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THE ICAC RECORDER

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Committee

Technical
Information Section

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Update on Cotton Production Research




Contents

Introduction

The Technical Information Section of the ICAC undertakes a survey of cotton production practices every three years. Extensive information is collected on varieties planted and their fiber quality characteristics, soil types, rotations followed in cotton production, crops competing with cotton, fertilizer applied, insects, weeds, disease, ginning, picking and five important cotton related activities per month. The huge database is maintained and regularly updated. Perusal of previous reports and the latest issue of the *Cotton Production Practices*, published in November 2014, showed that over years important changes have occurred in production practices. The first article in this issue of the *ICAC RECORDER* not only highlights how cotton is currently produced but also compares how cotton production practices have changed over the last two decades. About 300 varieties are cultivated in the world and 35 of them were planted on 7.7 million hectares or 24% of the world cotton area in 2013/14. With few exceptions, planting seed is produced locally. The seed rate used to plant a hectare of cotton varies considerably among countries, with a world average of 14.5 kg seed/ha. In India the average seed rate is 2-3 kg/ha because of high cost involved in producing hybrid seed. On an overall basis, over 26 million growers planted cotton on 32.7 million hectares in the world in 2013/14, each producing on average a ton of cotton. Read more in the first article 'Cotton Production Practices are Changing.'

The second article is a report on a project sponsored by the ICAC and funded by the Common Fund for Commodities and the OPEC Fund for International Development. The four-year project 'Development of National Cotton Classing Systems in Kenya and Mozambique' started in early 2012 with the objective of introducing national cotton classing systems similar to the one used in the USA. The main task for both countries was to have labs running under the optimum conditions required for obtaining reliable and repeatable data. The project experienced challenges during the construction of cotton classing facilities in Mozambique, including ensuring consistent temperature and humidity levels. The construction of a laboratory and other installations in Kenya was completed without incident, but more work is required on the Ambient Air Management Systems in Mozambique before all three facilities are fully functional. Consultations within the cotton sector on the mandatory introduction of 100% sampling and testing of cotton will promote collective ownership of the arrangement. Several operators/technicians were trained in handling, conditioning and running of classification systems in both countries. The two systems are independent but have the same objective of HVI classing of all cotton in the country.

For the first time in the history, India will produce more cotton than any other country in the world in 2014/15. However, cotton yields in India rank at 8th position among the 10 top cotton-producing countries in the world. Cotton yields in India were only 72% of the world average in 2013/14. This article examines the factors responsible for low yields and the prospects for improving yields in India with particular reference to commercial cotton hybrids. Hybrids tend to be vegetative in growth and performed well under production conditions during 1970s and 1980s. Under the changed production practices wherein fertilizer use has been optimized, insect control has improved due to biotech cotton and demand for insecticides has reduced, varieties have the same production potential as hybrids. Production of planting seed of hybrids is expensive and most hybrids have a longer growing season due to their bushy plant type. The hybrid cotton issue is extensively discussed in the third article of this issue of the *ICAC RECORDER*.

World Cotton Calendar

The ICAC has been collecting data on cotton production practices for a long time. Information is collected and compiled in a publication called *Cotton Production Practices,* which is updated every three years. The report provides information on varieties planted, insects, weeds, fertilizer use and all other aspects of cotton production including five important cotton related activities per month. In order to expand the use of the database on cotton production practices, ICAC has launched the World Cotton Calendar. The Calendar provides for

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changes as and when necessary and wider use of information. The information discussed in the first article is presented in the World Cotton Calendar, which can be accessed free online at http://worldcottoncalendar.icac.org.

World Cotton Research Conference-6

The World Cotton Research Conference-6 will be held in Brazil in the city of Goiânia, Goiás, from June 20-24, 2016. Pre-registration is now open online and additional information on the Conference is available at www.wcrc-6.com. CABI, FAO and CIRAD are sponsoring the Conference. Major support comes from the ICAC. The WCRC-6 will be organized under the auspices of the International Cotton Researchers Association (ICRA). The International Committee headed by the Chair of ICRA is advising the local organizing committee.

Technical Seminar - 2014

A Technical Seminar on the topic 'Enhancing the Mechanism of Input Interaction in Cotton Production' was organized during a the 73rd Plenary Meeting of the ICAC held in Thessaloniki, Greece from November 2-7, 2014. Five papers were presented, including a paper from the ICAC Researcher of the Year 2014, which will soon be available at https://www.icac.org.

Cotton Production Practices are Changing

Cotton production practices are changing from the heavily chemical dependent production system to an input conservative approach. Farmers were encouraged to increase their use of inputs first in the form of particular fertilizers and then in the form of insecticides. This practice was followed so strictly that a direct correlation developed between yield increases and the quantity of inputs applied. The effectiveness of fertilizer use peaked first, and then the heavy reliance on chemical insect control prompted the industry to explore alternative means of controlling insects, beyond the integrated pest management stage. Toward the end of this period, which lasted for almost fifty years, the backlash arose, first in the form of a drive to limit or eliminate insecticide use, and then to reduce fertilizer use. The demand to curtail, or even reduce, fertilizer quantities is now at its peak, but the focus is currently centered on containing input costs and maximizing net income rather than increasing yields and increasing gross income. The two directions are impacting every aspect of cotton production and actually changing the production systems used to produce cotton in the fields. The International Cotton Advisory Committee undertakes a survey of the cotton production practices every three years. Perusal of previous reports and the latest issue of the *Cotton Production Practices*, November 2014, will shed light on some of the important changes occurring in production practices.

Varieties and Planting Seed

One of the major changes has been the incorporation of biotech varieties. Area under insect resistant biotech varieties is expected to reach close to 70% of the total world cotton area in 2014/15. The countries that have commercialized insect resistant biotech cotton have almost peaked in terms of area planted to biotech varieties. Introduction and wide spread attack of *H. armigera* in Brazil is going to boost the use of biotech varieties as compared to the time when the boll weevil was the dominant pest in the country. It is estimated that half of the cotton area in Brazil will have been planted to biotech varieties in 2014/15.

A single variety was planted on 100% of the cotton area in Kyrgyzstan, the Western region of Tanzania, Togo, Uganda and Zimbabwe. There are a number of countries where a single variety is preferred and planted on more than ¾ of the total cotton area. India is an exception: hybrids are planted on over 90% of the area and the use of one hybrid to cover large areas across regions is just not feasible. Production conditions and the suitability of genotypes to specific agro-climatic conditions also prevent limiting the choice of planting material to a reduced number of varieties. In the USA, varieties are promoted under different brands, such as Deltapine, Phytogen, Fibermax. One Phytogen variety, PHY499 WRF, was planted on 10% of the cotton area in the USA in 2013/14, but the sum total of all Phytogen brand varieties covered only 16.3% of the US cotton area. The Deltapine (Monsanto) and Fibermax (Bayer CropScience) brands were planted on 33.4% and 25.3% of the area respectively.

The data in table 1 shows that 35 varieties were planted on 7.7 million hectares, i.e. 24% of the world cotton area. One variety may be popular in one region and not liked or preferred in another region. The variety PHY 499 WRF was planted on a significant area in all the four production regions of the USA. The spread of a variety in a country also depends on the presence of a company outlet in a target region. In Pakistan, MNH-886 Bt was developed by the provincial/state government public sector, but is also popular in other provinces, making it the variety grown on the greatest area in the world.

Planting seed is produced locally, with a few exceptions such as Colombia, Bangladesh, Mozambique, Paraguay, Spain and Turkey. Some planting seed is also imported into China. Colombia has not been able to establish its own seed production system and therefore relies almost exclusively on varieties developed and produced in the USA. Its two cotton-growing seasons allow it to cover its planting seed needs with seeds from U.S. companies. Paraguay commercialized biotech cotton in 2011/12 employing US varieties, so it needs

Table 1: Major Varieties Grown by Country 2013/14

Country	Variety	Planted Area (%)	Planted Area (000 ha)
Argentina, Chaco	Nu OpaL BG/RR	94	525.5
Australia, NSW and Queensland	Sicot 74 BRF	75	315.0
Bangladesh, *G. arboreum*	HC-1	90	14.9
Bangladesh, *G. hirsutum*	Rupali-1 (Hybrid)	44	11.0
Brazil, Semiarid	BRS Aroeira	90	2.4
Brazil, Cerrado	Fibermax WS975	74	830.0
Burkina Faso	FK 37	37	206.1
Cameroon	IRMA L457	67	143.4
Chad	A 51	57	146.5
China, Yellow River	CRI 50	40	635.4
China, Yangtze River	CRI 63	35	411.4
Colombia, Cordova	FM 1740B2F	36	5.9
Colombia, Interior	DP 141B2RRF	48	4.5
Egypt	Giza 86	85	104.6
Iran	Varamin	76	69.3
Kazakhstan	M-4011	31	43.4
Kenya	HART 89M	51	17.9
Kyrgyzstan	Kyrgyz-35	100	27.0
Mali	Stam 59A	50	240.5
Mozambique	CA-324	75	117.8
Myanmar	Ngwe Chi 6	75	224.5
Pakistan	MNH-886 Bt	52	1,459.1
Paraguay	Nu Opal	85	21.5
South Africa, Loskpop	DP 210BRF	70	8.4
Spain	Alexandros	24	15.3
Sudan	Acala	59	31.3
Tanzania, Western	UK 91	100	409.0
Togo	Stam 129	100	93.7
Turkey, Southeast	Stv-468	40	111.6
Uganda	BPA 2002	100	52.0
USA	PHY 499 WRF	10	305.3
Uzbekistan	C 6524	16	199.4
Vietnam	VN 04-3	35	4.2
Zambia	Chureza	50	145.0
Zimbabwe	Albar	100	230.0

to import seed from the USA. The seed industries in Spain and Turkey are free to import planting seed from other countries. In Turkey, the shift in the supply of planting seed from the public sector to the private sector also favored the trend toward importing varieties and seeds from other countries.

The seed rate used to plant a hectare of cotton varies widely among countries, but the world average is 14.5 kg seed/ha. Many countries use 20-30 kg of delinted seed/ha, but the world average is lower due to the use of hybrids in parts of China and India. The few exceptions are extremes, 60kg/ha in Egypt and 50 kg/ha in Côte d'Ivoire. The seed rate is generally higher in the West African countries. Low germination capability of the seed and field roughness are the main determinants of the seeding ratio used to plant cotton. Farmers generally do not want to take chances and would rather err toward the upper end, unless the technology fee makes it too expensive. In India the average seed rate is low, 2-3 kg/ha, because of high cost involved in producing F_1 hybrid seed. In the USA, a final plant population in the range of 100,000 to 125,000 plants per hectare is recommended. In most cases, precision planters are used to deliver a specified number of seeds per row length instead of following a specified weight of seed per hectare. The number of seeds to be dropped per meter is based on the germination percentage, variety structure and desired plant population. On average, the target is to have 10-12 plants per meter row. Based on this formula, the average seed rate is calculated at 14.5 kg seed/ha. About ten million tons of cotton seed is produced in the world every year, while slightly less than 500,000 tons, or only 5%, is used to plant the next crop. In India, about 30,000 tons of seed is used to plant cotton on 11 million hectares.

Table 2: Planting Seed Rate by Country 2013/14

Country	Area in 000 ha	Seed Rate/ha	000 kg seed	000 tons
Argentina, Chaco	559.0	30.0	16,770.0	16.8
Australia, NSW and Queensland	420.0	13.5	5,670.0	5.7
Bangladesh, *G. arboreum*	16.6	20.0	332.0	0.3
Bangladesh, *G. hirsutum*	24.9	8.0	199.2	0.2
Brazil, Semiarid	2.7	14.0	37.8	0.0
Brazil, Cerrado	1,121.6	10.0	11,216.0	11.2
Burkina Faso	557.0	20.0	11,140.0	11.1
Cameroon	214.0	30.0	6,420.0	6.4
Chad	257.0	37.5	9,637.5	9.6
China, Yellow River	1,588.6	30.0	47,658.0	47.7
China, Yangtze River	1,175.3	10.0	11,753.0	11.8
China, rest	1,836.1	30.0	55,083.0	55.1
Colombia, Cordova	16.4	13.0	213.2	0.2
Colombia, Interior	9.4	8.5	79.9	0.1
Cote Ivoire	361.1	50.0	18,055.0	18.1
Egypt	123.0	60.0	7,380.0	7.4
Greece	248.7	15.0	3,730.5	3.7
India	11,700.0	2.5	29,250.0	29.3
Iran	91.2	25.0	2,280.0	2.3
Israel	6.1	15.0	91.5	0.1
Kazakhstan	140.0	25.0	3,500.0	3.5
Kenya	35.0	15.0	525.0	0.5
Kyrgyzstan	27.0	55.0	1,485.0	1.5
Malawi	162.0	25.0	4,050.0	4.1
Mali	481.0	40.0	19,240.0	19.2
Mozambique	157.0	25.0	3,925.0	3.9
Myanmar	299.3	12.1	3,621.5	3.6
Nigeria	284.0	18.0	5,112.0	5.1
Pakistan, Punjab	2,806.0	17.5	49,105.0	49.1
Pakistan, Sindh	650.0	22.5	14,625.0	14.6
Paraguay	18.0	18.0	324.0	0.3
South Africa, Loskpop	12.0	9.0	108.0	0.1
Spain	63.9	24.0	1,533.6	1.5
Sudan	53.0	14.4	763.2	0.8
Tajkistan	189.0	30.0	5,670.0	5.7
Tanzania, Western	409.0	25.0	10,225.0	10.2
Togo	93.7	22.5	2,108.3	2.1
Turkey	451.0	25.0	11,275.0	11.3
Tukmenistan	550.0	30.0	16,500.0	16.5
Uganda	52.0	12.5	650.0	0.7
USA	3,053.0	14.5	44,268.5	44.3
Uzbekistan	1,246.0	30.0	37,380.0	37.4
Vietnam	12.0	6.0	72.0	0.1
Zambia	290.0	20.0	5,800.0	5.8
Zimbabwe	230.0	15.0	3,450.0	3.5
	32,092.6		Total:	482.3
			Average per ha	14.8
			Total minus India	453.1
			Total commercial seed produced in the world	9,915.0
			% seed used for planting	4.9

Average Farm Size

Farm size, or area planted to cotton, is not correlated with higher or lower yields. Large farm size is ideal for mechanized operations, but farms employing hand labor to produce cotton can be as productive as mechanized plantations. According to the latest survey of Cotton Production Practices, the largest farms dedicated to cotton production are in the Cerrado region of Brazil, where the average farm size is 3,300 hectares. In Australia, the average farm size is 1,800 hectares. In the USA, the average farm size is smaller in the Southeast (around 350 ha/farm), but is larger in other regions, standing at around 580 ha/farm. In China, the smallest cotton farms are clustered in the Yellow and Yangtze River valleys, but the Northwest region is characterized by much larger cotton plantations controlled by the state.

Table 3: Average Farm Size in Some Countries

Country	Farm Size (Ha) 1992/93	Farm Size (Ha) 2013/14
Argentina, Chaco	68.0	26.0
Chad	3.7	1.0
China, Yellow and Yangtze	0.1	0.3
Colombia, Cordova	8.0	11.5
Greece	2.9	5.3
India	2.0	1 - 2
Mali	7.0	2.9
Pakistan, Punjab	4.5	4.0
Paraguay	11.0	7-10
Spain	6.0	10.9
Turkey, Aegean	3.5	6.0
USA	569.0	346 - 584
Uganda	3.0	0.5

The size of a typical cotton farm can change, depending on how many small or large growers are planting cotton, but there are many countries where this is not applicable. In Argentina, for example, small growers and large growers who follow different production practices coexist. Production shifts between smaller and larger plantations even on an annual basis. In Argentina, a reduction in average farm size is most likely caused by a shift between the two size categories, rather than an actual reduction in farm size. In Chad and Mali there is a definite declining trend in farm size. China evidences a big increase in mean average size of farm (due to shift in cotton area to the Northwest), while India and Pakistan reveal a decreasing trend in farm size. Farm size in the USA has remained stable for almost twenty years. Turkey also showed an increase, but farm size in Uganda has declined significantly.

Women Cotton Growers

The ICAC also collects statistics on the percentage of female cotton growers in the various cotton producing countries. The data for 2013/14 showed that in China women growers account for 70% and 60% of the cotton producers in the Yellow River and Yangtze River Valleys respectively, the highest percentage in the world. In Vietnam, cotton was planted on about 12,000 hectares in 2013/14, most of which was planted by families headed by women. The percentage of women growers is also high in southern Africa. The percentage of women growers in the USA is lower in the Southeast, but women make up about 20% of the cotton growers in the rest of the cotton belt. In the Tamil Nadu state of India, women represent almost half of the cotton growers. Overall, more than 26 million planters produced cotton on 32.7 million hectares around the world in 2013/14, each turning out an average of one ton of cotton for the seven billion people in the world.

Rotational Crops in the Cotton Production System

Crop rotation can be defined in many ways but, in general, it is a cropping system wherein the fertility of the soil suffers the least and farmers' profits are maximized. The practice of growing a series of crops with dissimilar root systems on the same fields in successive seasons produces sustained benefits. Proper crop rotation also mitigates the chances of building up pathogens and pests, which often occurs when a single crop is planted over and over again. By alternating deep-rooted and shallow-rooted plants, rotation can also improve soil structure and fertility. Crop rotation is good for maintaining soil health and soil fertility, but growers are under pressure to produce more and more on the same limited farmland area year after year. Despite these advantages, cotton is grown as a

Table 4: Cotton Crop Rotations for Reducing the Incidence of Various Pathogens

Rotational Crop	Root Knot Nematode	Verticillium Wilt	Fusarium Wilt	Rhizoctonia and Pythium	Thielaviopsis basicola
Small grains and summer crops	Satisfactory	Satisfactory	Some	Satisfactory	Some
Winter small grains grown as silage	Some	Some	Some	Some	Some
Cowpea	Satisfactory	Satisfactory	Some	Minimal	Some
Corn	Satisfactory	Satisfactory	Some	Satisfactory	Satisfactory
Sorghum and Sudan grass	Satisfactory	Satisfactory	Some	Satisfactory	Satisfactory
Alfalfa	Satisfactory	Some	Some	Satisfactory	Some
Onion and Garlic	Minimal	Satisfactory	Some	Minimal	Satisfactory
Clean fallow (Weed free)	Some	Some	Minimal	Some	Some
Tomato (Root knot resistant)	Some	Minimal	Race 1: Satisfactory Race 4: Some	Minimal	Minimal

Key to ratings:
Satisfactory = significant suppressive activity but does not control
Some = has an inhibitory effect but less than satisfactory
Minimal = has very little effect

Source: University of California, USA

Table 5: Major One-Year Crop Rotation in Selecetd Countries

Country	Rotation	
	Crop	Area %
Australia	Wheat	40
Brazil	Soybean	70
Burkina Faso	Maize	60
Cameroon	Fallow	100
Chad	cereals	98
China	Wheat	50-70
Egypt	Wheat	50
India	Wheat and Fallow	
Pakistan	Wheat	85
Togo	Fallow	95
Turkey	Wheat	
Zambia	Maize	86

monoculture on a limited farmland area in the world. The best crop rotation structure is determined on the basis of soil type, availability of land and resources, suitability to grow crops and, of course, each farmer's technical knowhow and ability (production technology) to produce other crops successfully. Leguminous crops are, undoubtedly, the best for rotation because of their additional advantage of fixing nitrogen and, in most cases, a shorter cropping season. Any crops that are grown as a green manure crop will be good for the soil because they contribute organic matter and increase aeration. Rotations are, in general, effective in improving soil health in the medium and long terms. With respect to the containment of pathogens, the data in table 4 show that corn, sorghum and Sudan grass are more desirable for rotation with cotton wherever cotton is affected by any of the seedling diseases mentioned in the table. Corn, sorghum and Sudan grass do not provide satisfactory control of Fusarium wilt, when varieties prone to Fusarium attach are grown.

Major rotations as a one crop rotation in selected countries are shown in table 5. In African countries, maize is a major crop for rotation with cotton, while in other countries, wheat is planted on the greatest area after cotton has vacated the field for the next crop. Maize also seems to be one of the leading major crops competing with cotton.

When farmers do not plant cotton, they have the option of planting rice, sugarcane or maize as in Pakistan, wheat and rice as in China and the north region of India, and maize as in the Karnataka state. In the Central region of India, which accounted for 63% of the cotton area in India in 2013/14, farmers switch to soybean, groundnut and maize when they decide not to grow cotton.

Fertilizer Use

Some form of fertilizer is necessary, whether it is applied in the form of organic manure, synthetic fertilizers or a green manure crop that is grown and mulched into the soil. The degree to which plant needs are met has a high impact on the plant's ability to express its fullest potential. Nitrogen is undoubtedly the most necessary element, but the plant may also fail to exhibit its full potential if phosphorus and potassium are deficient. Although soil needs is the most important factor, the importance of micronutrients takes on a greater role as the soil reaches its fullest potential. Fertilizer is applied in most cotton-producing countries, with the exception of Argentina, Bangladesh (*G. arboreum*), Chad, Kenya, Mozambique, Paraguay, Tanzania, Uganda and Zambia where a significant extension of the cotton area does not receive any fertilizer. Applications of micronutrients per hectare are summarized in table 6.

Insect Pests and Their Control

The bollworm is still the most important arthropod affecting cotton in the world. All the countries that responded to the survey questionnaire on production have confirmed that

Table 6: Application of Micronutrients to Cotton

	Boron	Sulfur	Others
Bangladesh (*G. arboreum*)		9.0 kg	
Bangladesh (*G. hirsutum*)		22.0 kg	
Brazil (Cerrado)	4.0 kg	60.0 kg	Manganese & Zinc = 1-2 kg
Burkina Faso	1.5 kg	9.0 kg	
Chad	1.2 kg	5.0 kg	
Cameroon	1.7 kg	9.0 kg/ha	
Côte d'Ivoire	2.0 kg	12.0 kg	
India (North)			Zinc = 25.0 kg (only hybrids)
India (Andhra Pradesh)			KNO_3 (Foliar) = 2.5-5.0 kg/ha and Zinc = 50.0 kg/ha
India (Karnataka)			$MgSO_4$ = 12.5 kg/ha and Zn SO_4 = 12.5 kg/ha
India (Central)			$MgSO_4$ = 10.0 kg/ha
Iran (Ardebil)			Biologic = 2.0 kg/ha
Iran (East and Central)			Micro = 5.0 kg/ha
Iran (Fars)			Micro = 10.0 kg/ha
Mali	1.0 kg	6.0 kg	
Togo	3.0 kg	15.0 kg	

it is not a single bollworm, but a variety of bollworms that constitute a serious pest on cotton. While the resistance problem has been contained and the spread of bollworms of whitely had slowed down for quite a number of years, reports from Brazil last year indicate that there is great concern among cotton growers about the spread of *H. armigera* in the country, especially in the large-scale farming system in the Cerrado region. The cost of insecticide use is already high in the region because of the boll weevil, so any additional requirement to spray against the *H. armigera* may have a significant impact on the economic viability of the production system. *H. armigera* is also notorious for development of resistance, which may render obsolete the chemical control approach. One of the impacts foreseen as a consequence of the flare-up of the bollworm in Brazil is the additional demand for biotech cotton in the country. Biotech cotton will have no impact on the need to spray against the boll weevil; in fact, it may even hasten the emergence of a resistance problem. There is a need to devise a very careful bollworm control program, keeping in mind the fact that bollworm control should not add to the current amount of insecticides currently used to control other arthropods. There is no other pest that has encroached into additional areas in Brazil in the recent past, but the general consensus is that sucking pests are increasing in number due to the absence or reduction of sprays against the bollworm on biotech cotton. Plant bugs are now at the top of the list of insects damaging cotton in the USA.

The awareness of the need to produce cotton using the least possible amount of insecticides has grown significantly and that awareness continues to increase, as a result of the extensive availability of additional information and the implementation of a containment approach by which farmers have learned to use insecticides only when absolutely necessary. One of the reasons for this new approach or this shift away from the practices of the last 15-20 years has been the absence of a backstop to cushion farmers against higher production costs. Chemical products used to control pests have improved a great deal in their ability to hit only the target pests. Insecticide sprays are decreasing in most countries. Currently, Brazil sprays cotton with much greater quantities of insecticide than any other country in the world. The average number of sprays used to control insect pests on cotton in selected countries appears in the table 7.

Weeds vary greatly among countries. The most recent issue of ICAC's *Cost of Production of Raw Cotton* showed that weed control costs currently exceed the cost of all other individual inputs or operations and are on the increase. One of the reasons may be a higher emphasis on weed control and the fact that farmers are increasingly shying away from reliance on cultural operations and relying more and more on herbicides. The Technical Information Section of the ICAC began to compile data on the cotton area treated with herbicides in 2002. The data for harvest year 2001/02 showed that only Australia and Colombia used herbicides on 100% of the area. Only four other countries (Argentina, some production areas in Iran, Turkey and the USA) used herbicides on more than 75% of the cotton area. In the latest survey, which contains data for 20013/14, the list of countries using herbicides on 100% of the area also includes Sudan and the USA. In Brazil, only the Northeast region is believed to not be using herbicides. About twenty other countries have reported herbicide use in 2013/14. There are very few cotton-producing countries left, if any at all, where herbicide use is still avoided. For detailed information on important weeds by country, please refer to the publication on *Cotton Production Practices* – November 2014.

Table 7: Average Number of Insecticide Sprays on Cotton

Country	Insecticides Sprays	
	1995/96	2013/14
Australia	7-12	3.5
Brazil	4-8	15
Coet dIvoire	No data	5
Cameroon	5	5.1
Chad	No data	7
India	4-6	4-6
Iran	2-3	2-4
Mali	5	5
Myanmar	1	6-10
Pakistan	5	5-7
Spain	5	4
Togo	3	5
Turkey	5	2-5
Uganda	7	3
USA	2.5 - 10.8	3-4

Notes:
Australia, 1995/96 - Seven sprays in New South Wales and 12 in Queensland on irrigated cotton.
Brazil, 1995/96 - No more than eight sprays were made on cotton in any region of the country.
India, 2013/14 - Most area gets only four sprays.
USA, 1995/96 - Highest number of sprays was in Southeast followed by Midsouth.

Cotton Picking and Ginning

Hand-picking is still the dominant practice in the world. According to the data for the year 2013/14, one quarter of the world's cotton area is picked by machines and the rest manually. All cotton is machine-picked in Australia, Cerrado region of Brazil, Greece, Israel, Spain and USA. In Turkey, machine-picking has become increasingly popular due to the scarcity and high cost of labor, so over 80% of cotton was machine-picked in 2013/14. Large-scale growers in the Chaco province of Argentina and Interior region of Colombia have mechanized their cotton-picking operations. The trend toward machine-picking is rising due to the high cost of labor. Almost all the area that is currently not picked by machines still requires small machines that are not yet available. Uzbekistan is working on developing two-row, tractor-pulled spindle-pickers, but there is a dire need for even smaller, hand-held machines. One of the current challenges for agricultural engineers is to develop a machine that an individual small-scale farmer can own and maintain. Such a machine must be able to pick cotton without adding extra plant trash to the fiber, so as not to trigger changes in ginning. The machine must be efficient enough to make it economically feasible for use in picking cotton.

Roller ginning has increased in recent few years but not significantly. Available data shows that about 15% of the cotton produced in 2013/14 was processed in roller gins. Saw ginning is popular due to its greater efficiency and ability to open and automatically separate trash from cotton. Countries where most cotton is ginned on roller gins include Bangladesh (*G. hirsutum*), Egypt, India, Israel, Kenya, Myanmar, Spain, Tanzania, Turkey and Uganda. In the Farwest region of the United States, in Peru and in Sudan, where *G. barbadense* is produced, as well as in Egypt, all the fine and extra-fine cotton is processed on roller gins.

World Cotton Calendar

The ICAC has been collecting data on cotton production practices for quite some time. Information is collected and compiled in a publication called *Cotton Production Practices,* which is updated every three years. This report provides information on varieties planted, insects, weeds, fertilizer use and all other aspects of cotton production, including five important cotton related activities per month. In order to expand the use of the database on cotton production practices, ICAC launched the World Cotton Calendar. The Calendar provides for changes as and when needed, as well as for wider use of the information. Some of the information discussed herein is available in the World Cotton Calendar, which can accessed free-of-charge online at http://worldcottoncalendar.icac.org.

References

Technical Information Section. 2014. *Cotton Production Practices* - November 2014, International Cotton Advisory Committee, Washington DC, USA.

Technical Information Section. 2013. *Cost of Production of Cotton* - September 2013, International Cotton Advisory Committee, Washington DC, USA.

University of California. 2013. UC IPM Pest Management Guidelines: Cotton UC ANR Publication 3444, Available online at http://www.ipm.ucdavis.edu/PMG/r114900611.html

Development of National Cotton Classing Systems in Kenya and Mozambique

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Introduction

Cotton fiber, just like many other agricultural products, is differentiated by quality parameters in the trading processes. The fiber quality determines the quality of end product, and quality differences affect the price placed on each pound of cotton lint bought by manufacturers. The price of cotton lint is principally associated to fiber characteristics, but also to non-quality factors such as logistics and marketing.

Traditionally, cotton lint quality parameters have been manually and visually classed for staple length and grade (color, leaf and extraneous matter). However, automation and precision in textile manufacturing requires more characteristics and homogeneity from cotton fiber, which are impossible to determine without instrumentation. The traditional way of classing cotton has proven to be inadequate, in particular because it:

- is prone to subjectivity and human error since it cannot be calibrated.
- is inconsistent, since the performance of an individual classer is often affected by fatigue or state of mind.
- requires skilled and highly specialized classers, which are not easy to find.
- is affected by individual differences in visual acuity and the quality of lighting in different labs.
- is time consuming (values are tabulated manually and printouts are then sent to customers).

When cotton is classed using modern instruments, in a more objective and verifiable manner, sellers and buyers are offered a transparent platform for price determination, thus minimizing ambiguities in arbitration and litigation procedures. In addition, the insight gained into the objective quality parameters of the cotton placed on the national and international market enables cotton companies and farmers to negotiate better prices from clients. Price differentials are estimated to be as high as US$50 per ton of lint.

In efficient cotton processing facilities, cotton is bought and processed on the basis of instrument-assessed quality data that is compared with approved ratings of fiber properties, such as fiber length, strength, uniformity, elongation, color/brightness, maturity and micronaire, and in different grades such as good middling and strict middling. These quality specifications assist the buyer in making informed decisions depending on the end use of cotton and to improve operational efficiencies, with eventual reduction of material wastage and increased yarn quality. For example, for producing 40's quality yarn count, mills may opt to use cotton varieties with staple groups – 28mm, 29mm and even 30mm. Other yarn count qualities would require different staple groups. To supply cotton to such markets, a quality testing system must be in place on the supplier side to promote transparency and improve marketing efficiency. It can therefore be deduced that countries that cannot provide computer-based test results increasingly face price discounts on their offers, whereas suppliers that do provide test results are often able to negotiate premiums for supply of homogeneous quantities and/or quantities of confirmed qualities.

The Project Background

Cotton is one of most important commodities for many African countries, including Kenya and Mozambique. In the past five years, the governments of both countries embarked on agricultural sector development programs that specifically focus on support measures that are sustainable and income strengthening at the macro and micro levels. Based on these initiatives, Kenya and Mozambique, assisted by the International Cotton Advisory Committee (ICAC) as supervisory body, launched a project in 2012 to develop their national cotton classing systems. A grant for capacity-building and system institutionalization was received from the Common Fund for Commodities (CFC), with co-financing from the OPEC Fund for International Development (OFID). The governments of Kenya and Mozambique provided the necessary infrastructure, including buildings, high volume instrument (HVI) machines and ambient air management system (AAMS), as in-kind contributions. A private firm, Wakefield Inspection Services, is responsible for execution of the project.

The project has established a functioning national cotton classing system in both Kenya and Mozambique that covers all cotton production through 100% bale sampling and HVI testing. It is expected that, with a fully functional classification system, ginners will be able to negotiate better prices for their cotton lint based on quality parameters. With governments

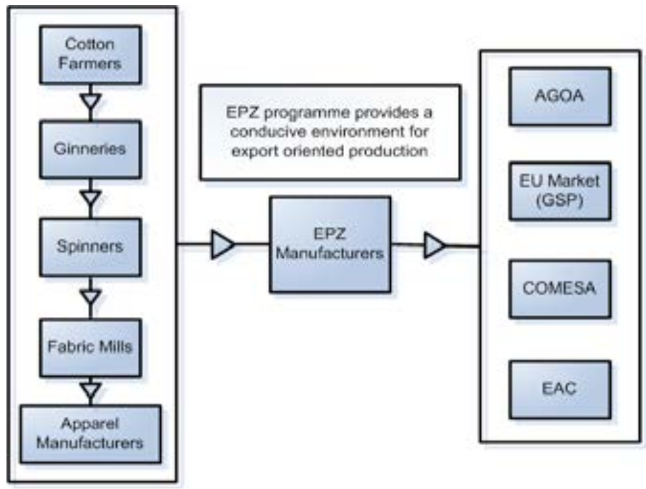
overseeing the cotton sector, ginners will be able to pay a higher price to farmers and both countries will achieve a better price for their produce.

In addition to the USA, which moved from human classers to instrument testing of cotton from 1992 onwards, other countries, such as Australia, Brazil, China, Colombia, Greece and Uzbekistan, have also built up national cotton classing systems in response to changing market requirements and technological developments.

Cotton Production and Consumption

Kenya and Mozambique provide production and consumption conditions that can apply to many cotton-producing countries interested in following similar approaches, as the project realizes its envisaged goals. It has been noted that one of the rationales for cotton reform in Africa is to increase the linkage between world prices for lint and producer prices for seedcotton. However, Kenya instead experienced a fall in cotton production, due to unbridled competition by private firms. Kenya is now striving to revive the sector in order to meet cotton lint demand from local textile manufacturers, which averaging 22,200 metric tons per annum in comparison to an annual production of 4,000mt. Over the years, local mills have become used to visually and manually assessing values or using other instruments [Shirley analyzer instrument for trash/leaf].

On the other hand, until 2014 Mozambique exported its entire annual production, averaging 40,000 metric tons of lint. Apart from commercial benefits to Kenya and Mozambique, the establishment of classing systems in the production and consumption environment provides the possibility for other producing countries to replicate the system as is or to cover a growing volume of their cotton production in a modular type of expansion.



Cotton Lab Facilities

Cotton in Mozambique is widely grown in the central and northern provinces. Establishment of lab facilities in Beira-Sofala, Montepuez–Cabo Delgado and Nampula-Nampula provinces aimed to reduce logistical challenges by ensuring proximity to the cotton ginneries being served. The three HVI labs are equipped with Premier ART 2 machines, whose combined installed capacity of 2,100 samples per day (based on an eight-hour shift) equals about 189,000 samples in a ginning season with a duration of three months. If an additional shift is added, the labs' capacity would be twice the current Mozambican production. Several interventions are being implemented with the objective of improving cotton production (productivity), whose resulting effect would be more samples sent to the facilities and hence a more favorable unit cost per sample. Lower unit cost is likely to influence the support from ginners, which is much needed for the economic sustainability of the classing system. These initiatives include the CFC/ICAC/37 project on "Improving Cotton Production Efficiency in Small-scale Farming Systems in East Africa (Kenya and Mozambique) through better vertical integration of the supply chain".

Cotton ginneries in Kenya are scattered sparingly, creating a strong case for the installation of a centrally located HVI laboratory in Nairobi. The installed capacity of an Uster-1000 machine is about 700 samples a day and, if deliveries were to be made daily, only 28 days would be sufficient to class the entire production. Since 1935, ginneries in Kenya use roller-ginning technology, which is relatively slower and therefore prolongs the ginning season to about 6-7 months. The lengthy season tends to stretch the labs' operating costs as well as it runs prolonged conditioning of samples. The economic sustainability of the lab will therefore depend not only on increased volume, but also on analyzing the cotton imported into Kenya to supplement the textile manufacturing demand gap.

Ambient Air Management System (AAMS)

Installation and commissioning of the AAMS at the Kenya laboratory was completed without incident, but more work was required on the AAMS in Mozambique before the facilities would be fully functional.

In figure 3, from extracted temperature and relative humidity data for a period of 12 hours indicate how monitoring is conducted to detect any deviations. The laboratory ambient air management is maintained at a controlled temperature range of 21±1^{0}C and relative humidity range of 65±2%. An integrated Ambient Air Management System, as opposed to separate devices for temperature and humidity, simultaneously controls the temperature and humidity parameters.

Samples are passively conditioned in a controlled environment to bring the moisture content into equilibrium. The Guideline for Commercial Standardized Instrument Testing of Cotton requires that samples be tested when the moisture level is in a range between 6.75 and 8.25 percent (on a dry-weight basis). In figure 4, the bubbles show the moisture content (7.2–8.1 percent) pattern of randomly collected cotton samples results, tested at a lab participating in this project. Both HVI 1000 and Premier Art2 have an inbuilt moisture-testing device. However, for best practices, the conditioned samples are randomly checked (using portable devices) to verify the moisture level has been reached.

Laboratory conditioning is monitored with sensitive and high-resolution electronic loggers; data is automatically captured and stored for traceability.

Figure 3: Ambient Air Management System (AAMS) monitoring

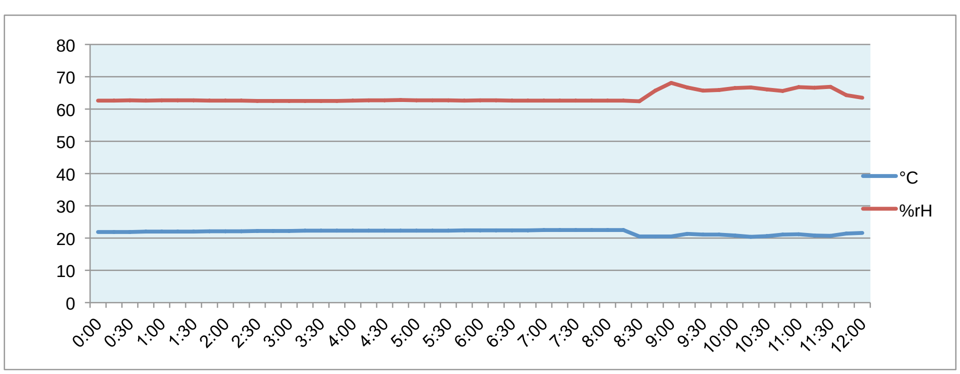
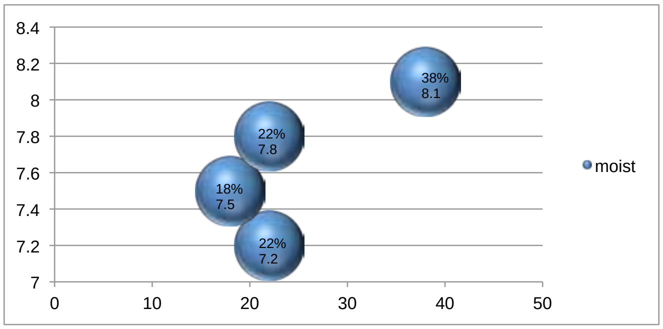


Fig. 4: Moisture Content for Tested Samples



Project Components

The development of a cotton classing system in Kenya and Mozambique is centered on five main components to realize the envisaged objectives, namely:

- description of main and operational principles, practices and procedures for a national classing system;
- consultation and adoption of proposed practices and procedures among stakeholders;
- integration of cotton testing results in contractual systems;
- training of staff in all aspects of the operations of the cotton classing system; and
- design and operationalization of a reliable database management system required for information sharing among stakeholders.

System documentation was imperative for two reasons: the need to institutionalize a transparent cotton classing system in parallel with other existing country structures; and, since it is a fairly new approach in the industry, all users of instruments measurements require guidance on procedures, practices and interpretation of the generated data. The Kenya Fibre Directorate and the Instituto do Algodão de Moçambique, the regulatory bodies in the two countries, reviewed their General Cotton Regulation and proposed enactment of relevant laws to institutionalize the classing system.

Documentation, such as sampling protocols, procedures for operating HVI machinery, cotton classification manuals and guidelines on data interpretation are designed to provide 'day to day' guidance on how the system should operate to minimize the discretion of individuals. Preparation of the documents incorporated different reference materials, mostly from guidelines of the ICAC Task Force on Commercial Standardization of Instrument Testing of Cotton (CSITC), the US Department of Agriculture and the International Textile Manufacturers Federation (ITMF). These procedures aim to ensure sanctity of samples from the origin to the labs, which is fundamental importance for at least two reasons:

- sample variations are the single largest source of errors in test data; and
- the sample delivered for classification must be representative of the larger package of cotton (bale) that it is drawn from.

Ownership-based workshops encourage consultation among stakeholders to make certain there is a consensus during the transition and a uniform adoption of proposed practices and procedures among stakeholders. The process is a precursor to regulatory bodies enforcing compliance of the implementation of accepted procedures.

Capacity Building for Cotton Classers and Marketing Officers

Building capacity of lab personnel is one of core components of the system development, taking into account that Kenya has had no classing system in place for years. While Mozambique has had a 100% sampling and cotton classing arrangement through manual and visual inspection, the classers had never been exposed to instrument testing of cotton. Three years after the start of the project there are 14 competent classers, trained at the USDA-Agriculture Marketing Service, Cotton Program and ICA-Bremen, where they underwent thorough training - from the classification of a variety of growths of cotton to practical HVI operating guidance on the latest Uster 1000 and Premier ART2 machines. Local classers have proven proficiency in classification procedures, practices and in the correct use of standardized equipment for lint testing**.** Some of the cotton classing and laboratory modules covered at ICA-Bremen include:

1) Classing modules
    - Influence of cotton planting up to bale pressing on grading;
    - overview and evaluation of visual quality parameters;
    - introduction to universal standards system and world standards;
    - introduction to visual grading and staple pulling;
    - training in visual classing of US standards;
    - visual classing of standards of different origins;
    - typical parameters of different important origins;
    - classing various origins; and
    - use of value differences.
2) Laboratory modules:
    - cotton fibers and fiber properties;
    - importance of fiber properties in cotton production and processing;
    - cotton properties and testing instruments;
    - influences on test results;
    - verification of instrument test results;
    - cotton testing on Uster HVI 1000;
    - cotton testing on Premier ART2; and

- cotton testing on additional testing instruments.

Training at USDA-AMS covered all aspects of HVI system:

1) Understanding the HVI system
   - overview of the USDA cotton classification program (mission, overview of functions, U.S. crop statistics, field locations, history, international initiatives);
   - components of a successful HVI testing program;
   - understanding the nature of HVI data; and
   - fiber properties
2) Sampling and sample handling
   - bale sampling procedure;
   - gin and warehouse inspections;
   - Permanent Bale Identification (PBI) system and PBI oversight;
   - sample handling and transportation; and
   - classification services and fees.
3) Classing office management
   - cotton testing procedures (entire process including HVI demonstration);
   - classing office management; and
   - HVI classer operations (HVI operator training, in-house verification)
4) Qualification of instruments
   - HVI system components;
   - HVI calibration & system setup procedures;
   - routine test verifications;
   - diagnostics and maintenance checks (HVI support tools, preventive maintenance); and
   - safety
5) Classification support equipment
   - support equipment for classification (HVAC, sensors, psychrometers); and
   - air compressors, RCUs, loose removal systems, etc.
6) Quality assurance
   - quality assurance procedures
7) Database management
   - networking;
   - HVI data handling procedures; and
   - reports and data dissemination.
8) HVI Round Tests programs
   - Round Testing programs and testing tolerance;
   - lab certification; and
   - developments/future direction of cotton classification.

An aptitude analysis is underway aimed at rating each classer/machine operator to ascertain any gaps in knowledge. Moreover, significant emphasis has also been placed on: Round Testing programs, specifically the CSITC Round Test; exposure to theory and practice related to the accuracy and precision of test results; and how to use correction factors not only for strength, but also for the other characteristics.

Training of marketing officers and market analysts is a market-oriented capacity building, with a focus on key areas of the raw cotton trade – from growing to spinning – in order to be able to integrate the instrument testing of cotton into a contractual system. The purpose of this empowerment is to provide practical experience to ensure that HVI system benefits are translated into farm gate prices for seedcotton by enhancing transparency in cotton pricing using data.

Management of the Database System

The National Database is a centralized electronic system that is integrated with other external systems, such as the HVI system that records cotton parameters and the extraneous matter element during instrument testing of cotton. The test results of different samples are published on a web portal to enable external stakeholders to access the information. The system allows sample owners or their authorized agents to access and retrieve classing data for the current year and for the previous four years. The database stores classing information from all samples tested at the country's lab facilities.

The project has contracted a Microsoft Dynamics partner in East Africa, appointed as a Microsoft Certified Partner, authorized to implement, develop and support the world class Microsoft Dynamics - Navision and AX Solutions. The vendor is assigned to design and develop:

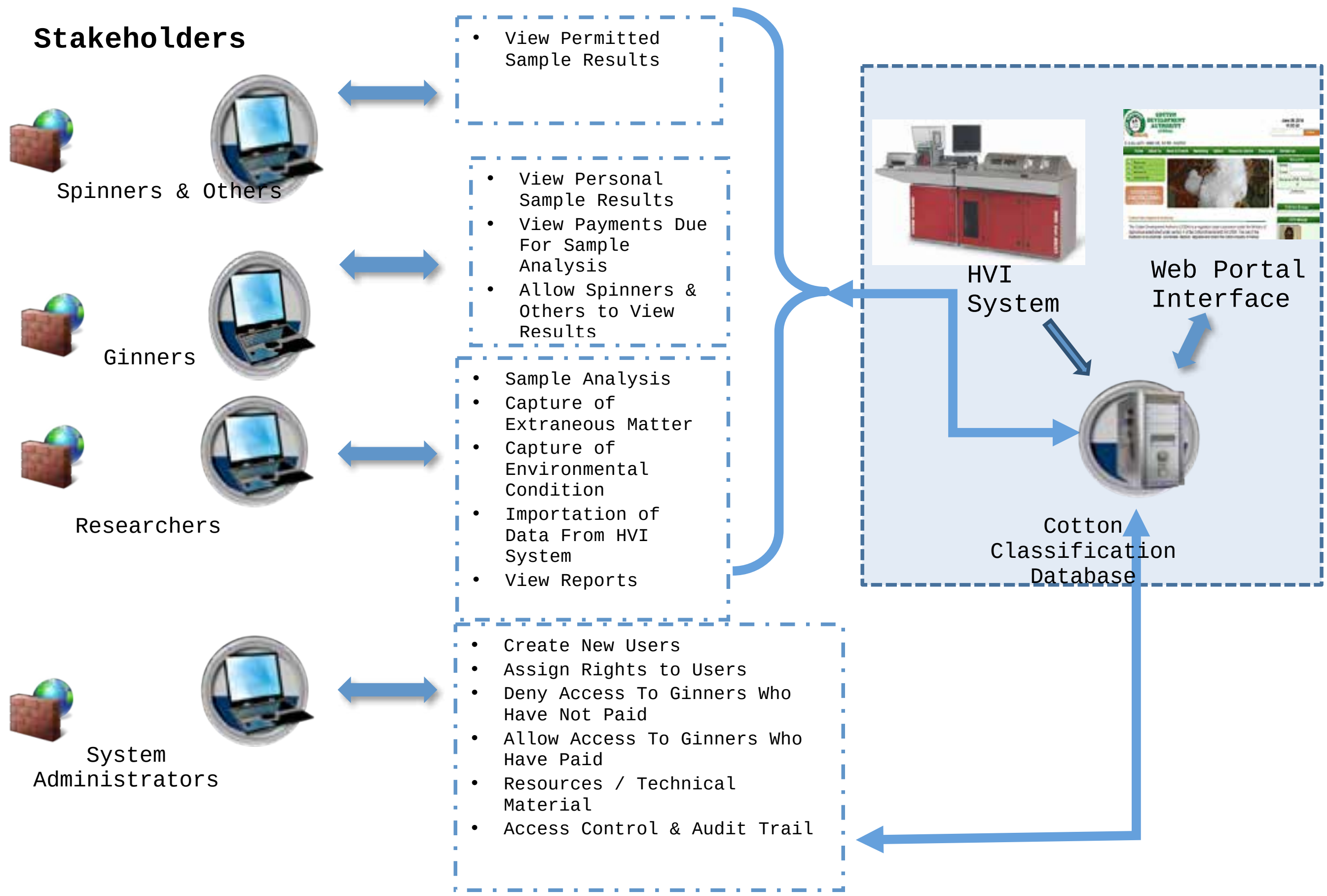
- The database system to be able to integrate with the HVI system and receive data in the desired formats; and
- The web portal for receiving and publishing of the HVI data in the form of reports to be accessed by the ginners, buyers, researches, spinners and other stakeholders. Accessibility of this information will be controlled by unique user IDs and passwords.

Owners of the samples tested are the sole copyright owners of the respective specific test reports. Ginners and authorized users of the national database will be assigned identification codes, passwords and access rights to the system.

Summary

The significance of the CFC/ICAC 44 project is that it has enabled the establishment of a 100% sampling and HVI system in countries where smallholder farmers grow cotton with moderate annual production as opposed to countries like Australia, Brazil, Uzbekistan and USA, where production is measured in millions of tons. The implication of this achievement is that the establishment of instrument testing of cotton for developing countries that produce cotton is realistic.

Fig 5: HVI Database Process & Procedures



The challenges experienced during the construction of cotton classing facilities, including ensuring that the Ambient Air Management Systems (AAMS) provide consistent temperature and humidity levels, will assist those interested to replicate the system as is or in a modular type of expansion depending on the volume of their cotton production. The construction of the laboratory and other installations in Kenya was completed without incident, but more work was required on the AAMS in Mozambique before the facilities would be fully functional.

Consultation within the cotton sector (including producers, traders, ginners, spinners, etc.) on the mandatory introduction of 100% sampling and testing of cotton will promote collective ownership of the arrangement. With increased production in the region, the project is deemed economically sustainable provided that HVI system facilities operate at the optimum capacity.

References

Drieling, A. and Gourlot, J.-P. (2012). Commercial Standardization of Instrument Testing of Cotton for the Cotton Producing Developing Countries in Africa (CFC/ICAC/33).

Dunavant III, B. (2002). Advantages of the High Volume Instrument System. USDA, AMS, Cotton Program. Presented at the Technical Seminar at the 61st Plenary Meeting of the International Cotton Advisory Committee, Cairo, Egypt, October 2002.

Ethridge, M. D. (2005). Harmonization of Rapid Machine Testing of Fiber Quality: International Textile Center Texas Tech University Lubbock, Texas USA. Presented at the Technical Seminar at the 64th Plenary Meeting of the International Cotton Advisory Committee, Liverpool, United Kingdom, September 2005.

Gérald, E. (2008). Quality and Marketing of Cotton Lint in Africa. Africa Region Working Paper Series No. 121, October 2008

ICAC Task Force on Commercial Standardization of Instrument Testing of Cotton and ITMF International Committee on Cotton Testing Methods, Guideline for Commercial Standardized Instrument Testing of Cotton (2008). Editors: Drieling, A., Gourlot, J.-P., Knowlton, J.

Regional Agricultural Trade Expansion Support Program (2003). Cotton- Textile & Apparel Value Chain Report for Kenya

Cotton Yields in India and Prospects for Improvements

By Dr. Rafiq Chaudhry and Rebecca Pandolph, ICAC

India is the largest cotton producer in the world in terms of area planted to cotton and, is likely to become the largest producer in terms of lint production in 2014/15. However, cotton yields in India rank in eighth place among the top ten cotton producing countries in the world. Cotton yields in India reached only 72% of the world average in 2013/14. This article discusses the factors responsible for low yields and prospects for improving yields in India with particular reference to commercial cotton hybrids and their role in improving yields.

The Production Scenario

In 2013/14, cotton was planted on 11.7 million hectares or 6.7% of the arable land in India. The top ten cotton producing states in descending order are Gujarat, Maharashtra, Andhra Pradesh, Karnataka, Haryana, Madhya Pradesh, Punjab, Rajasthan, Tamil Nadu and Orissa. The three important regions with cultivated species are shwon in the table next page.

Average cropping intensity varies by region depending on the pressure to produce food/alternate crops. In 2013/14, with an average cropping intensity of 134% at the national level, cotton was under higher pressure in the North zone to be grown within a shorter period because of pressure to grow other crops such as rice. It is estimated that 6.4 million farmers in India planted cotton in 2013/14. The national average cotton area per farmer is around 1.5 hectare. Nearly a quarter of cotton producers plant cotton on less than one hectare and almost half of the cotton producers plant on less than two hectares. In 2013/14, 65% of the cotton area in India was grown without assured irrigation (dryland). Scarcity of irrigation water is a major issue for Indian cotton, and can negatively impact yield. Rice, which has almost double the delta of water, fortunately does not compete with cotton throughout the cotton belt. Rice is grown in the north, northeastern, south and southern eastern border states in India. Major rice growing states are Utter Pradesh, West Bengal, Odessa, Chhattisgarh and Bihar where little or no area is used for cotton cultivation. Nevertheless, in addition to Punjab in the north, farmers have a choice to shift between cotton and rice in the south and southeastern states, particularly Tamil Nadu, Andhra Pradesh, and further to the north in Orissa, with some overlapping area in the West Bengal.

India is famous for growing all cultivated species of cotton. No other country has ever planted all four species on a commercial scale. The indigenous diploid species *G. arboreum* and *G. herbaceum* were planted on a combined 38% of cotton area in 1995/96 but have since slowly disappeared. The emergence of biotech cotton is considered to be one of the factors responsible for a reduced emphasis on producing diploid cottons, in addition to less focused research on diploid cotton and the inability to achieve similar gains in production and yield as with upland cotton.

Changes in Area Under Different Species in India (% Area)

Species	Years			
	1947/48	1995/96	2000/01	2010/11
G. hirsutum	8	24	33	5
G. hirsutum hybrids	-	32	40	86
G. barbadense	-	6	3	1
G. arboreum	64	25	15	3
G. herbaceum	28	13	10	5

The Story of Commercial Cotton Hybrids

India is a pioneer is utilizing hybrid vigor in cotton on a commercial scale. Commercial cotton hybrid work started much earlier but the first commercial

Cotton Growing Zones in India

Zone/States	Species Grown	Major Rotations	Major Competing Crops	Special Features
North (Punjab, Haryana, Rajasthan)	Intraspecies hybrids of *G. hirsutum* = 97%, *G. arboreum* = 3%	Soils are alluvial in nature. Most often cotton follows wheat	Rice, cluster beans, sugarcane to some extent	All irrigated, leaf curl virus threat, high temperatures resulting in sterility, shortage of water.
Central (Maharashtra, Gujarat, Madhya Pradesh)	Mostly Intraspecies hybrid of G. hirsutum, first hybrids grown	Soils are black soils or vertisols. Most cotton is mono cropping, highly dependent on rain, wheat, maize and legumes are grown as a rotation crops.	Green gram, sorghum, pigeon pea, vegetables	Major cotton zone, limited irrigation potential, ideal temperatures, chances for drought and flooding.
South (Andhra Pradesh, Karnataka, Tamil Nadu)	Intraspecies hybrids, *G. hirsutum* = 96%, other species also grown	Vertisols or red soils. Mostly cotton is a mono crop, vegetables, maize and legumes are rotated with cotton to some extent	Maize, sunflower, beans and chilies	Irrigated area fit for *G. barbadense* and intraspecific hybrids, extensive use of insecticides/chemicals

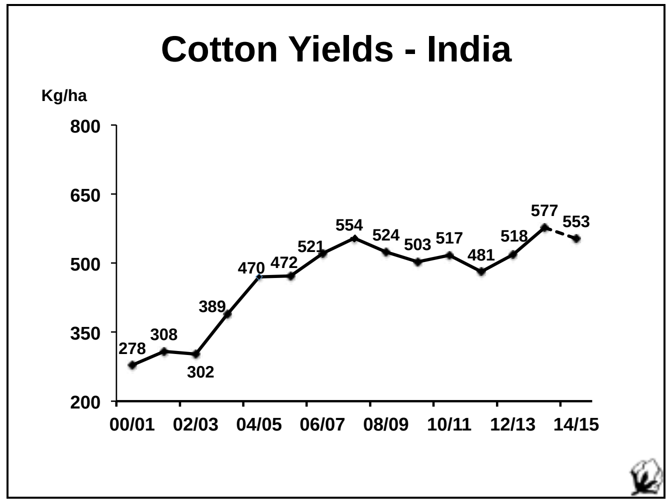
hybrid considered to be successful in India was an intra *hirsutum* hybrid released in the early 1970s. Since then, cultivation of hybrid cotton steadily increased and reached almost 1/3 of the cotton area by 1995/96. Currently, straight varieties of all species are planted on less than 10% of the cotton area. The first successful commercial cotton hybrid H4 had a bushy structure requiring a very small number of plants per hectare, perfectly suiting the sparsely planted cotton production system of the time. Cotton yields showed little increase during the 1970s but improved significantly during the 1980s as sowing of hybrid cotton became more popular. Although, improvements in agronomic practices continued simultaneously, most credit for higher yields was inappropriately attributed to commercial cotton hybrids. Gains in yields were so dominant that insecticides and their uses and the transfer of technology did not receive the attention they deserved. Both oversights were realized later and considerable improvements in yields occurred after the two weak links in technology were fixed.

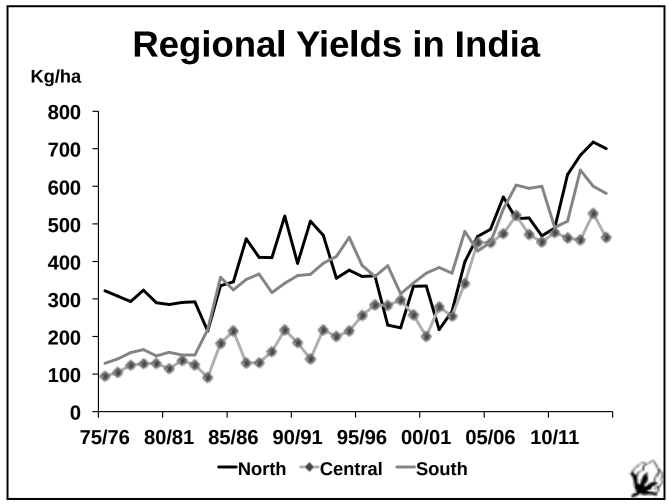
One of the main issues with hybrids is that the production of planting seed is more expensive compared to varieties. Consequently, lower quantities of seed are used per unit area, which increases the risk that a smaller crop will be produced. Farmers receive planting seed from private companies as a packet that also includes the cost of biotech genes, and less than 2 kg of planting seed per hectare is used. Male sterility systems were introduced in the world after the widespread use of hybrid cotton in India. While cytoplasmic male sterility has worked well, suitable restorer genes have not been found. Moreover, the restorer genes developed elsewhere were found to be prone to varying performance under different climatic conditions. By then, the atmosphere for hybrid production was so favorable in India that the withdrawal of support for commercial cotton hybrids was inconceivable. The textile industry supported hybrids because they received uniform quality from pure hybrid seeds. The seed industry quickly gained market share and became a dominant player in the cotton industry.

Cotton Yields Stagnate

It is still arguable whether yield improvements during the 1980s were caused by the widespread use of hybrids or the expanded use of insecticides to control insects. Insecticides, irrespective of the fact that they have their own consequences, would have positively impacted cotton yields of both hybrids and varieties. Yields increased significantly in all other countries that adopted insecticides, as was the case in the 1980s. No hybrids were used in Pakistan but yields nearly doubled during the 1980s.

By the mid-1990s, cotton yields stabilized while resistance to insecticides emerged as a key factor. Despite the growing issue of insecticide resistance, the success story of commercial cotton hybrids in India had already emerged as a highlight of the cotton sector worldwide, taking away some attention from the exploitation of hybrid vigor. Cotton yields had reached a plateau, and certainly required a magic bullet. Insecticide resistance was already being tackled in other countries, but this





issue is not easy to deal with in a small-scale farming system such as in India. Success stories of resistance management in Australia and the West African countries were hard to replicate in India. The basis for resistance had been researched and solutions were ready for introduction under Indian conditions, but their implementation would take time and require close coordination between the public and private sectors.

Biotech Cotton Arrives on Time

The insecticide resistance problem was the most convincing argument in favor of the adoption of commercial biotech cotton. The resistance management program worked sufficiently to contain insecticide use without any impact on yields. Adulteration of insecticides and inefficiencies in prey technologies were a common complaint worldwide. Under- and over-dosage of insecticides are inadvertent consequences of the resistance problem. The intricacies of insecticide use were minimally followed in India, as was the case in many other countries. Biotech cotton was a solution to all these problems. Commercial cotton hybrids were perfect way to avoid any counterfeiting of biotechnology as farmers had to revert to seed companies for hybrid planting seed. Biotech genes entered the market via hybrid technology, leaving no room for their misuse. But, at the same time, hybrid technology firmed its footing in the cotton sector in India. Technology costs were controlled through public regulation and local genes were introduced. The impact on yield was so huge that in five years the area under biotech cotton reached half of the cotton area in India. Liberal approval, in the form of an event approval process, flooded the market with biotech hybrids.

The North region, which had been dominant in terms of average yields for a long time and had not seen any benefit in growing commercial cotton hybrids, had to adopt hybrids because of biotech genes. Yields were higher compared to other areas because of irrigation facilities and, probably, better technical knowhow of cotton production. Bushy plants (hybrid or a variety) clearly tend to gain more vegetative growth under irrigated conditions compared to rainfed. This may be the reason why hybrids did not become popular in the Northern zone. The Asia-Pacific Association of Agricultural Research Institutes, operated from the FAO Regional Office for Asian and Pacific in Thailand, published *Hybrid Cotton in India – A Success Story* in 1995, which showed that no hybrid cotton was grown in the North zone while the Central and South zones planted hybrids on 36% and 61% of the area respectively. However, when biotech cotton was introduced in other zones, the North zone had to adopt hybrids in order to utilize biotech genes and eliminate insecticide applications as much as possible. The farmers may have given up the chance of over growth or this chance was reduced due to early formation of bolls. Once the plant is in reproductive growth, the plant is bound to devote more energy toward fruiting rather than continuing vegetative growth.

Concerns with Hybrids

Production technology has changed drastically since hybrids were adopted over 40 years ago and hybrids seem to have reached the end of their usefulness.

- Hybrids, being voluminous in stature, form bolls for a longer period of time, thus requiring protection for a longer period. The longer fruit formation period has a high risk of requiring more insecticides/chemicals.
- Fiber quality varies more in hybrids compared to varieties. Research shows that bolls located at various positions on the plant have differences in fiber quality parameters. While early-formed bolls have a higher micronaire and fiber maturity, bolls formed toward the end of the season have lower maturity and lower micronaire values. In hybrids, bolls are formed at various temperatures from the early boll formation to the termination of fruit formation. Variability also occurs in varieties, but most bolls are formed close to the main stem and within a shorter period of time.
- Production of planting seed is key to the survival of commercial varieties. When hybrids were introduced in India, seed certification was not as advanced as it is now. Varietal mixing results in a mixed fiber quality, which is not appreciated by the spinning industry. Private companies are responsible for providing quality planting seed and now they can implement stricter seed certification laws/practices and produce pure quality seed for not only hybrids, but also varieties.
- The cost of producing hybrid planting seed is high compared to varieties. Emasculation and pollination are quite labor intensive. The high cost of planting seed for hybrids compels farmers to use the smallest possible quantity of planting seed, risking optimum plant stand.
- Hybrids are also more difficult to breed than varieties. Cotton is often considered to a cross-pollinated crop but out-crossing is limited. Out-crossing in cotton depends on the weather conditions, and under Indian conditions, out-crossing in upland varieties should not be more than 2% at the most. Isolation of parental lines/varieties to a distance of 50 meters eliminates the chances of out-crossing in most cotton growing areas in India. The development of inbred lines and in-breeding depression are detrimental to the commercialization of hybrids in cotton. What is required in hybrid cotton is the development of good parents with all the required characteristics, i.e. morphological, yield and quality parameters, to be expected in the F_1 hybrid. A cross between a high yielding and a low-yielding parent may not produce a high-yielding F_1 hybrid. The same is true for other characteristics and parameters. So, hybrid cotton becomes a two-step breeding process requiring more time and interdependent on each other.

  - Regular conventional breeding has to be undertaken and completed to have varieties/cultivars/lines with all the desirable features of a commercial variety. Varieties require one line but hybrids need two desirable lines.

  - The combining ability of the two parental lines must also be such that a desirable hybrid is developed that excels in yields with a performance that is at least equal to a commercial variety or already grown commercial cotton hybrid. It is known that two good varieties/lines may not perform as good combiners. So, additional work and time is needed to find good combiners and confirm their consistent performance.

- The technology at the time when hybrids were popularized focused on increasing the number of bolls per plant rather than bolls per unit area. Indigenous practices recommended that cotton be grown sparsely so that the plant could grow horizontally as well as vertically. The fruiting period was usually longer, with much lower stress than nowadays, in order to increase cropping intensity. A longer growing period and multiple picks were not undesirable. However, the need to improve cropping intensity has grown significantly due to population increases and the need to produce more food crops. Now, short duration and fewer pickings are desired.

- Many other aspects of production technology have also changed. Insect damage was not high and insecticide use was uncommon. Fertilizers had been adopted but not reached their peak, as is the case now. Hybrids performed better under stress conditions. Now fertilizer use has been optimized and plant protection has been transformed in such a way that conditions are conductive for varieties to grow as successfully as, if not better than, hybrids. Under current production practices, yields are not expected to drop if varieties are grown.
- India rightfully regards itself as the inception and successful utilization of commercial cotton hybrids in the world. However, commercial hybrids do not have any technical complexities that prevent them from being utilized in other countries. Many countries including Australia, China, Israel, Pakistan and USA tried commercial cotton hybrids. John H. Turner published the paper "Hybrid Cotton Breeding Program" in the March 1959 issue of the California Agriculture. Since then, many more technologies, including cytoplasmic male sterility, genetic male sterility, restorers, gametocides and chemical sterility were tried. In Uzbekistan a unique technique of avoiding emasculation by covering the style with a paper tube was tried. None of the techniques worked successfully. Yet, India continued to produce hybrid seed claiming that labor costs are affordable.
- However, labor costs are rising in India, particularly the cost of picking, due to the growth in India's economy as the growth in labor demand outpaces the supply. Machine picking is being explored as a less expensive method of picking. It is time to move on and save on planting seed costs.
- Commercial cotton hybrids were also seen as a source of employment (labor engaged in emasculation and pollination). On average, five labor days are required to produce a kilogram of hybrid seed and 2.5kg of hybrid seed are used to plant a hectare. Significant increases in planted area and the shift to hybrids has further increased the demand for manual labor. Yet, scarcity of labor is also becoming an issue as India's economy continues to grow and more workers move to the manufacturing and service sectors.
- The data on page 14 show that *G. arboreum* and *G. herbaceum* were planted on over 90% of the area in 1947/48 while *G. hirsutum* varieties, which was introduced and commercialized almost 50 years ago, were planted on only 8% of area. The reasons why diploid indigenous species were popular are that they were well adapted to the fluctuating rainfall, poor growth conditions, no insecticides, no fertilizer and lack of technological innovations. As the means to overcome such constraints were developed and adopted, room for upland cotton automatically emerged. So, technology changes shifted the varietal pattern. Similarly, it is again time to look at technological changes in production practices and adapt to them.

Prospects for Yield Improvement

Hybrid vigor is already utilized, and biotech area has reached its peak in India. The other significant, but less acknowledged, contributor to recent increases in yields is the improvement in the transfer of technology. Technology transfer is a continuous and ongoing process. Cultivation of biotech cotton offloaded some of the pressure on cotton growers with respect to selection of insecticides, spray machinery and insecticide spraying, which had a considerable positive impact on yields.

The quality of seeds is also an important contributor to productivity and affects the usage and effectiveness of other inputs. India's breeding program is one of the most competitive in the world and cannot be more efficient, less ambitious or less creative. The more than fifty companies that have some share of the planting seed market in addition to public sector breeders provide more than enough competition for the development of the best breeding materials.

For many farmers in India, particularly those farming on two hectares or less, purchasing seeds and other inputs can be difficult. Many do not have access to credit through the formal finance sector, and instead borrow money at high rates from private lenders. Repayment can be difficult, particularly when prices are low. Furthermore, a tension exists between the high cost of inputs, such as fertilizers and herbicides, and their positive impact on yield, which may cause farmers to use less than optimal amounts. However, solutions to increase access to affordable financing are not readily available and take time to implement. This is particularly important given the rising costs of production.

Current production practices are conducive enough to produce hybrids with yields as high as hybrids can possibly produce. What is required is a decision to move to varieties without losing the ability to utilize biotech genes. Biotech gene technology and commercial cotton hybrids are so intertwined that it will not be easy to separate them and switch to straight varieties. The benefit is that this would not require any additional resources and research. The cost of planting seed would decrease and the rate of development of varieties should rise. Greater competition to release varieties will indirectly bring about improvement. However, a sudden shift is not advised, and at a minimum, performance studies could be initiated before a final recommendation is made. It is also possible that hybrids might still persist in some areas but not everywhere in the country. Kranthi (2012), in answering the question 'Are the yields stagnating in India and why?', stated that hybrids tend to be input-intensive, so they are not suitable for at least half of the cotton area in the India, which is under marginal soils in rainfed regions. He suggested that for rainfed regions, especially those with shallow-marginal soils and characterized by low input use, early maturing straight varieties are the best option. The main advantage with straight varieties is that farmers can reuse farm-saved seeds and take the liberty of early dry sowing, even before the onset of monsoon, without having to worry about the risks of poor germination and re-sowing. The recommendation appears sound and is in consonance with the thrust of this article, except that the use of certified seeds is recommended every year. If certified seed is not available in sufficient quantities, then it is recommended to go to the next generation, which, according to the ICAC, is 'registered seed'. The registered seed category is a seed produced from certified seed by a farmer under his own supervision. For more information on ICAC planting seed categories, refer to the September 2013 issue of *THE ICAC RECORDER*.

While yields have reached a plateau in many other countries, yields in India still have a huge potential for growth. Many other countries have reached the limits of their potential under current production practices, but not India. Recent experience showed that adoption of biotech cotton complemented by improvements in conveying the production technology message to growers more opportunities are there to utilize. Even if the yield for varieties is the same as hybrids, production costs will fall and save money for growers.

References

Basu, A.K. and Paroda, R.S. 1995. *Hybrid Cotton in India – A Success Story*, available at http://www.apaari.org/wp-content/uploads/2009/05/ss_1995_01.pdf

Handbook of Cotton in India. 1999. Indian Society for Cotton Improvement, Mumbai, India. Edited by V. Sundram, A. K. Basu, K. R. Krishna Iyer, S. S. Narayanan and T. P. Rajendran.

Kranthi, K. R. 2012. *Bt-Cotton Q&A.* Indian Society for Cotton Improvement, Mumbai, India.

Technical Information Section. 1997. Commercial Cotton Hybrids. *THE ICAC RECORDER*, Volume XV, No. 2, June 1997, International Cotton Advisory Committee, Washington DC, USA.

Technical Information Section. 1998. Breeding for Yield Improvement Needs Changes. *THE ICAC RECORDER*, Volume XVI, No. 1, March 1998, International Cotton Advisory Committee, Washington DC, USA.

Zumba, Jimmy X., Gerald O. Myers, Ernest L. Clawson, Donnie K. Miller, Robert G. Danka and Sterling B. Blanche. 2013. Developing Hybrid Cotton (Gossypium spp.) Using honey bees as pollinators and the Roundup Ready® phenotype as the selection trait. *The Journal of Cotton Science* 17:293–301 (2013).

Zumba, Jimmy X. 2008. Developing hybrid cotton (*Gossypium* spp.) using honeybees as pollinators and Roundup Ready® gene as selection trait. A dissertation for partial fulfillment of the requirements for the Degree of Doctor of Philosophy, available online at http://etd.lsu.edu/docs/available/etd-02132008-102450/unrestricted/JZ-Dissertation-Final.pdf