Cotton Yield Stagnation: Addressing a Common Effect of Various Causes

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ABSTRACT

Yield is stagnating at world level in developed countries and in developing countries, under irrigation or rainfed conditions. Analysis of yield results from economic optimization by farmers under existing technical and/or economic factors is a tool to help clarify the issues cotton research has to address in order to modify the current yield stagnation. In a limited number of countries, actual yields are close to potential yields. Cotton research has then to cope with the increase of potential yields, in particular, through better exploitation of favourable interactions between genotypes and technical practices. However, in many countries, actual yield is still far from potential ones. Cotton research has then to reduce this gap. This paper emphasizes the role social scientists should play in clarifying the reasons for this gap. Reluctance of many cotton producers to use costly inputs is also underlined. Promoting more efficient use of inputs is, therefore, a challenge to be addressed, giving rationale to studies to assess, for instance, the mechanism of cotton response to input use.

Introduction

It is common to consider yield as an indicator of a production competitiveness for a country or an indicator of its profitability for the producers. Unconsciously, we scientists used to take yield as an indicator of our research performance. So, if yield is stagnating, such phenomenon could be interpreted as a demand addressed to scientists to carry out new outputs destined to improve production performance. Implicitly, we think that this demand is only a call for new techniques or new varieties. This paper is devoted to somewhat clarify the issues cotton scientists have to tackle in order to have yield follow again an upward trend.

From a producer's point of view, yield is not the final goal. Yield is only a means by which cotton producers could achieve better income and higher profitability. Under certain circumstances, yield increases lead to better revenue but beyond some point, yield increase would cause income reduction if it depends on higher production costs that are not matched by the additional income from the marginal gain in yield. This distinction has to be made between technical optima and economic optima. Yield stagnation, therefore, is the result of economic optimization in the current production environment associated with technical and economic factors. Consequently, new economic optima at a higher yield level would require either new techniques or changes in production environment, or both. Our position is to advocate that cotton research must go beyond only seeking new techniques.

This paper emphasizes the extend of the phenomenon of cotton yield stagnation, then clarifies the issue of this stagnation for cotton scientists, finally research topics and methods are underlined.

Reliability of the yield information could be a limitation to this contribution. Yield is a ratio combining production and acreage. Commonly speaking, in the case of cotton production that needs to be processed at ginnery, availability and reliability of production figures are of little trouble. Reliable acreage data cause greater concern because systems for registration of crop acreage may be lacking. Even when there are such systems, they provide acreage data, but this does not necessarily ensure data reliability. In many Francophone cotton producing countries, farmers are said to willingly under-declaring their cotton acreage (Cousinié, 1993) while farmers in other countries may have rationale to over-declare their acreage. However, as we are focusing on recent trends of the yield evolution, reliability of the exact value of yield has limited impact on our analysis.

World-wide Yield Stagnation Phenomenon

From the world level perspective, it seems clear that yield is stagnating, this phenomenon takes place from the beginning of the 1980s (Fig. 1).

Cotton is produced either under irrigation or rainfed conditions so we have separated cotton producing countries into two groups, a group with no irrigation at all and a group with at least partial irrigation. Fig. 2 and Fig. 3 show that yield stagnation occurs with both types of production, although our distinction is rather rough as the level of irrigation is very diversified between countries within the second group.

At the country level, yield stagnation occurred in developed countries (Australia, USA, Israel, Argentina) by the end of 1980, as well as in developing countries (China, Francophone African countries, India, etc.) by the mid-1980s. In these developing countries, during the same period, even yield decrease is observed (Zimbabwe, Uganda, Paraguay, Mexico). There are few countries experiencing yield increase during the last period, Turkey being a special case. Within a country, yield trends could be homogenous for some countries, like in the USA, or divergent in others, like in several cotton provinces in China.

We should however remember that yield stagnation is not a new phenomenon. If we refer to the case of the USA which has played so significant role in cotton production in the world, yield stagnation was the normal course for a long time, until the end of the Great Depression, without stagnation of the cotton production. We should then clarify the issue with the current yield stagnation and its impacts.

What's the matter with yield stagnation?

Issue of the impacts of yield stagnation

At first glance, one can wonder whether yield stagnation is an issue. In spite of such stagnation, world cotton production has kept on increasing, although at a low rate compared to the world potential demand[1]. Yield stagnation does not necessarily mean production stagnation, just like the period prior to WW1. However, to some extent, such limited growth may have been a factor in loss of competitiveness of cotton towards man-made fiber.

In locations such as the Delta or the Southeast cotton Regions of the USA, yield stagnation may imply income stagnation or even decrease. This effect on income, however, is not a generalized one. In countries where farmers have access to more land, they can compensate yield stagnation by increased cotton acreage to preserve or even increase their income (e.g. African countries, in particular Mali. Nevertheless, cotton acreage extension may concern fragile soils that are not very suitable for cropping, threatening cotton production sustainability (Berckmoes, *et al.*, 1990).

Yield stagnation, however raises serious questions regarding the attractiveness cotton production, at least in locations where farmers have choices of cash crops. In China, as a consequence of yield stagnation, cotton value-added per unit of labour is less favourable than rice growing and cotton production has become more financially risky because of high input costs. Hence, withdrawal from cotton production is occurring in several Chinese provinces like Zhejiang, Shandong, Shanghai, and in many countries of Central America (Gabriele, 1994; Micarelli, 1991; Uribe Calad, 1994).

Reduction of cotton production in some countries has direct impact on their cotton exchange patterns. Recently, India has faced insufficient production to cover its national consumption needs and has been pushed to import (Ferguson A.F. & Co, 1994; Sheth, 1997; Singh *et al.*, 1993). Yield stagnation, if not reduction, has made some countries, e.g. Zimbabwe, miss the opportunity to take advantage of export opportunities to regional markets (Macrae, 1995).

It makes sense to resume an upward trend in yield evolution. However, the reasons for the observed yield stagnation need to be clarified.

Clarifying reasons of yield stagnation

Yield stagnation may derive from climatic constraints, but such constraints only concerned few places. As yield stagnation has occurred more or less world-wide for about the last decade, climate could not have been a general limiting factor. However, in some areas, like Sahelian regions of some African countries, diminshed rainfall has been critical during the last 20 years, making cotton production less secure. As there are limited cash crop opportunities in these places, farmers keep on producing cotton although with less yield expectation (Fok, 1993).

Yield stagnation could signal also limits of the existing technical practices. Nevertheless, even if this hypothesis could not be rejected, such limitation only apply to a small number of countries. Fig. 4 and Fig. 5 provide the distribution of cotton yields obtained by various countries in 1996, with distinction of irrigated and non-irrigated production. Under irrigation, cotton yield varies from 300 to 1800 kg/ha, with only 5 countries showing yield over 1000 kg/ha. Under rainfed production, yield varies from 80 to 1100 kg/ha, with most countries having yields below 600 kg/ha. The current performance does not point out that there is full exploitation of existing research outputs to reach higher yields, although resistance of insects to some pesticides has limited yield expectation in major cotton producing countries. In many countries, there is still a great gap between the actual yield and potential yield with existing technical practices. For these countries, extending the yield potential through new techniques will not, in itself, increase cotton yields.

In many countries, particularly developing countries, yield is constrained by unfavourable conditions for the application of new technology. This applies to both food crops and cash crops like cotton. To some extent some unfavourable conditions also apply in developed countries.

Among unfavourable conditions, lack of appropriate information dissemination is emphasized. This relates to the wider topic of agricultural extension that is not elaborated here.

1 According to a long term analysis, the annual growth rate of world cotton production has been 2.30% during the second half of the century, while the rates for population growth and income growth have been of 1.85% and 2.18%, respectively (Fok, 1997).

However, one thing is to know how to use and how profitable it could be to use inputs, another is to be actually enabled to use inputs. The Training & Visit is an extension method promoted in many countries. This method only considers provision of technical information, paying no attention to how farmers would get the inputs they need. For this reason, input application and desired yield progress have not been experienced significantly in countries where this method has been followed.

Lack of incentive for using inputs is another big issue. Although cotton is a cash crop ensured of finding an outlet, insufficient price is a factor that could discourage investment in inputs. Non-price factors could also discourage farmers to do so (Lele *et al.*, 1989a, 1989b). Tanzania is a case in point. For many years, cotton farmers experienced very delayed payment of up to one to two years (Dercon, 1994). Farmers delivered their seedcotton but did not know when they would be paid, so it was too risky to invest too much in production costs.

It is pitiful to observe that, even when farmers feel incentives to use inputs in order to increase their yield, they are not available. In many countries of Eastern and Southern Africa, inputs are often not physically accessible because no operator takes charge of the service of input provision. When there are such operators, they either do not accept to provide inputs with credit, or if they do, they apply high interest rate under various guises (Upton, 1992).

In many countries, including developed countries, rising costs of inputs have resulted in a decline in their use. This occurs in developed countries, like the USA and in developing countries, like in Mali. This expression of farmers' adaptation is an implicit demand towards cotton scientists, expressing a need for new combination of production factors that can ensure better profitability than the existing ones. In Mali, according to a survey by CIRAD-CA, farmers are using less compound fertilizers than recommended but they are using more urea. This is less expensive but not perfect substitutes (Programme coton, 1998).

What are research issues to address

From our analysis, we can consider two groups of research issues, one to deal with the reasons why yield is stagnating, another is to have yield improved. To have yield be improved, there is either to extend the existing yield potential or to decrease the gap to existing potential yield.

Analyzing specifically reasons of yield stagnation

Reasons of yield stagnation is location-specific that need location-specific studies and that should involve more social scientists. Studies for identification and clarification of these reasons are a basis for setting up or amending cotton policies. In some countries those studies exist or have been implemented. It is however common to notice that such studies are implemented by external consultants, with little involvement of national scientists.

It is quite curious to realize that decision makers on cotton policies seem not to expect outputs regarding the functioning of cotton sectors from national scientists. It is worthwhile to correct this situation, this is beneficial also to technical scientists to know more about the conditions of application of their technical recommendations.

Achieving a new increment of potential yields

Yield potential could be improved following 3 possible ways. One is to have new varieties better fitted to an existing set of technical practices or technical patterns, this would mainly call for geneticists' implication. Another is to question the existing technical practices, available cultivars remaining unchanged, this would essentially call for agronomists' implication as well as crop protection specialists. Finally, a more promising one would be to achieve new interactions between new cultivars and new technical practices, such way demands actual multi-disciplinary approach.

Improving yield potential without change in technical practices

Such improvement is requested for instance after environment change, either biotic or abiotic, is limiting yield potential. The most obvious phenomenon in this case is the occurrence of insect resistance to pesticides. Answers are expected from genetics, and in particular through biotechnology. These answers are already implemented, although still at a limited scale and we are still too close to have a proper view about the sustainability of such answers. Less obvious is the climatic change that demands new varieties more adapted for instance to reduced rainfalls.

For countries where farmers are reluctant to use costly fertilizers, implementing then a kind of soil mining through cotton growing (Van der Pol 1990), breeding for genotypes with high fertilizer efficiency ratio makes sense. This breeding could concern also mechanisms of nutrient assimilation, or schemes of vegetative growth leading to higher harvest index.

Extending yield potential through new technical practices

Research and implementation of new practices has become a reality in developed countries or at commercial cotton farms in developing countries. This is the case of ultra-narrow row planting (Reed, 1997; Stalcup, 1997) and of no-tillage, direct sowing as reported in Brazil (Seguy *et al.*, 1998).

In the area of crop protection, some achievements deserve to be mentioned. Scouting as a method to monitor chemical pest control has become common in developed countries, while Mali and Cameroon are experimenting a similar approach with illiterate farmers (Silvie *et al.*, 1998). In the USA, there are software programmes to fine tune crop monitoring in terms of irrigation, fertilizing and pest control while a new generation of models is being achieved (Jallas *et al.*, 1998). It is likely that that this will result in great progress to help achieve better cotton crop management, ensuring better yield, better income and better control of undesirable environmental impacts.

However, in developing countries, little is being done to carry out new technical practices that save input use, limit mineral exportations from the soil, ensuring both better yield and better income. For sure, new technical practices in the USA or Australia are not relevant to developing countries. Computerized crop monitoring neither. Nevertheless, there are implicit demands being addressed. In Francophone African countries, yield of around 1200 kg/ha of seedcotton is achieved with cotton plants up to 2 meter tall. There is room to maintain or even increase this yield level by limiting the vegetative growth which would favour a better mineral balance under the current practice of low fertilizer use. In Mali, according to a survey we have conducted, it is clear that farmers are implementing plant density lower than recommended (Programme coton, 1998), while the situation is quite reverse in Bolivia, where farmers are implementing high densities up to 100 000 plants/ha, and geneticists are keeping on testing genotypes at a constant density of 50000 plants/ha. It seems that there is a demand from farmers for new densities, in accordance with their strategies in input use.

Yield increase through new genotypes x technical practices

We think that the most promising way of extending yield potential could derive from exploitation of new genotypes x technical practices interactions. Genotypes react differently to technical practices. It seems therefore sound to expect that new technical practices should be experimented along with genotypes screening to obtain better outputs. This is not however the common practices. It is very usual that geneticists just ask agronomists what are the technical practices to follow. Therefore, genotypes are selected taking technical practices as given for ever.

Thus there are promising prospects of progress from breeding, based on genotypes x technical practices interactions. Clearly, this process will need an interaction between different disciplines, genetics, entomology, agronomy. As farmers' actual practices could differ significantly, interaction with farmers makes sense. This is one factor that justifies participatory breeding.

Reduction of the gap to potential yield

Of course, the existing large gap between the potential yield and yields that farmers achieved actually has some relationship, in many countries, with the issue of extension or more generally speaking with the information upon the use of inputs. Lack of information induces that valuable techniques remain unknown. However, non-application of research outputs does not necessarily mean that farmers do not know them, non-application also means that existing techniques are not suitable to farmers under constraints that were not taken into account by scientists.

Moving forward more efficient use of costly inputs

In many developing countries, as a consequence of suppression of subsidy policy for input use, there is an obvious reluctance by farmers to use costly inputs at dosages previously recommended. As it was indicated in the case of Mali, farmers are trying to recombine fertilizers to decrease fertilizing costs. They are also delaying fertilizer spreading, in the extent that they may spread fertilizer at the most rainy period, with high leakage. In other words, trying to save costs, farmers may actually waste their money in a bad use of fertilizers.

Such situation means that scientists have to carry out new techniques more suitable to reluctance for using costly inputs. This is not an impossible challenge. Using less inputs but more efficiently is not an impossible task. The issue is to achieve better understanding of cotton response to input use, it is also to carry out new ways of diffusing information about input use, in order to allow farmers to monitor input use according, for instance, to the crop development or the rainfalls patterns.

Contribute to make inputs more accessible

Making input costs more acceptable is not an issue for technical research but it is not beyond the scope of research. The reasons for input costs to be un-acceptable to farmers are the costs level but this is not only an issue of input price. The real reasons and how to satisfactorily address them deserves to be tackled through specific studies.

Because of landlocked situation, some countries are facing transaction costs that could double the input price at farm gate position. In addition, some debatable tax policy could make input affordable to only few farmers. In Sub-Saharan Africa, international fertilizer providers use to claim that preferential tax policy on fertilizer is the best incentive to promote actual fertilizer supply, even in remote areas, and therefore to promote yield. A 5% tax is a maximum, the best being no taxing at the importation of fertilizers.

Affordability, pertaining to the price of inputs, is a factor of input accessibility. There are other factors being involved. In many developing countries, inputs are just not physically available at the locations where they are needed, at the right time, for the types expected (Fontaine and Sindzingre 1991; Gergeley, 1992; Lele *et al.*, 1989a). This is a situation that we, in developed countries, can hardly imagine, but this is a very common thing in developing countries.

Beyond the availability, there is also the constraint of liquidity or credit access that prevent many farmers to get the inputs they need (Creupelandt, 1979; Lele *et al.*, 1989a). Reasons of non-accessibility are nevertheless very diversified, studies about the issue of input accessibility must be also location-specific. By the time being, there is a dominating belief that privatizing input provision will improve the situation, there are few research works to contest this belief (Upton, 1992). In which extent this solution is working belongs also to cotton scientists' research scope, involving of course more social scientists.

Conclusion

The issue of yield stagnation has an impact on farmers' incomes, on the country production and exchange of cotton fiber and on undesirable environmental effects, signaling the need for new technical progress. Technical progress is expected is to advance the limits of potential yield, but this only concerns a small number of countries. Many countries actually need to move actual yields closer to potential yields.

Cotton scientists have to develop new genotypes, new technical practices and, more promising, outputs arising from exploitation of interactions between genotypes and technical practices in order to address this challenge. Exploration of these interactions demands a multi-disciplinary approach, within which social sciences play a role. In addition, social sciences need to be involved in setting up policies that ensure input accessibility.

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Figure 1. Cotton yield evolution in the world.

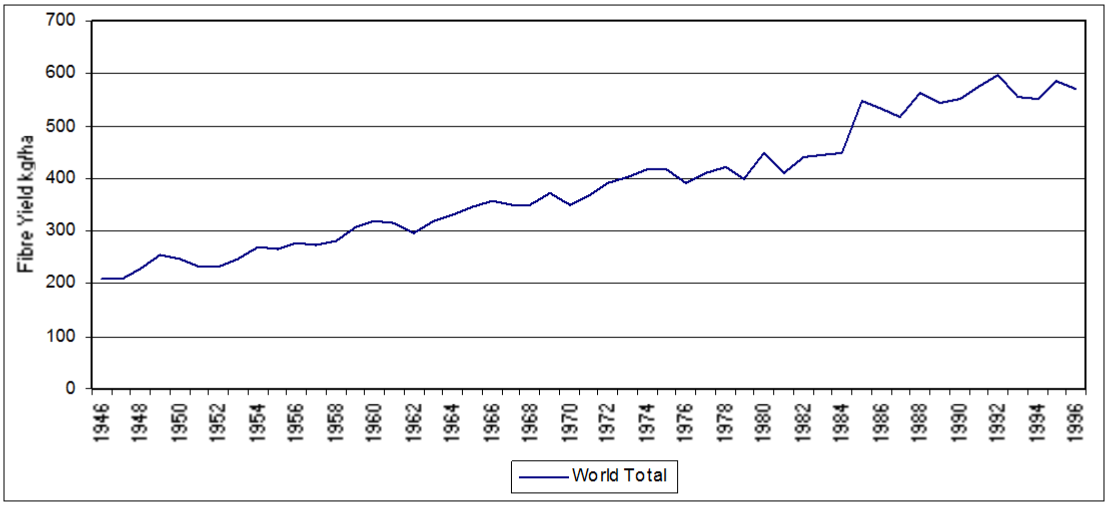

Figure 2. World yield evolution, irrigated production (data from ICAC).

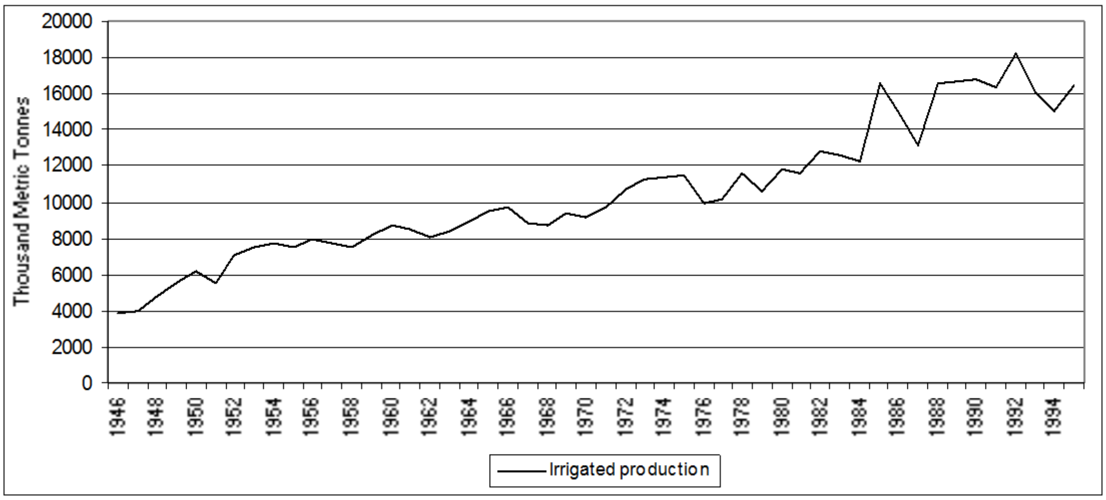

Figure 3. World yield evolution, rainfed production (data from ICAC).

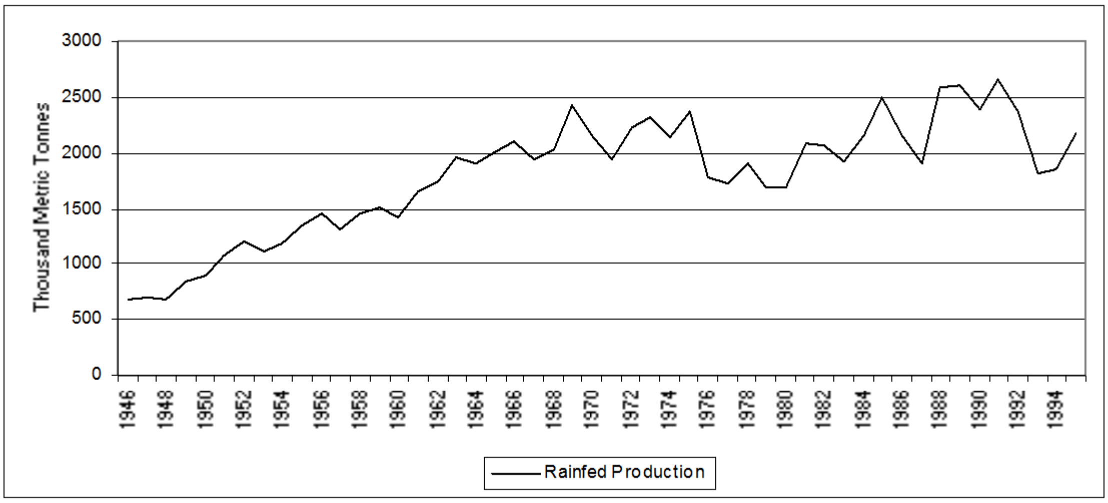

Figure 4. Yield distribution of rainfed cotton.

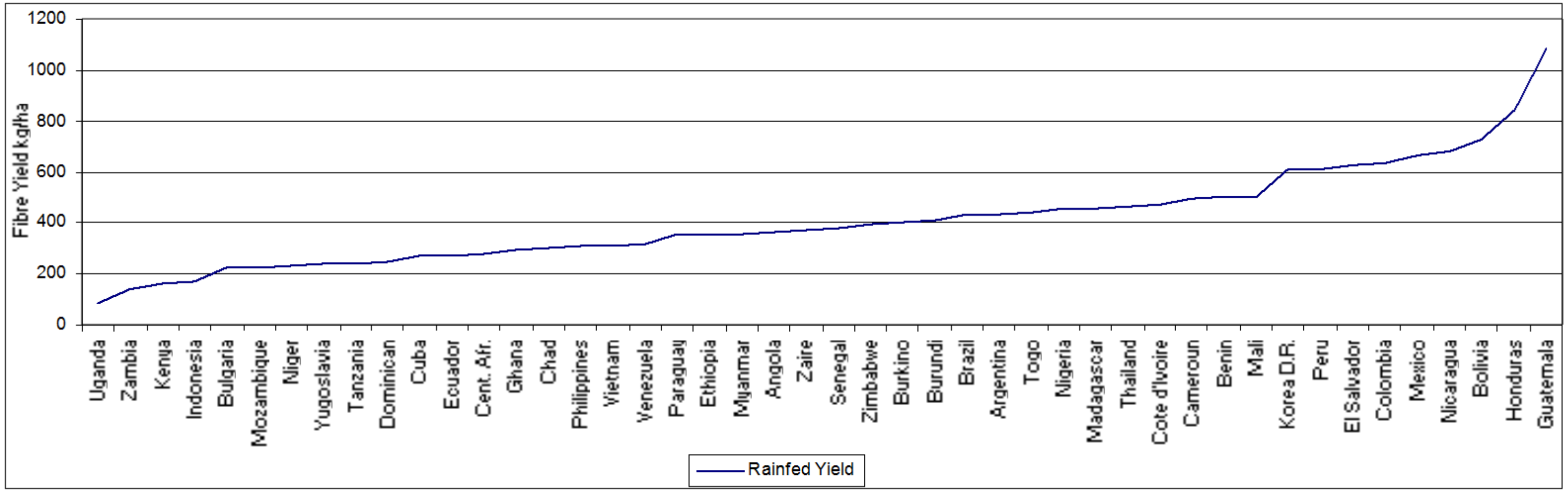

Figure 5. Yield distribution of irrigated cotton.