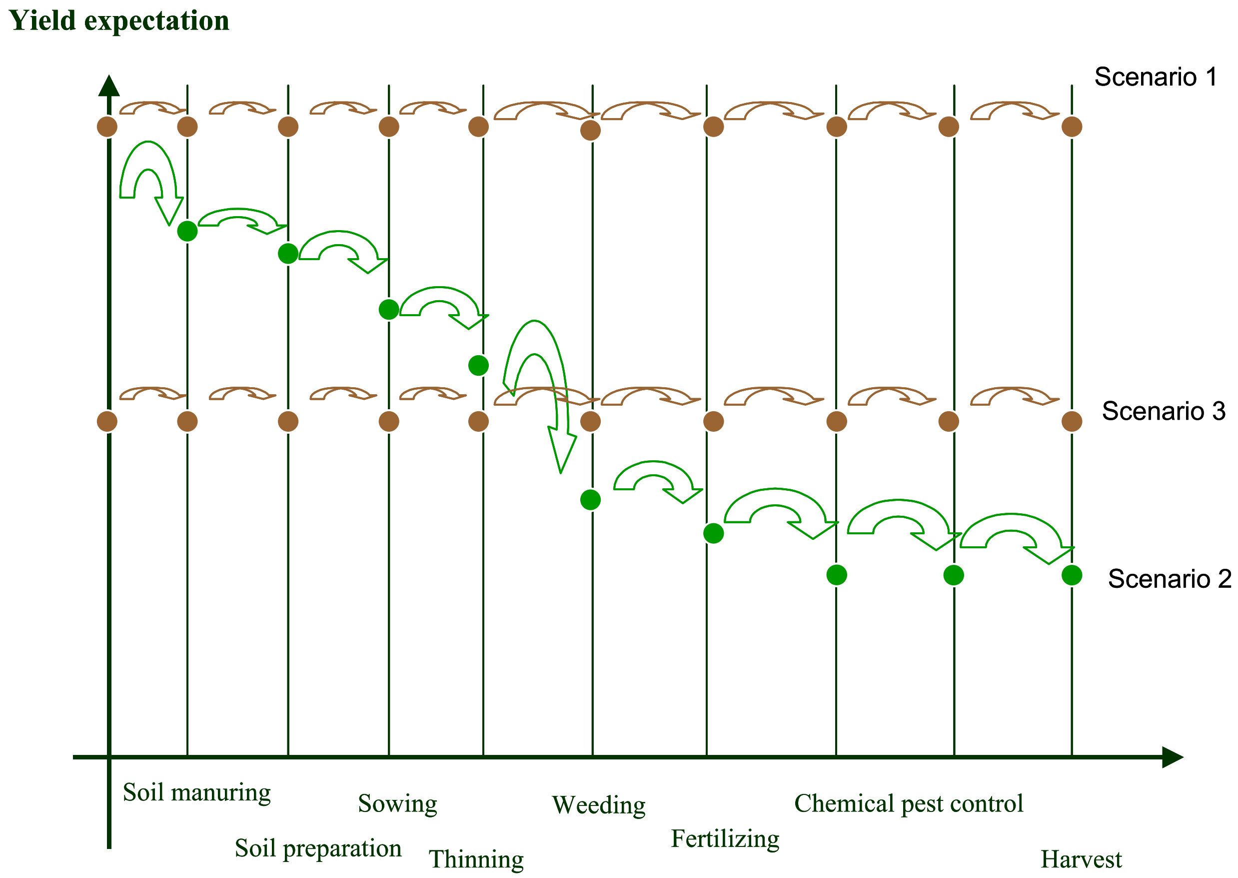
Graphic 4: Farmers' practices in spreading fertilizers on cotton plots in Mali



Graphic 5: Constant if not delayed implementation of the first insecticide spray in connection with delayed sowing



Graphic 6: Adjustment of the length of chemical protection in accordance with the sowing date



Graphic 7 : Management of the yield expectation along the cropping season

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