THE ICAC RECORDER

International
Cotton
Advisory
Committee

Technical
Informational Section

VOL. XXII No. 3
SEPTEMBER 2004

Update on Cotton
Production Research

Contents

Introduction

The latest ICAC estimates are that the world yield in 2004/05 will be 654 kg lint per hectare. Israel will be the highest yielding country in 2004/05 with an average of 1,786 kg lint per hectare. Fifty-eight other countries will grow cotton on more than 5,000 hectares. The yield in Kenya from an area of 50,000 hectares will be as low as 97 kg lint/ha. The yield in Mozambique is expected to be only 114 kg/ha from a total cotton area of 230,000 hectares. The yield in Uganda from almost the same area will be 129 kg/ha. Out of the total of 59 countries, the average yields in 41 countries will be less than the world average, while 18 countries will produce more than 654 kg/ha in 2004/05. The average yield in 17 countries will be less than 50% of the world average yield. The average yield in the Middle East region will be 1,189 kg per hectare, compared with 213 kg/ha in the Southern and East African countries. The first article on variation in yields among countries analyses reasons for the differences in yield, and looks into the possibilities of reducing those differences.

The second article 'Input supply system in Iran' describes how seed, fertilizers, irrigation water, insecticides and farm machinery are supplied to cotton growers in Iran. Iran continues to grow varieties that were developed many years ago. The General Department of Cotton and Oil Seeds produces and supplies planting seed to growers. The Iran Cotton Union, a newly formed organization, is preparing to take over seed production from the public sector. Some private seed companies already operate in Iran, but their share of the market is very low. Fertilizers and insecticides are supplied by the government. Prices in the open market for these inputs are higher, thus cotton growers rely on the public sector for inputs. Improvement in the delivery of irrigation water and other inputs would enhance yields in Iran.

India is the only country in the world where both, diploid and tetraploid cultivated species are grown on a commercial scale. India maintains a huge germplasm bank of cotton, and the bank is effectively used for cotton improvement. India has released many varieties and hybrids involving cultivated and non-cultivated species. The third article 'Use of wild species for cotton improvement in India' explains difficulties faced in utilizing useful traits from non-cultivated species. The article also highlights the successfully developed introgressed hybrids and varieties involving non-cultivated species.

The International Cotton Advisory Committee has published a book COTTON FACTS that is available from the ICAC Secretariat. The price of the 158 page hardbound book, including shipping and handling is US$20. For more details and to place orders visit the ICAC web page at <http://www.icac.org> or send your request to the following address.

Publications Manager
International Cotton Advisory Committee
1629 K Street, Suite 702, NW
Washington DC 20006
USA
Phone: (202) 463-6660 Ext 11
Fax: (202) 463-6950
Email: publications@icac.org

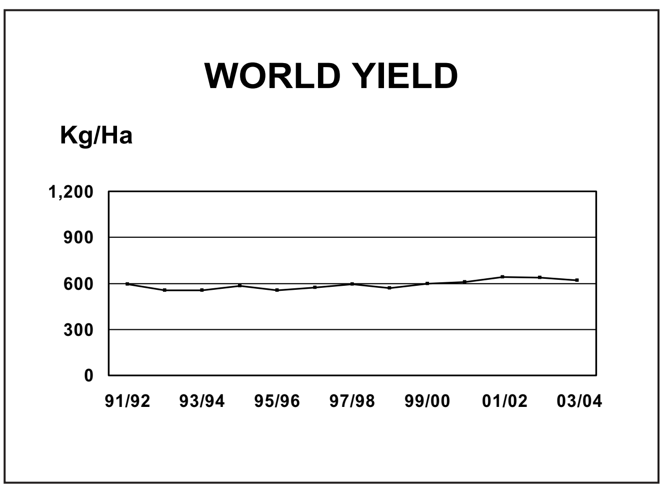
The International Cotton Advisory Committee constituted an expert panel on biotechnology in cotton in early 2000 with the mandate to prepare a balanced, science based report on cotton biotechnology written in language understandable to most people. Dr. Phillip Wakelyn of the National Cotton Council of America chaired the nine-member expert panel. The panel prepared a report in November 2000, which is available on the ICAC web page under cotton biotechnology. The 62nd Plenary Meeting of the ICAC held last year in Poland decided to reconstitute the panel and update the report published in 2000. Dr. Gary Fitt of CSIRO, Australia is the chairman of the current panel. The panel communicated through email, conference calls and met once in Washington DC. The report is ready and will be presented to the 63rd Plenary Meeting of the ICAC in India from November 28 to December 3, 2004. The report will also be available on the ICAC web page after the Plenary Meeting.

The ICAC RECORDER (ISSN 1022-6303) is pulbished four times a year by the Secretariat of the International Cotton Advisory Committee, 1629 K Street, NW, Suite 702, Washington, DC 20006-1636, USA. Editor: M. Rafiq Chaudhry <rafiq@icac.org>. Subscription rate: $175.00 hard copy, $140.00 electronic version.

Regardless of whether yields are high or low, farmers are concerned about the cost of production per kilogram of cotton. High yields achieved with extremely high production costs per kilogram are not as attractive for growers as good yields produced at lower cost. The Technical Information Section produces a report on cost of production of raw cotton every three years. The latest report covering data from 30 countries has been published and is available from the ICAC Secretariat. The ICAC is the only source of information on cost of production at the international level. The ICAC data include cost of all inputs and field operations, including harvesting and ginning, required to produce cotton. Most countries have also reported economic and fixed costs involved in cotton production.

Variation in Yields Among Countries

Fifty-nine countries will grow cotton on at least five thousand hectares or more in 2004/05. The latest ICAC estimates suggest that the world average yield will be 654 kg/hectares in 2004/05, the highest ever. Out of the 59 countries, average yields in 41 countries will be less than the world average, while 18 countries will produce more than 654 kg/ha in 2004/05. The average yield in 17 countries will be less than 50% of the world average yield. Among them are Kenya, Mozambique, and Uganda, where average yields will be less than 25% of the world average. Israel will have the world's highest yield of 1,795 kg/ha lint. The average yield in Australia is expected to be 1,667 kg/ha, while seven other countries will produce more than a ton of lint per hectare: Brazil, China (Mainland), Greece, Mexico, Spain, Syria, and Turkey. Although such differences among countries have always existed, the invention and adoption of technology, including new varieties, have widened differences among countries. As we will see in the present article, the differences may have narrowed in some countries within a given region, but in general, the level of adoption of technology has widened gaps among countries.



Average Yield by Region

Only Mexico and the USA produce cotton in North America, though some reports indicate that a few thousand hectares are occasionally planted to cotton in Cuba. The average yield in 2003/04 in Mexico, where 62% of the total area was planted to transgenic varieties and almost 100% of the area was planted to varieties developed in the US, was 42% higher than the US average yield of 818 kg/ha. The average yield in Mexico has been higher than in the USA since 1964/65, with the exception of 1991/92, 1993/94, and 1994/95. Most of the time the margin has been significant.

Though the area devoted to cotton shrank in most countries, total production in South America has not changed much for over the last 30 years. The average yield in South America has almost doubled in the last 15 years. The largest contribution to the regional average comes from Brazil, where there was almost a three-fold increase in the average yield since 1990/91. Cotton area in most other countries decreased significantly due to the high cost of production, but they managed to maintain yields if not increase them.

Egypt and Sudan are the only two significant cotton producing countries in North Africa. Average yields in Egypt have not increased. While in Sudan there have been some increases, but they have been erratic in general.

The West African countries started to expand cotton production in the early 1960s. Cotton area more than doubled since the early 1990s. But there has been no significant increase in average yields in any country. Southern and East African countries are the lowest yielding countries in the world. The average yield for the region was only 34% of the world average in 2003/04, with six countries out of eleven producing less than 200 kg of lint per hectare.

Only Greece and Spain produce cotton in the European Union, and average yields are at least 50% higher than the world average.

Yields have gone down in all Central Asian countries during the 1990s. Average yields for the East Asia and Australia region is high due to Australia and China (Mainland). The South Asian region includes two of the five largest cotton producing countries in the world, but the average is low due to India's having the largest area and producing only about half of the world average yield.

The Middle East and the Mediterranean region is the highest yielding region in the world. Iraq is unable to realize its yield potential for obvious reasons, but the average yields in all other countries are significantly higher than the world average.

Average Yield by Region - 2003/04

Region	No. of Cotton Producing Countries	Average Yield (Kg/ha)	Range (Kg/ha)	Highest Yielding Country
North America	2	811	808-1,146	Mexico
South America	8	798	340-1,086	Brazil
North Africa	2	492	485-845	Egypt
West Africa	11	450	244-533	Senegal
Southern and Eastern Africa	11	213	97-445	South Africa
European Union	2	959	952-984	Spain
Central Asian countries	6	603	400-906	Kyrgyzstan
East Asia and Australia	6	1,007	357-1,554	Australia
South Asia	5	385	206-560	Pakistan
Middle East	5	1,189	545-1,730	Israel

Egypt is not included in this region in the table but the average yield in Egypt, where only G. *barbadense* is grown, was 845 kg/ha in 2003/04.

Reasons for Yield Variation

Yields vary within a field (if fields are big), across fields, within a region, across regions, within a country and across countries. Yield in cotton is a function of at least five sets of factors–soil, variety, weather, input use and crop management. Each of these sets of factors affects yield directly and significantly, and each factor interacts with the others in such a way that improvements in yields and minimization of variability is complicated. In order to minimize variability, one must understand the relative contribution of each of these factors and the manner in which these factors interact with each other. Only with a good understanding of what causes yield variability can one consider changes and improvements that will minimize variability and improve production efficiency. The factor that can be least manipulated is the weather, which can be anticipated on the basis of past trends. However, rains received during the season, particularly in the dry land areas, increase the importance of weather.

Varietal Factors

There is variation in yield potential among varieties, but the variation is small, and in most cases yield variation can be managed to a large extent through input uses and management practices to minimizing differences. All varieties are high yielding and able to produce national average yields, provided agronomic practices and other technology recommendations are followed. By varieties we mean approved or adopted cultivars for any country or a region within a country. Breeders develop and introduce improved germplasm and utilize it in hybridization programs for finding the best yielding variety for their growing conditions. Genetic principles are followed, but since genetic control for higher yield is not controlled by specified and known genes, in most circumstances, breeding works as an art of selecting the best performing genotypes under a given set of growing conditions. Consequently, breeding is hybridization and selection of the most suitable genotypes for a set of growing conditions and input practices. If the selection process is followed under high-input conditions, it is apparent that a genotype having the capability to perform the best under high-input conditions will be selected. But if the segregating generations are scrutinized under low-input conditions, the genotypes selected at the end of the process will have better resistance to adverse conditions. It is not necessary that such genotypes will perform equally well under high-input conditions. Genotypes that have proved successful in the selection pressure exerted under high-input and better agronomic practices may not be able to maintain their superiority under poor management of input conditions, necessitating the need to select the variety best suited for growing conditions.

Field performance shows that different farmers can grow different varieties more successfully. While the genetic potential between two varieties may not be different, different farmers can realize different yields from the same variety. Apart from the agronomic practices mentioned above, approaches to treating different varieties vary among farmers. Farmer A may be able to obtain higher yields from variety 1, while Farmer B may be able to get higher yields from variety 2, even though their growing conditions are similar if they are neighbors. A third grower may be able to get competitive yields from both varieties.

Weather

Cotton is affected by weather from emergence to picking, and even during storage. All areas within a field, and many fields in a region or country experience the same weather. However, the impact on yield within a field (if the fields are large) and on many fields can be different. Weather conditions, particularly rains, may not be uniform, thus enhancing variability in yield among fields. Assuming that rains were uniformly distributed over a large area or in a region, the physical and chemical characteristics of the field could impact variability in yield. Ten to fifteen centimeters of rain in a sandy loam soil can be entirely beneficial to the crop, while the same amount of rain on a clay soil could have a negative impact on yield. Inundation of cotton fields suffocates the root system, resulting in wilting of the crop during hot sunny days.

Low atmospheric temperature at the time of planting can delay emergence and result in poor establishment. Lower-than-normal temperatures at early stages of plant growth can delay formation of flower buds. Lower-than-normal temperatures can also affect the rate of formation of flowers and bolls thus delaying maturity and extending the effective fruiting period, making the plant vulnerable to conditions close to the termination of the crop. Late-formed bolls may not be able to acquire optimum degree-days and mature on time for contributing toward productivity. In addition to effects on quantity, the effect on quality can be enormous.

Initial low temperatures can delay formation of fruiting buds and exert higher pressure on the plant to produce higher photosynthates for meeting daily per-day per-boll requirements. Failure to meet per-day photosynthate needs of all bolls on the plant results in lower yields and higher variability in yield among regions and countries. In countries where the cutout date is stringent, which is the case in most cotton producing countries, the effect of low temperatures can be an even more significant determinant of yield. The plant must go into reproductive phase at a proper time, maintain its optimum fruit formation rate, and physiologically surrender to the unfavorable conditions only on time.

Higher than normal day and night temperatures can be useful as well as harmful, but it depends on the growing conditions under discussion. The general principle of field conditions is that the duration of the period from sowing to first square decreases with increases in maximum and minimum temperatures. Higher temperatures enhance plant metabolic rate thus reducing the time taken by an open flower to become an open boll. The open flower can take 45 to 60 days, or even more, to mature as an open boll. Though soil fertility status will have a role, the duration is largely determined by maximum and minimum temperatures. Greater differences in the maximum and minimum temperatures (day temperature remaining normal but night temperature falling below normal) at the crop-maturing stage enhances boll opening. The condition may not apply to many countries where the daytime temperature does not exceed 40°C, but where it does happen, thermo-toxicity is a big concern. The thermo-toxic effect is more pronounced on bud shedding rather than flower or boll shedding. Extremely high temperatures at the time of flower fertilization can abort pollen tube growth, resulting in non-fertilization of the flower, which is bound to shed. High temperatures three weeks prior to flower opening can increase the chances of flower bud shedding and incomplete fertilization.

Low temperatures slow the metabolic process thus affecting plant growth and fruit formation, while extremely high temperatures have their own consequences. The resilience of the cotton plant with respect to unavoidable deviations from optimum temperatures is one of the reasons that different countries and regions have different yield levels.

Crop Management/Understanding of How to Grow Cotton

The understanding of how to grow cotton is an important factor that determines yield level. Cotton is a technical crop compared to other field crops. A farmer may have a high yielding variety and all inputs available, but will not be able to realize a good yield level if he/she does not know when and how much of a given input to apply in response to a particular crop condition in the field. For example, cotton is a crop in which the application of a particular input including irrigation in the morning or evening will have consequences. If the crop is suffering due to a shortage of moisture in the ground, any delay could cause squares to shed. Similarly, if the crop is suffering due to a particular pest or pests, irrigation or fertilization before spraying the crop with an insecticide may not bring the expected benefit of irrigation and fertilization. The farmer must also understand the varietal behavior and response to individual inputs and the interaction among inputs in addition to the resultant effect on the variety. Without this understanding, the farmer could suffer losses in yield. Farmers' understanding of growing cotton varies significantly among countries/regions. This factor is responsible for variation among yields. Research farm yields are always higher than common farmers' yields, signifying the importance of know-how in growing cotton successfully.

Role of Inputs

Inputs play a critical role in meeting plant needs not only for vegetative growth but also for protection against insect pests and fruit bearing at the right time and in proper numbers.

Irrigation

Cotton needs irrigation for taking-up nutrients from the ground and to compensate for evapotranspiration losses. Yield will be affected if sufficient moisture is not available in the ground. Water needs can be met from rains in case assured irrigation is not available, but rains are not regular and cannot be timed unlike an assured irrigation supply. All cotton is irrigated in Egypt, Pakistan, Sudan, Syria, and Uzbekistan. More than 90% of cotton area is irrigated in China (Mainland), Greece, Israel, Spain, and Turkey. All other countries grow cotton under rain-fed and irrigated conditions or only under rain-fed conditions. The data from many countries show that rain-fed or dry land cotton produces only half the yield compared to irrigated land. The differences can be lower under certain conditions depending on the need for irrigation, but whatever the farmer does, rain-fed and irrigated cotton yields will not be the same. The reason for a reduction in yield under rain-fed conditions is known, but no easy solutions are available.

Fertilizers

Nutrients leach with water, and roots take them up as needed by the plant to grow, form bolls, and mature fruit. Major nutrients, particularly nitrogen, are a must for good yields. Nutrients can be supplied either through organic fertilizers, green manuring or synthetic fertilizers. As the plant grows and increases its volume, plants' need for nitrogen and other nutrients change drastically. Nitrogen needs progressively increase with the growth and deficiencies are supplemented with synthetic fertilizers. Nutrient supply must match the plants' needs, otherwise the plant could remain either under-nourished or over-nourished, and in either case yield will be affected. The availability of fertilizers and their optimum use brings differences in yield.

Pesticides

Good varieties, timely irrigation and optimal fertilizer use will maintain proper growth and enable the plant to produce fruiting parts. Fruit on the plant can be lost due to insect pests if pesticides are not used or if an alternate means of pest control is not adopted. Because cotton is attractive to a variety of pests, particularly insects, the level of protection against pathogens and insects has a direct and significant effect on yield. Insect pressure has increased in all countries to the extent that insecticides have become an integral part of production practices. Insecticide use in the form of what to spray, when to spray, and how to spray has become the most critical factor in determining the level of yield. What, when, and how to spray are responsible for a significant part of the variation in yields among countries.

Agronomic Operations

Agronomic management is a combination of input use in addition to preparing the field for planting, hoeing, and removal of weeds. The primary purpose of efficient agronomic management is to apply inputs at the most suitable time only in required quantities such that the cost of production remains at a minimum. It is possible to achieve this only if the complex interaction among inputs and their effects on plant growth and development are properly understood and can be foreseen in advance their uses. A failure to forecast the impact on plant growth can result in inefficient use of inputs and higher costs of production. The effects of agronomic management practices are evident from the work published by Ramey, Jr. (1972) on the performance of six cultivars tested under two management regimes. Six varieties were tested from 1935 through 1938 and in 1967 and 1968. According to Ramey Jr. (1972), in almost 30 years, fertilizer use increased from almost 50 kg/ha to approximately 100 kg/ha, and organic insecticides were replaced with more effective products in the latter regime. The data from 1935 to 1938 is an average of four years while the data from 1967 and 1968 is an average of two years, which to a large extent automatically eliminates the effects of seasonal variation. In 30 years, the average yield of six varieties increased by 61%. The reason for the increase in yield is the ability to produce and retain a higher number of bolls, which is evident from the data below. Data were also recorded for seeds/boll and lint/seed which increased an average of 3% and 2% per year respectively.

Number of Bolls in Six Cultivars

Variety	Number of Bolls/m2		
	1935 through 1938	1967 and 1968	% Change
Deltapine 11A	30.6	57.3	+87
Stoneville 5A	33.8	50.6	+50
Ambassador	26.0	37.1	+43
Stoneville 2B	29.7	40.0	+35
Washington	26.1	35.0	+34
Missdel 1 WR	22.6	39.3	+74
Average	28.1	43.2	+54

Is it Possible to Eliminate Variations in Yield?

There is wide variation in average yields among countries. It is possible to reduce, but not to eliminate variation. Each set of growing conditions has a maximum yield potential, and actual yields vary with levels of adoption of production technology, input use, and agronomic management of the crop. The approach to minimizing differences is generic to some extent, but depends primarily on local growing conditions. The constraints causing lower yields have to be identified first. This is as true for low yielding countries wishing to initiate a program to reach the world average as it is for higher yielding countries like Australia and Israel which may be seeking to maintain previous performance. Some specific examples are given below.

Australia

Australia has been the highest or the second-highest yielding country in the world for the last several years. The average yield per hectare has been more than a ton of lint for almost three decades. According to Constable (2000) the relative contributions from breeding (varieties), soil-nutrition-irrigation management, insect control, and disease control to good yields in Australia are 45%, 25%, 20%, and 10% respectively. Australia seems to have optimized utilization of these components, and significant increases are not expected. The same is probably true for Israel.

Brazil

Cotton area in Brazil was reduced by almost 75% in about the last 20 years, but average yields have almost tripled. This has come about because of a shift in the area planted to cotton. Cotton moved from the north and northeast to the south and southwest where soils are inherently more fertile. Most contributions to higher yields have come from fertile soils, suitable weather, and mechanization of high-input production practices. Three-fourths of the total area is grown under such conditions, and any expansion in area would not reduce yields.

China (Mainland)

Average yields in China (Mainland) increased significantly during the 1980s, and then showed erratic trends during the early 1990s. Since 1992/93, the yield in China (Mainland) has almost doubled to 1,177 kg/ha in 2002/03. All increases in yields in China (Mainland) have come from better protection against insects, high insecticide use in the 1980s (resulting in an insecticide resistance problem), and IPM followed by biotech cotton since the mid-1990s. The Chinese situation exemplifies the role of pest control in reducing variation in yields among countries.

Egypt, Greece, Pakistan, Spain, and Syria

These are the countries where most components of yield improvement have been optimized. Significant improvements are not expected, but further perfection in technology adoption can reduce the margin with other high-yielding countries. Many other countries fall into this category where little can be done to reduce variation among countries.

India

Cotton yields in India are far below their potential. As discussed above, potential is determined by a combination of factors, and the reasons for low yields in India seem to be other than those mentioned by Constable (2000). Close to half of the cotton area is planted to commercial cotton hybrids, so varieties are not a limitation, and weather conditions are suitable for cotton production. On the average, cotton is sprayed at least six times a season, which indicates that agronomic practices and understanding of farmers of how to grow cotton may be the factors responsible for low yields. India has the potential to narrow the gap in yield with other high yielding countries.

Turkey

Turkey has seen significant increases in yields due to good plant protection during the 1980s. An expansion in irrigation water supplemented further increases. Improvements in more than one aspect of production contributed to the upward momentum, which can be repeated in other countries.

Central Asian Countries

Average yields in Azerbaijan, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan have declined since the early 1990s. Reasons for the decline are disruptions in input supply, inadequate research facilities, insufficient technology development, and poor technology transfer and adoption. Improvements in these areas can help to recover yields, but yields in Central Asia will probably not exceed the yields achieved during 1980s. The other important but common factor among these countries is the lack of sufficient degree-days where variety development could contribute, but the shortness of the growing season has its own consequences.

West African Countries

The West African countries have a unique situation compared to most other cotton producing countries with respect to input use and agronomic practices. Cotton area has significantly improved without increases in yields. The important common factors that can improve yield and reduce variation with other higher yielding countries are the use of fertilizers and insecticides and improvements in agronomic management of the crop. West Africa has not availed itself of the use of inputs which can be easily used to reduce variation in yield among countries in the world.

Conclusions

Neither technological innovations nor new varieties are secrets anymore in the world. Seed companies advertise their new varieties and are always willing to sell planting seed to other countries as long as the country's own regulations permit importing planting seed. If a variety is imported, it comes with a package of technology to grow it successfully under those conditions. On the other hand, local breeding programs make their utmost efforts to meet challenges and develop the most suitable varieties for their conditions. No doubt, local programs may have many constraints.

The variation in yield among countries cannot be eliminated but it can be reduced. Countries vary in their yield potential. Potential is determined by a number of factors that vary among countries thus the variation will continue to exist. A number of factors individually and interactively are responsible for variation. Every country must identify the limiting factor or factors and implement plans accordingly for improving variation in yields. No uniform recommendations can be made for bringing the variation to a minimum. Many countries have already set examples that can be copied by other countries but every country has to discover which model suits their own conditions.

References

ICAC. 2003. *COTTON WORLD STATISTICS*, September 2003. International Cotton Advisory Committee, 1629 K Street, Suite 702, Washington, DC 20006, USA.

Ramey, Jr., H. H. 1972. Yield response of six cultivars of Upland cotton, *Gossypium hirsutum* L., in two cultural regimes. *Crop Science*, Vol, 12, May-June 1972, page 353-354.

Constable, Greg, 2000. The components of high yield in Australia. *THE ICAC RECORDER*, Vol. XVIII, No. 3, September 2000.

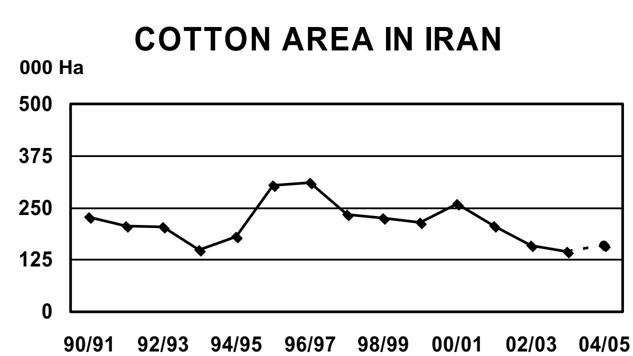
Input Supply System in Iran

Cotton production is a product of several interacting factors which form the input supply system of a given country or region. These factors include the quality and variety of planting seed, fertilizer, insecticides, water, equipment, and the cost of production. In this article, we examine these factors in the case of Iran, where several variables combine to limit cotton production.

About 10% of the land in Iran is arable, and agriculture contributes just over 15% to the gross national product but employs almost a third of the labor force. Wheat is the main crop, but barley, corn, cotton, rice, rapeseed, fruit (including citrus) and nuts are also grown on significant areas. The principal obstacles to agricultural production are primitive farming methods, overworked and under fertilized soil, poor seed and scarcity of water.

Cotton is grown in 16 of the 24 provinces in the country. The cotton areas can be divided into four main regions that contribute about 90% of the production in the country. All cotton produced in Iran is used domestically. Significant reduction in the area planted to cotton in the last three years forced Iran to import 20,000 tons of cotton for the first time in 2003/04. Most cotton is grown on land vacated by wheat. Cotton area fluctuates drastically, but normally is over 200,000 hectares. Cotton area has exceeded 300,000 hectares only twice, in 1995/96 and 1996/97. However, for the last three years, planted area has been around 150,000 hectares. The main reasons for the decline in area are lower international prices and an inability to improve yields in spite of rising production costs.

Average yields rose from 520 kg/ha in 1990/91 to 571 kg/ha the next year, to 612 kg/ha two years later and then to 681 kg/ha in 1994/95. The average yield dropped to 541 kg/ha in 1995/96. Yields in Iran have always been variables, but the behavior was more volatile during the 1990s. The average yield reached a record of 745 kg/ha in 2003/04. The reason for the increase could be the elimination of lower yielding areas from production. Mid-season indications are that Iran will be able to maintain this level in 2004/05.



Planting Seed

The Cotton Research Institute is responsible for developing new varieties. The Institute is located in Gorgan, 400 kilometers northeast of the capital, close to the Caspian Sea. However, conditions for research are more suitable at Varamin, closer to Tehran, and that is why most research on cotton is conducted in Varamin, where a subordinate office of the Cotton Research Institute has a team of breeders supported by other disciplines and a fiber quality lab. The Institute has developed all the currently grown varieties in Iran. Research on cotton was conducted at the Seed and Plant Improvement Center of the Ministry of Agriculture, but it was only a few years ago that the Cotton and Fiber Research Department of the center was upgraded to a full-fledged institute. Nevertheless, the Institute became recognized quickly by the government, and by cotton growers and other segments of the cotton industry. The Institute staff has actively participated in the meetings of the Interregional Cooperative Cotton Research Network for the Mediterranean and Middle East regions. Researchers from the Institute have also attended the three world cotton research conferences. Most research on cotton is centered on development of new varieties. A few years ago, DPL 16 was planted on a commercial scale, but now only varieties of local origin are planted in Iran.

Cotton Varieties Grown in Iran

Variety	Area (%)	Where Planted
Varamin	> 65	Central and eastern parts
Sahel	20-25	North region
Bakhtegan	10-15	South region
Mehr	4	Only 6,000 hectares planted in the northwest

Mehr is the newest variety and was released in 1995. Sahel and Varamin were released in 1971 while Bakhtegan was released for commercial planting in 1986. Cotton growers insist that they need new varieties, but researchers claim that the current varieties are the best and they do not plan to change in the near future. The cropping system practiced in the cotton areas shows that cotton planting has to be delayed considerably due to wheat in the field, if cotton is to follow wheat. Cotton and wheat overlap for more than a month. Overlapping of cotton with wheat limits the area to be planted to cotton. Iran could increase cotton area significantly by accommodating wheat and cotton in a one-year cropping system. It is only possible if wheat maturity is enhanced and cotton planting is delayed without sacrificing yields in either crop.

Planting seed can be categorized by generation: Nucleus, Super Elite, Elite, Mother and Certified seed. The Cotton Research Institute produces Nucleus and Super Elite seed under its direct supervision. Nucleus and Super Elite seed is supplied free of cost to the General Department of Cotton and Oil Seeds of Iran of the Ministry of Agriculture for multiplication. The General Department of Cotton and Oil Seeds produces Elite seed for multiplication as a Mother seed which is planted to produce Certified seed. Mother and Certified seed are produced with registered/progressive growers and supplied to cotton growers for planting. The General Department of Cotton and Oil Seeds makes sure that the crop to be certified meets certification requirements. A separate Department of Seed Certification exists, but with regard to cotton, the Cotton Research Institute dominates and has acquired the final authority to accept or reject any field for planting seed purposes. The Institute's bigger involvement in the certification process leaves less time for research purposes.

The Cotton Research Institute, being the only organization involved in the development of varieties, faces no challenge from other organizations linked to cotton production and development. This enables the Institute to claim that old varieties are still good and that there is no need to change varieties. The situation is not expected to change in the next several years, although a newly formed private organization, Iran Cotton Union, plans to initiate a private breeding program. This Union, being private and new, will take many years to gather the basic germplasm and come up with their own varieties. The Union is more interested in seed production and competes with a few comparatively smaller private seed companies already in business. The General Department of Cotton and Oil Seeds also wants to hand over seed production and distribution to a private organization like the Iran Cotton Union. The Iran Cotton Union initiated some seed production activities last year, and it appears that in the next few years, seed production in Iran will change hands. How successful and farmer-friendly the new seed system will depend on the successful establishment of the Iran Cotton Union. It also remains to be seen how the Iran Cotton Union performs when compared with the other companies like 'Dehkan Yar' and 'Zaire Yar', but change is on the way.

The General Department of Cotton and Oil Seeds of Iran maintains a list of registered growers who own good, fertile land and have enough resources and water to produce seed for planting purposes. The General Department of Cotton and Oil Seeds extends technical help if needed and also facilitates loans if registered growers need financial help to grow a successful crop. At the end of the season, the Department advises registered growers to provide seedcotton to designated ginneries. On the average, the General Department of Cotton and Oil Seeds pays a 10% premium for seedcotton compared to the market price. The price premium is shared between the grower and the gin on a 40% to 60% basis respectively. Payment is made to gins but it is difficult to track whether 40% actually reaches growers.

Seed is supplied by the General Department of Cotton and Oil Seeds at the rate of 40 kg/ha but farmers usually need more than 40 kg/ha. The Department has four delinting plants but due to problems with the equipment is able to provide only 5% delinted seed, 95% is not delinted nor treated with any fungicides. Sometimes ginneries also sell seed for planting purposes to meet additional requirements. The seed industry requires drastic changes to produce pure and high germination seed. All planting seed should be delinted and farmers must have high confidence in the purity and germination of seed. This is a challenge the Iran Cotton Union faces.

Fertilizers

Farmers report the area they have planted to cotton to the government, and the government provides fertilizers to farmers. Each province has an Agriculture Department, and within the Department the Agronomy Section deals with input supplies. The provincial Agriculture Department issues a voucher to farmers who can take it to the government supply store or a government contracted private supplier and buy fertilizer. Fertilizer purchased on the requisition issued by the Agriculture Department is subsidized, but they are only available in a limited quantity. The authorized private suppliers offer fertilizer at a price decided by the government. They cannot sell fertilizer or other inputs at a price higher than that decided by the government. Farmers have the choice of buying inputs from private stores in quantities greater than the requisition issued by the government but at a higher cost than the government's price. Farmers have to pay cash or arrange their own loans when they go to the government supply depots and/or government designated suppliers. Arrangements regarding the extra supplies are on terms and conditions agreed to by the supplier and the farmer.

Fertilizer Recommendation in Cotton

Nutrient	Soil Availability (ppm)	Recommended Dose (Kg/Ha)
Nitrogen	0.06	200-250
Phosphorous	5-6	200
Potassium	250-300	25

Inputs are supplied only for strategic crops: cotton, rice, wheat and rapeseed. Depending on the area and province, sometimes fertilizers and other inputs are also supplied for fruits but not for vegetables. Cotton is a strategic crop, but not in all provinces. Currently, cotton is a strategic crop in 15 provinces and the 16th province has a choice of whether or not to supply fertilizers for cotton. The decision is based on the quantity available from the provincial government.

Fertilizer Supplied in Major Growing Provinces 2003/04

Province	Urea Kg/ha	Ammonium phosphate Kg/ha	Potassium sulphate Kg/ha
Khorasan	250	145	60
Fars	150	100	50
Golestan	124	50	30
Average	**130**	**100**	**36**

There is great variation in the quantity supplied by the government. The consequences of this system are:

- Farmers can report more cotton area than actually planted to acquire more fertilizer than needed. The extra fertilizer can then be applied to crops not considered strategic in that province, or the fertilizer can be applied to vegetables. Fertilizer is not recommended for vegetables.
- The government supplies only specific brands, and farmers cannot choose fertilizers of their own preference. Sometimes farmers have a choice, but the number of types is limited.
- Soil conditions vary in fertility status from region to region and from field to field. Larger cotton growers with bigger fields may have variation even within a field, but according to the current system, all farmers in a region get a uniform quantity of fertilizer. Further, the amount supplied varies from year to year.
- All nitrogenous fertilizers are produced locally while most phosphorous types are imported. The supply of fertilizers depends on the quantity available from the government rather than the need of growers. This means that most fields are under-fertilized. Some progressive farmers go for soil testing to know the nutrient status of their farms, but they are unable to make full use of the information if they rely only on the government supply.

Insecticides

Sucking insects are more of a threat in Iran than bollworms and cutworms. Insecticide use is not high, and cotton is sprayed only three times per season on average. The first spray is against thrips, and the second spray is usually against a complex of sucking insects. Most farmers must have these two sprays. Additional sprays of insecticides depend on the intensity of bollworms and cutworms. Seasonal variation is great and in some years, more than two sprays may be required to control worms. For the last several seasons, whitefly has appeared on cotton, but the attacks have not been severe, and no sprays are needed against this pest. *Tetranychus* are more prevalent than whitefly, and require changes in the timing of insecticides applications. All Upland cotton is sprayed with insecticides, but some indigenous diploid varieties are not sprayed. About 80% of pesticides are formulated locally, while 20% are imported. Currently, only the government supplies pesticides, but the government is considering releasing control in the next four to five years.

Major Insects in Iran by Region

Region	Sucking & Mites	Cutworms & bollworms
Ardabil	*Thrips tabaci* *Aphis gossypii* *Tetranychus urticae*	*Agrotis* spp. *Helicoverpa armigera*
Fars	*Thrips tabaci* *Aphis gossypii* *Tetranychus urticae* *Empoasca* spp.	*Helicoverpa armigera* *Earias insulana*
Golestan	*Thrips tabaci* *Aphis nigrum* *Tetranychus urticae* *Gryllotalpa gryllotalpa*	*Heliothis obsoleta*
Khorasan	*Thrips* spp. *Aphis gossypii* *Tetranychus urticae*	*Euxoa segetum* *Heliothis obsoleta* *Earias insulana*
Mazandaran	*Thrips tabaci* *Aphis gossypii* *Bemisia tabaci* *Tetranychus urticae*	*Agrotis* spp. *Helicoverpa armigera* *Spodoptera* spp.

Insecticide Spraying in Iran

Region	Av. No. of Sprays	Area not Sprayed (%)	Spray Method (% Area) Hand	Motorized	Tractor	Arial
Ardabil	3	1	-	22	70	3
Fars	2	-	2	65	33	-
Golestan	2	-	-	87	5	8
Khorasan	2	20	10	60	30	-
Mazandaran	3	3	-	55-60	35-40	-

Irrigation Water

Most cotton in Iran is grown on irrigated land, and only about 5% is rainfed every year. Non-irrigated areas, usually receive enough rain during the cotton season. On average, cotton is irrigated four to five times in Gorgan and 10 to 12 times in Fars. The number of irrigations varies greatly among provinces depending on the amount of rain received in the area. Most cotton areas are irrigated by furrow and flood methods.

The two sources of water are rivers and wells. The Aras River in the northwest is the main river that irrigates cotton fields. In Iran, precipitation occurs mainly in the winter and decreases from northwest to southeast. Much of the precipitation in the mountains is in the form of snow. Melt-water is vital for Iran's water supply. Wells are private and belong to individuals or groups of farmers.

Irrigation Method	Cotton Area (%)
Flood	39
Furrow	60
Drip	1

Large growers usually have their own wells. Maintenance, including labor, oil, taxes and power supply, are calculated and divided among participating farmers. Water charges for river water are estimated by the irrigation organization of each area, and the price usually depends on the value of products (yield of agricultural products in the area). On average, 15,000 to 17,000 cubic meters of water are used to irrigate a hectare throughout the cotton season, and the cost is about 160 Rials/m^3 (US$300/ha) in the current season. Water from wells costs more because of high taxes and electricity charges. A shortage of irrigation water is a common complaint among cotton growers. Low water use efficiency of close to 30%, high evaporation losses due to high temperatures, and the cost of well water are of concern to cotton growers. The old system of sub-drain canals known as 'Ghanat' is deteriorating, and the rising cost of irrigation water is becoming a big concern.

Most cotton is planted on ridges at a configuration of 80 x 20 cm and Iran is searching for more effective methods of irrigation. Work has also been undertaken to improve water use efficiency but without much success so far. The water supply is limited and the need for irrigation at the time of planting cotton competes with the need for the last irrigation of wheat and barley. Sprinkler irrigation, particularly in the Gorgan and Gonbad areas, where the weather is not extremely hot, has been tried extensively. Pot irrigation, in which small cylindrical mud pots are placed below the ground surface, have been researched, but are not commercialized yet. Pots are made from a special mud and pore spaces allow enough water leakage to the plant. Pots are connected with tubes, like a drip tube, and most of the time pots retain some water in them. The water flows from one pot to the other via tubes. Research has shown that the system reduces water use by six to seven times compared with furrow irrigation. The normal life of such a system is seven years, but it is expensive and difficult to maintain if a tractor will be in the field a number of times.

Equipment

The Soil and Water Research Institute undertakes research on various aspects of soil fertility and improvement, in addition to irrigation methods. The Agriculture Machinery and Engineering Institute works in close cooperation with the Agriculture Department office in each area that deals with the purchase of tractors. New tractors can only be purchased through the Agriculture Department offices. Old tractors and other agriculture equipment are available from the market. It is estimated that the Agriculture Department office is able to provide 70% of the requisitions for new tractors every year. The Agriculture Department plays a crucial role in the agriculture sector in Iran, and the five important functions of the office are 1) the transfer of production technology to farmers, 2) to organize special training courses, particularly dealing with agronomic aspects of all crops, 3) the distribution of inputs, 4) to plan and execute land leveling projects and 5) to deal with receiving and processing requests for tractors.

Cost of Production

The average cost of production in Iran is high mainly due to the high cost of water and labor. The high cost of labor also makes cotton harvesting expensive. With an average cost of production at US$1,400 per hectare, a farmer will be able to produce 2,500 kg of seedcotton, or 800 kg of lint, 1,375 kg seed, and about 250 kg linters, which are also a source of income to the ginner. The average net cost for producing a kilogram of lint is US$1.38.

Cost of Production in Iran

Input/Operation	Cost in US$/Ha	Remarks
Land rent	174.4	
Land preparation	62.3	Includes ploughing and leveling to sowing
Seed	31.4	Cost is for the treated seed
Thinning	38.4	
Irrigation	262.5	Cost of water and labor for application
Weeding	91.6	Mostly done manually
Fertilizer	47.8	Cost of about 200 kg of fertilizers
Insecticides	37.2	
Harvesting	215.1	
Ginning	138.4	Includes transportation of seedcotton to gin
Economic cost	218.6	Covers interest
Other costs	105.8	
Total costs:	1,423.5	

Use of Wild Species for Cotton Improvement in India

Vinita Gotmare and Phundan Singh
Central Institute for Cotton Research, Nagpur - 440010, India

Introduction

Wild species of *Gossypium* are rich with rare, desirable attributes that are not available in the germplasm of cultivated species. Hence, conservation of wild germplasm, along with other genetic stocks forms an integral part of a meaningful breeding strategy in cotton improvement. Hybridization between species is undertaken either for exploiting the hybrid vigor or to incorporate a desirable gene or a constellation of genes into a cultivated species. Hence, introgression of characters through interspecific hybridization is used to enrich the genetic heritage of a cultivated species with genes to produce more desirable economic characteristics.

In addition to high-yielding varieties and hybrids, there may be future demands for new plant types suited to varied agro-climatic regions, cotton for easy-care properties, varieties with multi-adversity resistance, etc., which represent a change from existing varieties. These changes could be achieved only by introgressive hybridization utilizing the wild species, which are rich sources of these characters. Though introgressive hybridization is time consuming, it is worth pursuing, since there is ample scope for introducing rare genes (hitherto not available in the cultivated gene pool) into the cultivated species to evolve superior varieties.

Gossypium Species and their Distribution

Out of the 50 known species of *Gossypium*, 45 species are diploid and 5 allopolyploid. They are distributed throughout the arid and semi-arid regions of Africa, Australia, Central and South America, the Indian Subcontinent, Arabia and Hawaii. The diploid *Gossypium* species fall into eight cytological groups, designated as A through G and K; five allotetraploid species are designated with AD genome (Table 1). A peculiarity among the 50 species identified and described so far in *Gossypium*, is that four species are cultivated and the remainder are wild species belonging to B, C, D, E, F, G and K genomes.

All 50 species of cotton have an aggregate geographical range encompassing most tropical and sub-tropical regions of the world. The cultivated species possess considerable genetic diversity as they are acclimatized to coastal as well as desert ecosystems. This reveals the diverse nature of genes present in cotton, which are of high commercial value and tolerant of many environmental vagaries. All four of the cultivated species are commercially grown in India. There are six land races in *G. arboreum*, four races in *G. herbaceum*, seven in *G. hirsutum* and two in *G. barbadense* (Table 2).

The maintenance of a wild species garden is itself an art. Seeds of many wild species have a hard seed coat. This trait requires pre-treatment to enable them to germinate, but generally they are propagated vegetatively. Establishment and maintenance of some wild species are difficult due to susceptibility to diseases.

Table 1: *Gossypium* Species, their Genomes and Distribution

S. No.	Species	Genome	Distribution
Diploids (2n = 26)			
1	*G. herbaceum (cultivated)**	A_1	Afghanistan
2	*G. arboreum (cultivated)**	A_2	Indo-Burma, China and Arab
3	*G. anomalum**	B_1	Africa
4	*G. triphyllum**	B_2	Africa
5	*G. capitis-viridis**	B_3	Cape Verde
6	*G. sturtianum**	C_1	Australia
7	*G. robinsonii*	C_2	Australia
8	*G. thurberi**	D_1	America
9	*G. armourianum**	D_{2-1}	America
10	*G. harknessii**	D_{2-2}	America
11	*G. klotzchianum**	D_{3-k}	America
12	*G. davidsonii**	D_{3-d}	America
13	*G. aridum**	D_4	America
14	*G. raimondii**	D_5	America
15	*G. gossypioides**	D_6	America
16	*G. lobatum**	D_7	America
17	*G. trilobum**	D_8	America
18	*G. laxum*	D_9	America
19	*G. turneri*	D_{10}	America
20	*G. schwendimanii*	D_{11}	America
21	*G. stocksii**	E_1	Arabia
22	*G. somalense**	E_2	Arabia
23	*G. areysianum*	E_3	Arabia
24	*G. incanum*	E_4	Arabia
25	*G. benadirense*	E	America
26	*G. bricchettii*	E	America
27	*G. vollesenii*	E	America
28	*G. trifurcatum*	E ?	-
29	*G. longicalyx**	F_1	Africa
30	*G. bickii**	G_1	Australia
31	*G. australe**	G	Australia
32	*G. nelsonii**	G	Australia
33	*G. anapoides*	K	Australia
34	*G. costulatum*	K	Australia
35	*G. cunninghamii*	K	Australia
36	*G. exiguum*	K	Australia
37	*G. enthyle*	K	Australia
38	*G. condonderriense*	K	Australia
39	*G. merchantii*	K	Australia
40	*G. nobile*	K	Australia
41	*G. pilosum*	K	Australia
42	*G. populifolium*	K	Australia
43	*G. pulchellum*	K	Australia
44	*G. rotundifolium*	K	Australia
45	*G. sp. nov.*	K	North Kimberley, WA
Tetraploid (2n = 52)			
46	*G. hirsutum**	AD_1	America
47	*G. barbadense**	AD_2	America
48	*G. tomentosum*	AD_3	Hawai
49	*G. mustilinum*	AD	America
50	*G. darwinii*	AD	America

* Species available at Central Institute for Cotton Research, Nagpur.

Utilization of wild species

Researchers have made tremendous efforts to identify useful genes in wild species, particularly since 1940. Species were subjected to screening for reaction to diseases, insect pests, drought, etc. Through interspecific hybridization programs, synthetic polyploids and their derivatives were subjected to thorough study. Many wild species were identified as possessing genes for superior fiber characters, fiber yield, high ginning output, and resistance to insects (particularly bollworms), diseases (bacterial blight, grey mildew), drought, frost, etc. Some characters that were successfully introgressed into cultivated species, appear in Table 2.

Table 2: Characters Transferred Through Introgressive Hybridization

Tranferred Character	Species Transferred From	Species Transferred To
Jassid resistance	*G. tomentosum*	*G. hirsutum*
Smoothness for boll weevil resistance	*G. armourianum*	*G. hirsutum*
Rust resistance	*G. raimondii*	*G. hirsutum*
Blackarm resistance	*G. arboreum*	*G. barbadense*
Fiber length	*G. thurberi*	*G. hirsutum*
	G. raimondii	*G. hirsutum*
Fibre strength	*G. thurberi*	*G. hirsutum*
Cytoplasmic male sterility	*G. anomalum*	*G. hirsutum*
	G. anomalum	*G. arboreum*
	G. harknessii	*G. hirsutum*
	G. aridum	*G. hirsutum*
Drought resistance	*G. arboreum*	*G. hirsutum*
	G. herbaceum	*G. hirsutum*
Fiber length	*G. barbadense*	*G. hirsutum*
Fertility restorer	*G. harknessii*	*G. hirsutum*
High ginning outturn	*G. arboreum*	*G. hirsutum*
Hairiness	*G. tomentosum*	*G. barbadense*
Caducous bract	*G. armourianum*	*G. hirsutum*
	G. harknessii	*G. hirsutum*

Problems in Introgression of Characters

Introgression of wild germplasm into cultivated cotton is difficult because of hybrid breakdown among interspecific hybrids and reduced chiasma frequencies in many of the interspecific hybrids, especially when the species involved in the hybridization are different at the genome and ploidy levels. There is also the risk of introducing undesirable genes along with useful ones. The problems of interspecific incompatibility get in the way of securing hybrids of some cross combinations. This problem could be solved by utilizing an embryo culture technique. Hybrid sterility is another hurdle that is mainly due to differences in genome and ploidy levels of the species involved in crosses. However, this could be overcome by synthesizing amphiploids. For transferring the desired characters, the amphiploid has to be backcrossed repeatedly to the cultivated species so as to obtain a cytologically stable genotype with the desired character. In this process, there is a risk of losing valuable genes present in the alien chromosome, which usually gets eliminated. It takes several generations to obtain a genotype with introgressed characters. Use of molecular markers in selecting plants with desired genes will greatly help in hastening this process.

Difficulties in Attempting Wide Hybridization

Interspecific hybridization has limited or no success, depending upon parents and species involved in crossing. Species that cannot be crossed with each other require non-conventional techniques to make it feasible to use genes from both parents in a combined genotype. Sikka and Joshi (1960) view problems of interspecific crossing as follows:

- Only crosses between the Old World species, excluding some of those involving G. *sturtii*, produce viable seeds.
- The crosses involving New World diploid species set viable seeds if fertilization is effective, except those involving *G.davidsonii and G. gossypioides*
- In the crosses between the New World and Old World diploid species, fertilization is effective but most seeds are not viable. Incompatibility is caused by post-fertilization disharmony.
- Tetraploid species hybridize with most diploid species, except with *G. kloztschianum and G. davisonii*.
- Interspecific crosses with the tetraploid group can be made easily.

There are several levels at which hybridization between two *Gossypium* species may fail. To recover viable hybrids, several techniques have been tried to overcome the incompatibility barriers. These include *in-vitro/in-vivo embryo* culture, *in-vitro* fertilization and ovule culture, mixed pollen technique, use of radiation, use of stimulants, use of different pollination technique and grafting. A number of modified approaches, such as haploids, polyploids/synthesized autopolyploids and allopolyploids, spontaneous tetraploids have been tried on the basic aspects in the interspecific hybridization. Modification, such as ovule culture methods and hormone application at the time of crossing, need to be tried as well.

So far, few efforts have been made to utilize tertiary gene pools for the improvement of cultivated cottons. Hence pre-breeding efforts need to be made to introgress traits from tertiary gene pools to cultivated cottons.

Achievements

Many breeding stocks as well as varieties have evolved in India through interspecific hybridization involving wild species. *Hirsutum-arboreum raimondii* (HAR) and *arboreum-thurberi-hirsutum* (ATH) lines were produced in the early 1940s. Derivatives of *G. hirsutum* x *G. tomentosum* were utilized for developed varieties like B-1007, Badnawar-1, Khandwa-2, SRT-1 in India as well. A *hirsutum* variety - Arogya - was developed through the *G. hirsutum* x *G. anomalum* hybridization program at the Central Institute for Cotton Research, Nagpur and was released for rainfed cultivation in the Central Zone of India. Immunity to bacterial blight and tolerance to sucking pests were introgressed into this variety from *G. anomalum*. The development of

Table 3: Varieties and Hybrids Developed Through Interspecific Hybridization in India

Varieties/Hybrids Released	Species Involved
Varieties	
Badnawar 1, Khandwa 1 and 2	*G. hirsutum* x *G. tomentosum*
Deviraj (170 Co2), Gujarat 67	*G. hirsutum* x *G. arboreum*
Devitej (130 Co2 M)	*G. hirsutum* x *G. herbaceum*
MCU 2, MCU 5	*G. hirsutum* x *G. barbadense*
PKV 081	*G. hirsutum* x *G. anomalum*
Rajat	*G. hirsutum* x (*G. thurberi* x *G. anomalum*)
AKA 8401	*G. arboreum* x *G. anomalum*
Arogya	*G. hirsutum* x *G. anomalum*
Hybrids	
Varalaxmi, DCH 32 and DHB 105	*G. hirsutum* x *G. barbadense*
DDH 2	*G. herbaceum* x *G. arboreum*
DH 7, DH 9	*G. herbaceum* x *G. arboreum*
NHB 12	*G. hirsutum* x *G. barbadense*
Pha 46	*G. herbaceum* x *G. arboreum*
TCHB 213	*G. hirsutum* x *G. barbadense*
Shruthi	*G. hirsutum* x *G. barbadense*
Caducous bract	*G. armourianum*
	G. harknessii

cytoplasmic male sterile (CMS) lines utilizing the cytoplasm of wild species is a great boon to the industry producing commercial cotton hybrid seeds. In India, the CMS system with *G. harknessii* (D_{2-2}) cytoplasm is used widely for hybrid seed production. Recently, a new CMS line with a cytoplasm of G. *trilobum* (D_8) has also been developed.

Interspecific hybridizaiton between Old World and New World cottons initiated at Surat, India in the early 1920's provided the basis for the development and spread of *G. hirsutum* varieties in India. The interspecific cross of CO^2 (*G. hirsutum*, *G. tomentosum*) yielded CTOM cultures at Surat. The plant has shiny, velvety-hairy leaves that show a high degree of tolerance to drought as well as sucking pests. Broadening of the breeding material base by involving wild species such as *G. stockii*, *G. harknessii, G. aridum, G. raimondii* and *G. tomentosum* may to produce drought resistance in crosses with the cultivated ones.

Narayanan et al, (1984) described the economically important characters of the wild species of *Gossypium* (Table 3). *Tetraploid* species are important genetic stocks of diploid cottons (*G. arboretum* and *G .herbaceum*) for fiber as well as boll features. Such introgression breeding was successfully tried at various agricultural universities in India.

Work on interspecific hybridization has intensified under the Institute's National Agriculture Technology Projects, Technology Mission on Cotton as well as under externally funded projects. Good results have been achieved in improving characters, especially fiber parameters, yield components, disease resistance, insect resistance, drought and salinity resistance, earliness and plant type, high ginning output, oil content, etc. A large number of promising genotypes for these characters have been identified for multiplication testing.

Selected References

Brubaker, C.L., E.M. Bourland and J.E. Wendel. 1999. The origin and domestication of cotton. In: Smith, C.W. and Cothren, J.T. (Eds). *Cotton: Origin, history, technology and production.* John Wiley and Sons, New York, pp. 3-31.

Gotmare, V.P., P. Singh and B.N. Tule. 2000. Wild and cultivated species of cotton. *Technical Bulletin* No. 5, Published by CICR, Nagpur, India.

Gotmare, V., P. Singh, C.D. Mayee, V. Deshpande and C. Bhagat. 2004. Genetic studies on seed oil index and seed index in some wild species and perennial races of Cotton. *Plant Breeding* 23, 207-208.

Khadi, B.M., V.N. Kulkarni, A.S. Ansighkar, V.V. Singh and V. Gotmare. 2003. Genepool concept for diploid cultivated cotton. *Proceedings of the World Cotton Research Conference –3*, Cape Town, South Africa, 9-13 March 2003, pp. 213-225.

Khan, S.A, D. Hussain, E. Askari, J. McD. Stewart, K.A. Malik and Y. Zafar. 2000. Molecular phylogeny of *Gossypium* species by DNA fingerprinting. *Theor. Appl. Genet*. 101, 931-938.

Narayanan, S.S., V.V. Singh, M. Punit and V. Gotmare. 2004. Germplasm utilization in cotton improvement – retrospect and prospects. In: *National Symposium on Cotton* : 3-24, (August, 2004) held at Hyderabad, India.

Percival, A.E. and R.J. Kohel. 1990. Distribution, evaluation and collection of *Gossypium. Adv. Agron*. 44, 225-256.

Sikka, S.M. and A.B. Joshi. 1960. Breeding. In: *Cotton in India* (a monograph of Indian Central Cotton Committee). Bombay 1960, pp. 137-335.

Stewart, J.M. and C.L. Hsu. 1978. Hybridization of diploid and tetraploid cottons through in *ovulo embryo* culture. *J. Hered*. 69, 404-408.

Wendel, J.F. and R.C. Cronn. 2003. Polyploidy evolutionary history of cotton. *Advancesin Agronomy* 78, 139-186.

Short Notes

• VipCot™ Gets Closer to Commercialization

Field testing of VipCot™ is complete but the varieties carrying the vegetative insecticidal protein (VIP) have not been commercialized yet. The Syngenta Group Company has developed VipCot™, and the VIP gene has insecticidal abilities against a variety of lepidopterans. The protein also exhibits significant bioactivity against *Agrotis ipsilon* (Black cutworm), *Spodoptera frugiperda* (fall armyworm) and *Spodoptera exigua* (beet armyworm). The VIP protein is an exotoxin developed from the same soil bacterium *Bacillus thuringiensis*. As an exotoxin, the VIP protein is structurally, functionally and biochemically different from Bt genes in Bollgard and Bollgard II. The efficacy of the gene against target pests is adopted; varieties must be demonstrated to introduce any new transgene on a commercial scale. A good gene could fail in a farmer's field if it is commercialized through poor yielding and unacceptable varieties.

The Delta and Pine Land Company (D&PL) and Syngenta have come to an agreement to commercialize VipCot™ through Deltapine varieties in the next few years. D&PL has acquired licenses from Syngenta to deliver novel biotechnology products to cotton growers worldwide. Under the agreement with Syngenta, D&PL obtains global licenses to develop and commercialize Syngenta's innovative insect resistance traits, as well as licenses to a wide range of other Syngenta technologies that may be useful in developing new valuable technologies for use in cotton. However, the first product to be commercialized under the agreement will be VipCot™, a novel insect control trait. Depending on the timing of regulatory approval, D&PL expects to have limited quantities of seed available as early as 2006. Subsequent varieties are expected to contain VipCot stacked with an herbicide-tolerant trait and thereafter with another insect resistant gene.

• Oil and Fatty Acids Composition in Seeds of Various Cotton Accessions

(The following note has been contributed by Everina Lukonge, Maryke Labuschagne and Arno Hugo, University of the Free State, P. O. Box 339, Bloemfontein 9300, South Africa. The work was undertaken by Everina Lukonge of Tanzania as part of her Ph.D. studies).

Cotton (*Gossypium hirsutum* L.) is mainly used to produce fiber used in the textile industry and seed for cottonseed oil production. Cottonseed oil is used in the manufacture of cooking oils, shortenings, and non-edible products like soap. Cottonseed oil contains 40% to 55% linoleic, 20% to 25% palmitic, 2% to 7% stearic, 18% to 30% oleic and small proportions of myristic and arachidic fatty acids. Cottonseed oil has a 2:1 ratio of polyunsaturated to saturated fatty acids; however, it contains relatively high levels of palmitic acid (25%), which is considered a major contributor to increased levels of blood cholesterol. Linoleic acid occurs in a high percentage. This gives the oil a rapid drying quality that results in an oxidative instability. Oleic acid has the same low-density lipoprotein cholesterol- (LDL) lowering effect as linoleic acid, but is not susceptible to oxidation. The aim of this study was therefore to assess the level of natural variation for oil content and fatty acid composition in a selected cotton germplasm so as to identify suitable parents for use in hybridization to improve varieties with reduced palmitic and increased stearic and oleic fatty acids.

Oil Content in Some Varieties

Variety	Oil Content (%)	Unsaturated Fatty Acid (%)	Saturated Fatty Acid (%)
McNair	20.7	70.3	28.6
Fregobract	23.3	70.2	29.0
RebaW926	22.3	70.9	28.9
Highgossyp	20.7	70.2	28.7
Dpacala 90	21.0	72.3	26.9
Aubarn56	24.6	70.7	28.4
NTA88-6	18.7	74.2	25.2
BJA 592	21.1	70.6	28.8
Stoneville	19.3	74.9	24.2
Ezra	19.2	71.6	27.7
CIM 70	19.0	72.1	27.5
Cyto12/74	19.8	72.2	27.7
UK 82	21.0	71.9	28.0
NTA 93-15	20.6	71.0	28.5
Irma 1243	18.9	71.0	28.1
Guazuncho	18.3	70.9	28.5
DP 4049	16.4	72.3	27.2
HC-B4-75	19.8	71.4	28.0
Nectarless	19.7	70.5	28.4
Des119	14.0	71.3	28.0
Dixie King	16.7	71.5	27.8
SG 125	21.9	73.0	26.5
Coker315	16.5	72.5	28.0
F 135	19.7	71.1	28.5
NTA93-21	19.2	75.7	23.8
MZ 561	20.3	77.2	20.3
Okraleaf	19.3	76.9	22.6
Acala SJ2	23.3	76.4	22.8
Delcot 344	24.2	77.2	22.3
UK 91	23.5	77.7	22.2

The lipid extraction procedure described by Folch and a modified methylation procedure described by Slover and Lanza were used to determine C16/C18 fatty acid ratio, Elongation Ratio (ER), Desaturation ratio (DR), Oleic desaturation ratio (ODR) and linoleic desaturation ratio (LDR). The statistical package NCSS and Agrobase (Agrobase 2000) were applied for analysis.

The results showed that predominant fatty acids were linoleic, palmitic, oleic, stearic, myristic, palmitoleic, arachidic, and behenic. The oil content results revealed a large variation from 13.6 to 24.7% with an average of 20.2%. The intervarietal variation for fatty acids was prominent. The ratio for polyunsaturated to saturated fatty acids was 2:1 and the unsaturated to saturated ratio was 3: 1. Accession Delcot had the highest linoleic acid (62.2%) and lowest oleic acid (14.5%) while accession NTA88-6 had high oleic acid (16.4%) and low linoleic acid (57.2%). Others had high palmitic fatty acid. The elongation ratio was zero, except for NTA 93-15, as it contained eicosenoic (C20:1). DR was high for Delcot (0.811) and low for Irma (0.74). The high DR value indicated the efficiency of desaturation and increase of linoleic fatty acid (C18:2). The low LDR (0.002) value leads to a decreased linolenic content to about 0.1%.

Oil content showed a significantly negative correlation with DR and ODR, while the correlation with C16/C18 ratio, oleic, linoleic and linolenic fatty acids was significantly positive. Palmitic fatty acid was significantly positively correlated with arachidic, behenic, lignoceric, nervonic, stearic, linoleic, myristic fatty acids and C16/C18 ratio and was negatively correlated to unsaturated fatty acid (USFA), Poyunsaturated fatty acid (SFA), unsaturated:saturated ratio, DR, ODR and LDR. Linoleic showed a significant negative correlation with behenic, lignolenic, nervonic, stearic, oleic, myristic, palmitoleic, margaric, saturated fatty acid and C16/C18 ratio. A positive correlation of linoleic was observed with linolenic, palmitic arachidic, eicosenoic, unsaturated fatty acid, polyunsaturated fatty acid, unsaturated:saturated ratio, DR and ODR. Stearic acid was significantly positively correlated with oleic, myristic, palmitic, palmitoleic, margaric and saturated fatty acid, and a significant negative correlation was observed with linoleic, linolenic and unsaturated fatty acid. Although linoleic and linolenic are positively correlated, selection for genotypes with high linoleic content is possible because linolenic content was very low. Also, the positive correlation of linoleic with oil will make selection possible. Stearic acid and palmitic acid are positively correlated, stearic and linoleic acid are negatively correlated, linoleic and palmitic are positively correlated; therefore, breeding for increased stearic acid, oleic, linoleic acid and reduced palmitic acid at the same time is difficult if using conventional breeding. However, this can be done by metabolic engineering in cotton. CIM 70 and Cyto 12/74 (both from Pakistan) had high values for stearic (2.8%, 2.7%) and oleic fatty acid (18.3% 18.5%) respectively and can be used as parents to improve these fractions.

The dendrogram for oil content, palmitic fatty acid, oleic fatty acid, stearic fatty acid and linoleic fatty acid showed eight main clusters and other sub-clusters. Coker and Macnaire had their own clusters each because of differences observed in their oil and fatty acid content. Some clusters and sub-clusters showed varieties from the same region or varieties with the same oil or fatty acid content. The genetic distances ranged from 0% to 71%. This indicated the diversity of these varieties. This study revealed that the genetic distances and dendrogram can indicate the relationship. This was observed from the varieties from the same region, like CIM 70 and Cyto 12/74 both from Pakistan, and Des 119, Guazuncho and Dixieking, all from the USA, which had probably the same genetic background. Therefore it can be concluded that with oil and some fatty acids, there is a chance of heterosis by crossing the accessions that showed high distances between them to improve these characters. However, it must be considered that some of fatty acids are quantitatively inherited.

Dendrogram for 30 Cotton Accessions Based on Oil and Fatty Acids