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No Growth in World Cotton Yield[1]

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World cotton production is currently estimated at 19.9 million tons during 1997/98 as against 19.6 million tons during the previous crop year. The one percent increase in world production this season is attributed to improvement in yields compared with 1996/97. World cotton production has increased as a result of innovations in production technology and has been over 20 million tons twice. The highest productions are related to highest world cotton yield and area during 1991/92 and 1995/96 respectively. It is anticipated that during 1997/98 the five major cotton producing countries i.e. China, USA, India, Pakistan and Uzbekistan will produce 69% of world production. Changes in area, production and yields in the five countries have a big impact on world cotton industry.

It is anticipated that cotton was grown in 68 countries on 33.5 million hectares during 1997/98. In the last 50 years, many times the cotton area has been about 33 million hectares, but it has exceeded 35 million only a few times. But, the cotton area has never exceeded 36 million hectares except 1951/52. During 1994/95, the world cotton supply fell short of demand for cotton, and in early 1995 the Cotlook A Index price was quoted at over 2 dollars a kg. The ever-record prices affected area in the following year when cotton was grown on 35.5 million hectares. It seems that, how high the prices may be, the current cropping systems and need for food crops does not permit growing cotton on over 36 million hectares.

In the last 50 years, while the area grown to cotton has fluctuated in the world, total production has increased as a result of increases in the yields. Yields increased in every country, However, the increases have varied depending upon the development and use of production technology. From 1950 to 1990, the world cotton average yield increased at the rate of 2% or 8 kg lint/ha. The world average yield was close to 600 kg/ha in 1991/92 which is the record so far. But, for the last 6 seasons, the world cotton average yield has not increased over 1991/92. It seems that the world cotton industry has entered into a period of no growth in yields.

Stagnation in Cotton Yields

Since 1992 world cotton average yields have failed to keep pace with the long-term average increase of 2%. 1997/98 was a good year in most cotton producing countries and according to the ICAC forecast, the average yield for 1997/98 will be 590 kg/ha which is 7 kg lower than 1991/92. However, the six year average data from 1992-97 shows over 4% decrease in yields. World cotton yields are not increasing any more. The stagnation in cotton yields could be attributed to specific difficulties affecting productivity in several of the largest producing countries. No growth in cotton yields is due to stagnation and specific problems faced in at least three of the five largest cotton producing countries. Similar specific problems also exist in some other countries.

Specific Problems in Major Producing Countries

Over the last nine years, cotton yields have not increased in the USA. Comparing cotton growing conditions at the world level, cotton production conditions have been comparatively more steady in the USA compared with other largest cotton producing countries of the world and yet yields have not increased.

In China (Mainland), during 1980/81 the average yield was 550 kg/ha. The 1991/92 average yield stood at 867 kg/ha and since then there has been no increase in yields in China. Due to pest problems particularly in Hebei and Shandong provinces, cotton production has moved to the Northwest in Xinjiang province where new areas have been brought under cotton production. A slight recovery in yields in China can be attributed to replacement of bollworm affected area with new area in Xinjiang. Since bollworm resistance became a problem in China, share of Xinjiang province has increased from less that 10% to over 25% of national production.

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In India, due to high yields, total production reached 3.0 million tons during 1996/97. The average yield was 327 kg/ha, which is a record. The current ICAC estimates for India suggest that the average yield during 1997/98 will be 307 kg/ha. The forecast for 1998/99 also does not show any increase over 327 kg/ha. India has not suffered from any serious production problems and growing conditions also suggest that India is one of the few countries where the full potential has not been utilized yet.

In Pakistan, the leaf curl virus disease is responsible for heavy losses in yields. Highest yields were achieved during 1991/92 and since then there has been no increase in yields. Rather, how much less than 1991/92 has become more important. Whitefly is responsible for transmitting the virus and it is not possible to eliminate whitefly from the production system. The national breeding priorities had to be reconsidered for inclusion of resistance to leaf curl virus disease as the most important criteria for approval of varieties. Through a project from the Common Fund for Commodities, ICAC is also helping Pakistan to produce transgenic cotton resistant to the disease.

Uzbekistan is passing through a transitional period of structural changes which have affected input supply for cotton production. In 1980/81, the average yield in the Central Asian countries was as high as 890 kg/ha. After 16 years, during 1997/98 the average yield in Uzbekistan is expected to be 712 kg/ha. Recently, the input supply has improved and yields have slightly recovered. But the stagnation effect is there and the current yield level is significantly less than in early 1980s.

Cotton yields in four of the five other largest cotton producing countries of the world i.e. Argentina, Australia, Egypt, Greece and Turkey are also not increasing. In Turkey, the GAP (Southeastern Anatolian Project), consisting of 22 dams and 19 hydroelectric power plants, will provide irrigation facilities to 1.7 million hectares. About one third of the total area irrigated by GAP is expected to go to cotton. Part of the project has already started working since 1995/96, which has an impact on yields. Expansion of the irrigation system will increase yields in Turkey in the next few years.

Reasons for Stagnation of Yields

Yield is an outcome of genotype interaction with the environment. Breeders invent new genotypes and try to accumulate as many favorable genes/characters in a plant as possible for obtaining the highest yield. All cotton varieties always have a huge genetic potential exploitable under suitable growing conditions. Growing conditions include climate and input applications. In the recent past, since the use of agrochemicals became popular in agriculture, technological innovations for best utilization of inputs have become of critical importance. Thus, in addition to genotypic constitution and environment, knowledge for most efficient use of inputs has also become an important criterion for realizing yield.

Unfortunately, the mechanism of genetic determination of yield is not properly understood in cotton. Yield is a complex quantitative character and breeders and geneticists do not have control over inheritance of hereditary material. According to Meredith, Jr. (1991) the increases in yield of cotton are due largely to many unidentified quantitatively inherited gene combinations. The nature of genetic control of yield or factors responsible for determination of yield do not permit breeders to manipulate the plant genetics according to their wishes. The available knowledge on inheritance of yield does not allow establishing what desirable genes have been transferred in the new genotype. Techniques are also not available to isolate desirable yield genes and induct them in the new genotype according to breeder's wishes. Consequently, it seems that a stage has been reached where further accumulation of desirable genes through conventional breeding can contribute little to yield improvement. Meredith et al (1991) also concluded that cotton breeders are not improving yields as much as they were 25 years ago.

The cotton plant has an enormous yield potential but only a part of that potential is realized. Under production practices, currently followed in most countries, input use has attained a dominant role. But, there is an upper limit for most efficient use of inputs. Given the limitations (possible to be resolved and not possible to be resolved) in every country, it seems that the available technological innovations for maximum profitability have been utilized and consequently yields have stagnated (ICAC 1997).

Yields vary among countries because growing conditions and levels of adoption of production technology are different. The available options have been utilized in many countries including the world's highest yielding

countries as well as low yielding countries.

Breeders Contributions

Yield records on cotton are available for about 130 years in the world. 130 years can be divided into four periods of prominent yield behavior. The four phases are 1860 to 1930s, 1930s to 1960s, 1960s to 1980s and the current regime, which started from 1992 onward. The first and the longest phase is characterized by almost no growth in yields. Development of varieties was based on non-scientific methods, as fundamental principles of inheritance of characters were not applied. Mendel's fundamental principles of genetic control and inheritance were widely accepted and applied from 1915 onward. Scientific cotton breeding started in most countries, and yields in most countries increased during the second phase from 1930s to 1960s. The third phase coincided with the introduction of insecticides and experienced increases depending on the extent of losses due to insects. The current phase is characterized by most efficient use of genetic development, synthetic fertilizers, insecticides and knowledge about physiological behavior of the plant. Plant reaction to the growing conditions was widely understood and utilized to a larger extent. Though the situation may vary from one country to the other, breeders contributions were more significant during the 2nd phase.

Role of Agrochemicals in Cotton Production

In the last 5-6 decades, there have been two significant developments in the form of agrochemicals, fertilizers and insecticides, that affected cotton yields in every country. If both types of inputs are eliminated from the production practices, it is doubted that 50% of the current yield level may be achieved. There are no efficient alternatives to synthetic fertilizers and cotton production has to bear the use of nutrient supplements in the form of inorganic fertilizers. At least there are two good things about the use of synthetic fertilizers versus the other major group of agrochemicals i.e. insecticides. Synthetic fertilizers are not expensive and they are also not as harmful to the environment as insecticides. In addition to meeting plant needs, synthetic fertilizers have played a great role in manipulating the cotton plant for utilizing its maximum potential. Large increases in yield, occurring in every country of the world, can directly be attributed to fertilizer use.

Insect pressure on the cotton plant increased and insecticides were developed which are now extensively used on cotton. Most countries adopted chemical control during 1970s and 80s. Insecticides use increased to the extent that it caused a serious impact on the economics of cotton production. While countries like Australia and China (Mainland) are faced with insecticide resistance problems, some Central American countries had to stop cotton production because of inability to control insects. Australia has been able to overcome the problem to some extent and control the use of insecticides through an effective resistance management program. China is currently implementing a resistance control program. Resistance problems have been noted in India and Pakistan, and they may be launching similar programs in the next few years.

Factors Responsible for Yield Improvement

A paper "Cotton Yields Stagnating" was published by the ICAC in the March 1997 issue of *THE ICAC RECORDER*, which also tried to identify the factors responsible for slow growth in yields. Most yield improvements in every country are ascribed to variety development. It is often claimed that high yielding varieties are responsible for yield improvement. While this phenomenon does not seem likely to lead to drastic improvements in the near future, the role of new varieties can be identified by following methods.

- If yield potential is due to superior genetic constitution for higher yield, low yielding varieties would always perform poorly at least at the same location. Growing obsolete varieties under the current production practices can assess such a genetic potential.

- If the quantitatively inherited characters have been accumulated in the new genotypes, they should out yield obsolete varieties even under obsolete production practices. Thus, it is proposed that modern varieties be grown under obsolete growing conditions and yield increases compared to old varieties.

- A third option is to grow the same varieties after every 2-3 decades and assess their yield level under the changed growing practices.

The first two options can be tried anywhere and anytime. A similar trial was conducted in Pakistan and one year data indicated that obsolete varieties were not far behind the modern varieties in yield. Fiber quality did vary significantly but no great differences were found in seedcotton yield. The third option could be utilized if long term trials were planned. Fortunately similar trials have been conducted in the USA. Ramey (1971) has reported the yield performance of same varieties after 32 years. Data are available for bolls/m2, seeds/boll and lint /seed. Yield data are reproduced here.

Comparative Performance of Varieties in the USA

Year	1935 through 1938	1967 and 1968	% Increase in 1967 and 1968
Deltapine 11A	628	1072	71
Stoneville 5A	622	1014	63
Ambassador	591	871	47
Stoneville 2B	568	861	52
Washington	538	858	59
Missdel 1WR	440	780	77
		Average	62

Yield increases ranging from 47 to 77% are due to no other factors except change in the growing practices. Six varieties' average increase of 62% in 32 years is equal to the long run world average increase of 2% per year. Evans (1980) has rightly observed that plant breeders contributions in increasing yields can be divided into four categories as follows:

Adaptation to local environments - Breeders develop varieties under local conditions and, knowingly or unknowingly, they select varieties most suitable for the local environment. Local conditions may have cool early temperatures, extremely high summer temperatures, high humidity, shorter growing season etc., but all varieties having gone through selection process under such conditions have the capability to resist such climatic adversities.

Resistance to pests - Insects are no doubt limiting factors for yield improvement. Some programs like the multi adversity resistance program of the Texas A&M University are exclusively devoted to resistance to pests but all current breeding programs include resistance to insects in their primary breeding objectives. Minimization of losses due to insects consequently increases yield.

Selection for higher yield potential under favorable conditions - Selection under specific irrigation method and soil type automatically screens the highest yielding genotype for specific conditions.

Suitability to continually changing agronomic and management practices - Production practices vary greatly among countries. From the segregating population breeders identify the most suitable genotype for production practices of various regions.

Evans (1980) has also concluded that breeders are now placing higher priorities on local adaptation than they did before. Varieties now change after every short distance, possibly contributing to increased yields.

Impact of Yield Stagnation

The stagnation of cotton yields has significantly affected the world industry. World production is lower than it would be if yields had continued to rise during the 1990s, resulting in a tighter world supply, higher average prices and reduced consumption of cotton. Further, rising costs for inputs applied in the production of cotton have not been offset by increases in productivity.

The average Cotlook A Index over the past two decades has been 74 cents per pound of lint. However, the Index rose to more than 90 cents in 1994/95, and, while lower now, the Cotlook A Index remains near the long run average three seasons later. Because of reduced import demand from China (Mainland) and concerns about world economic growth arising from the devaluation of currencies in East Asia, world cotton prices have declined this season, and an additional reduction in imports by China (Mainland) could result in lower prices

again in 1998/99. Nevertheless, because yields are not rising while income and population growth continue to boost the demand for cotton, international prices are expected to remain near the long run average through 1998/99, and prices are expected to climb higher than average during most of the time over the next five seasons.

Cotton's share of world textile fiber consumption dropped from 50% in 1986 to 44% in 1997, and further declines in market share are inevitable if production does not rise to match demand. Because yields have not risen while input costs have continued to climb, the cost of cotton production per kilogram of lint has increased in the 1990s.

How Cotton Yields Could Be Improved?

Currently available technology has been utilized and consequently yields have stopped growing. Researchers in many cotton producing countries are confronted with maintaining the current status of yields in their countries. However, the cotton producing countries that have not utilized the available technologies to their fullest extent have a chance to improve yields. Further perfecting the technology can also bring slight improvements in yields. Slow growth in some countries may be coming from similar improvements. But, for any significant increases in world yields, like the one achieved during the last 3-4 decades until 1991, there is a need to invent new technology. This technology has to be different from the routine work done to develop varieties, assess agronomic requirements of varieties, control insect pests, etc. If new technology is developed, yields can be improved in every country. How much improvement depends on the ability in technology to increase recoverable potential of the cotton plant. However, the target could be to increase the number of bolls equal to the number of leaves on the plant. How to get there is an issue for researchers.

New Technologies

It seems that a new technology capable to bring in yield improvements equivalent to synthetic fertilizers and insecticides will not be available for many years. Consequently, the world cotton production industry has entered into a long term period of slow growth. Demand for cotton is increasing and the current ICAC projections show that the world cotton industry would need 22.3 million tons in 2005. In the absence of new technologies, solutions to the specific problems in the affected countries should be expedited to enhance world cotton supply for the textile industry.

Currently, one of the areas of most interest to the cotton industry is developments in the field of genetic engineering. Recent advances in the field of genetic engineering have provided an additional tool in the hands of breeders and geneticists for directed breeding. The technology provides for induction of non-species genes into the cotton plant and their utilization generation after generation. Single or multiple genes can be identified in relatives and non-relatives of the cotton plant, isolated and fused into the cotton genome. The effect is permanent and stable. One such example is Bt cotton wherein a gene from the soil bacteria was inserted into the cotton plant for obtaining resistance to bollworms, particularly the tobacco and cotton bollworms.

The gene insertion process has become easier. The Ballistic gun method and agrobacterium mediated transformation are commonly used by many laboratories. But, the areas of interest are resistance to insects, herbicides, improvement in fiber characters and novel qualities like colored cotton. Nobody is working on yield improvement, knowing that there is a gap between yields obtained and genetic potential of the cotton plant. Many fruiting positions on the plant remain vacant. Many countries have improved the ratio of recoverable potential to genetic potential and improved yields. It is not only filling of vacant positions; genetic engineering could improve yields by other means. The only technology in the offing at this time is genetic engineering.

Can genetic engineering convert the cotton plant from C_3 to C_4 plant is not known. Again no work is reported to be going on on this aspect. Cotton is a C_3 plant and photorespires at about 30% of the photosynthetic rate. If cotton is converted from C_3 to C_4 there could be a large increase in yield.

A broader genetic base is must for genetic improvement in the population. There is no formal way to exchange cotton germplasm among breeders at the international level. The modern trend to patent more and more varieties/germplasm is likely to further curtail open exchange of germplasm, thus limiting genetic progress. It is important that easy exchange of germplasm may be encouraged for continued growth in yields.

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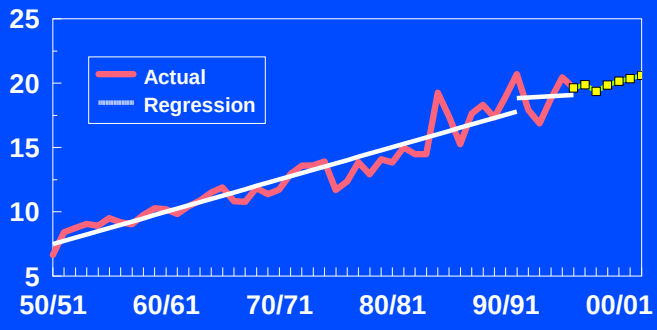
WORLD COTTON PRODUCTION

Million Tons

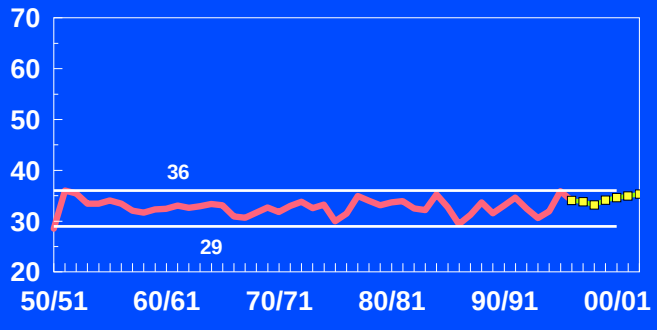


WORLD COTTON PRODUCTION

Million Tons

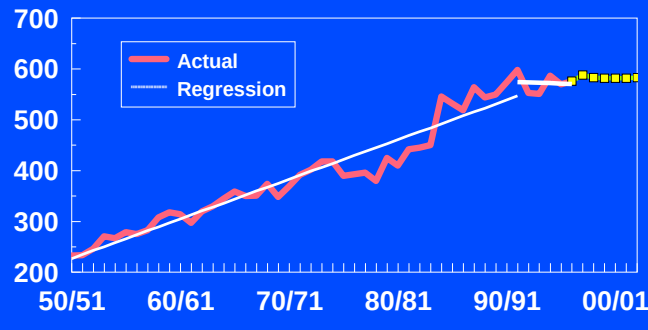
WORLD COTTON AREA

Million Hectares



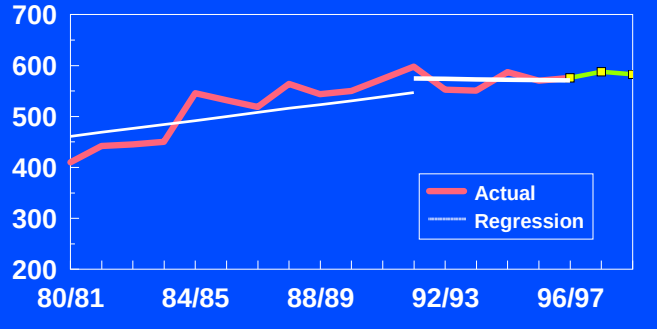
WORLD COTTON YIELDS

Kilograms/Hectare



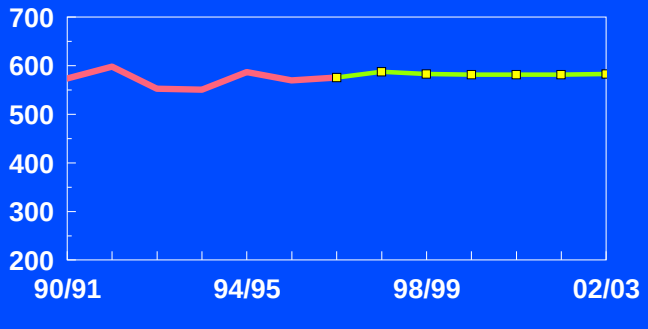
WORLD COTTON YIELDS

Kilograms/Hectare



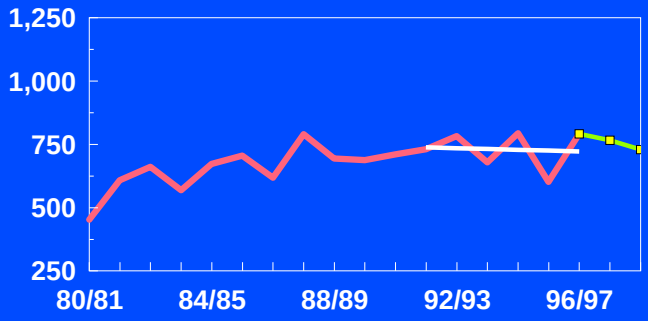
WORLD COTTON YIELDS

Kilograms/Hectare



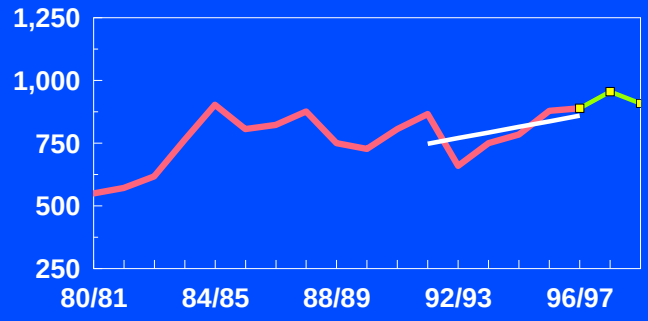
COTTON YIELDS: USA

Kilograms per Hectare



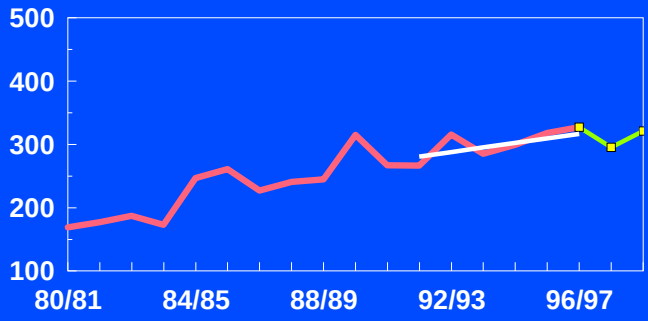
COTTON YIELDS: CHINA (M)

Kilograms per Hectare



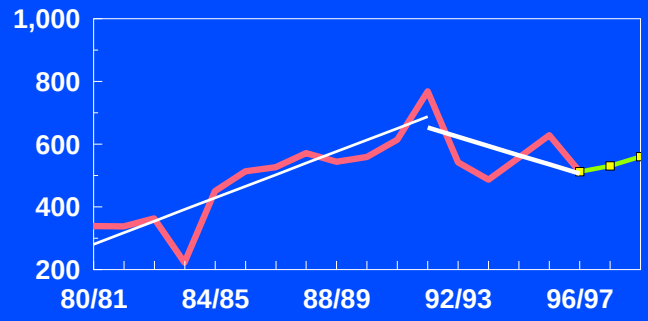
COTTON YIELDS: INDIA

Kilograms per Hectare



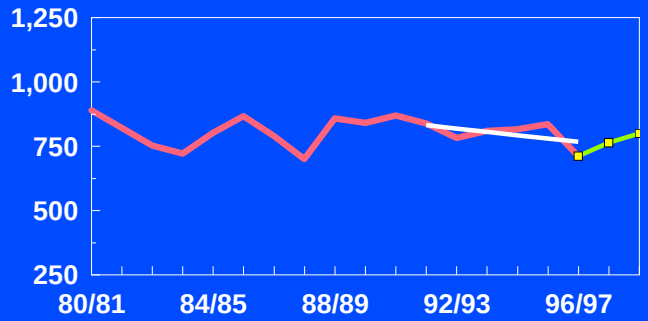
COTTON YIELDS: PAKISTAN

Kilograms per Hectare



COTTON YIELDS: UZBEKISTAN

Kilograms per Hectare



YIELDS IN SOME COUNTRIES

Country	1997	1998	Record
Argentina	414	450	573 (1987)
Australia	1,487	1,487	1,781 (1991)
Egypt	814	834	>1,000 in 80s
Greece	958	1,000	1,007 (1995)
Turkey	1,107	1,143	New record