OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

The role of Research Centres in developing countries in promoting a versatile exploitation of cotton and an effective cooperation among the countries in Technology Development and dissemination

17453

A paper presented by

Ibitoye Aladeselu C. Text, A.T.I; C. Chem MRSC

At The

Expert group meeting on the processing of Raw Materials held in VIENNA, AUSTRIA,

22—26 AUGUST, 1988

INTRODUCTION

Cotton is the world's leading textile fibre accounting for almost half of the world fibre production. It is an annual plant grown in about ninety countries, on every continent, between latitudes from 45^{o} North to 30^{o} South. Cotton producing areas vary in climate from arid to semi-humid. The United State of America (USA), USSR ,China and India account for about two-thirds of world population of cotton. India has the highest area, USSR the best yield and China the highest production. Apart from Spain and Greece which produce raw cotton in sizeable quantities, the other producers are spread among about seventy developing countries in Asia, Latin America and Africa. Among agricultural commodities it was as at 1980 the biggest foreign exchange earner for ten developing countries, ranks second in fourteen and lies between third and sixth for another fourteen nations. In the recent past, some of these exporting countries have acquired manufacturing capacity beyond the supply from their production.

The developing countries are endowed with a massive area of cultivable land and weather to grow cotton but lack the infrastructural facilities of improved agronomy to have increased production, high yield and better quality of cotton fibres as obtained in the developed nations. These four major cotton producers owe their achievements in high cotton production to their investments in Research and Development (R & D) activities, in support with their governments' policies towards achieving self sufficiency. Cotton consumption, to a large extent, follows population patterns. Cotton is needed not only to cloth the millions of people in the developing countries, but its production is required to be maintained at a higher level, matched with quality to meet the various end uses in the domestic and foreign textile industry.

The crop therefore requires constant care from the growers and vigilance by the research workers and scientist for improvement in its production and quality according to the changing patterns of national and international demand for cotton fibre.

ESTABLISHMENT OF RESEARCH CENTRES IN DEVELOPING COUNTRIES

There are few textile degree-awarding institutions in developing countries. This may be due to their low cotton production, supplemented, in most cases, by on open market for importation of finished fabrics. It is only India, the highest cotton producing country in the third world and Pakistan that have established textile research centres. Some research activities may however be on in some departments of some Universities and Polytechnics on purely academic basis on specific topics like cotton seed breeding. The main objectives of research in developing countries should be for industrialisation, carried through successive stages of basic in laboratory scale operations, applied to full scale processing. This can then bring a change in the structure of the textile industry from a labour-intensive industry satisfying people's needs for their daily lives to a technology and capital intensive industry, the type of industry operating in advanced nations, meeting people's needs for life styles and cultural requirements.

The above task can be successfully accomplished if research centres are well equipped in terms of technocrats, machinery, modern testing equipment, essential research apparatus and facilities which are supported by engineering services capable of working to precise limits. This is a capital intensive venture. In the four major cotton producers in the world, textile research began with the establishment by the governments. Research and Development in the developing countries should be supported by subscription from the cotton processing industries, who are the ultimate beneficiary of research results, in the shape of membership subscriptions together with subscriptions in support of specific research programmes, in collaboration at the onset with the government in order to qualify for aid from international or other governmental agencies. Such co-operative Research and Development scheme is cheap, since the results as well as the costs are shared by the contributors, and since the companies are involved in the financing, programme, planning and running of the centre, they have a feeling of participation and even pride, and assume an obligation to make a success of the centre.

Relationship between the companies and researchers is close, and this ensures a degree of speed in the transfer of technology. Further, since a large number of companies manufacturing the same product are members of the centre, it enables the researchers to review and monitor the industry's progress over a period of time, an information which is of interest to the government in policy formulation and in long term decision making. The involvement of the government will have a restraining effect on unnecessary pressure from the company members and also promote long term projects that will be of ultimate benefit to the industry and the consumer. When the research centre is well established, the government can withdraw its subvention, but maintaining its patronage, leaving the centre to be self-funding through contract research, supplemented by subscription from member firms and organisations wishing to share the benefits of research, testing, certifying and advisory services.

The main objectives of research centres in developing countries in promoting the utilisation of cotton should therefore be -

1. To conduct fundamental and applied research on cotton fibre, yarn, cloth and cotton seed, and on processing of cotton fibre with a view to optimum utilisation

2. To provide facilities for the scientific evaluation of fibre properties and yarn characteristics of the improved varieties of cotton evolved at the various breeding stations and to compare their performance with the established varieties.

3. To carry out fibre and spinning tests on the trade varieties and disseminate technological information to the trade and industry.

4. To provide testing house facilities for the benefit of trade, industry and export agencies.

The range of activities which might ultimately be undertaken can be classified into four sections.[5]

i. Research

ii. Technical Services

iii. Education and Training

iv. Technical Evaluation and Demonstration of New Machinery and Processes.

RESEARCH

Fibre Development:

Cotton availability is linked to population trends and availability of land for cotton growing and socio economic conditions. In developed countries, like the USA, land holdings and cotton acreages are traditionally high. In developing countries of Asia and Africa, on the other hand, land holdings are usually very small. Main concern is in food production, individual farms under cotton is very small, yield is low and the quantity of seed cotton, as shown in Table 1 produced is usually low. There are still vast areas of land in developing countries where potentials are yet to be developed. Consumption patterns in general tend to follow population concentration, although there may be variation in pattern of consumption by product. Although demand for more cotton may be affected by fashion trends, quality, price, availability, promotion and technical developments, the developing countries of Latin America, Asia and Africa which are under the greatest population pressure will in course of time, with the increase in manufacturing capacity, be unable to meet the fibre requirements of their mills to cloth their population.[25] Current levels of production in Nigeria represent only 24% domestic market requirements,[26] whilst India has a negligible export of spinnable cotton. In the ICAC's February 1988 forecasts of cotton output on African countries, only Egypt and Sudan are likely to produce more than 800,000 bales in the 1987/88 cotton season.[27] Except for a few countries like Egypt, Syria, Turkey, Guatemala and Mexico, developing countries have very low cotton yields. This calls for a governmental policy on increased production of cotton and adequate research input under skilled management of husbandry to achieve increased production, increased yield and increased quality, to cope with the imminent automation in textile industry which will require fine, mature, strong and long cotton for processing. The involvement of the research centre starts with land preparation for mechanised production, through seed breeding and cropping, baling, classification to experimental Spinning, in relation to soil type, climate and availability of water.

The success of mechanised farming, depends, partly on the use of tractors to prepare the land. A chemical analysis of the soil might be necessary to know the appropriate fertilizers-Nitrogen, Phosphorous or Potassium-based to be employed to increase yield and also to facilitate soil pests and termite control.

Breeding of mature and healthy strains of cotton seed is vital to increased production and improved yield. Cotton plant belongs to the genus Gossypium.[25] The genus has about 39 species, of which 35 are wild and only four are cultivated. The cultivated species are Gossypium Arboreum which has the shortest and roughest staple, and Gossypium Herbaceum both of which are now confined to Pakistan and India. The 'New World' species are Gossypium Hirsutum (Upland) which accounts for about 90% of total world produce and Gossypium Barbadense which produces the longest and finest staple. Variants of these species were developed in the four major cotton producing countries before the evolution of cultivars suitable for their climate and soil.[29] Staple length of cotton is influenced not only by cultivar, but also by environmental factors during growth.

Better agronomic techniques for plant population through identification of suitable cultivars can be achieved through -

- Species selection and development of cultivars
- Mixing and cross fertilization of different varieties and selection of suitable types - the source of evolution of Egyptian Cotton[29]
- Hybridisation to obtain either multiple-disease-resistant or multi-adversity resistant varieties[30]
- Acclimatization for increased tolerance to heat, cold and drought
- Selection and multiplication for plant population
- Dressing by treatment against fungus diseases and insects.

Cropping for better yield should consider -

- Identification of appropriate sewing time
- Weed elimination through the use of herbicides
- Insect and Pest Control through application of insecticides and fungicides
- Spacing for adequate plant density
- Development of special short-season varieties to suit local conditions for example - double cropping in the tropics and subtropics.
- Application of appropriate fertilizer
- Adequate supply of water
- Intraseasonal rotation due to deep rooting system of cotton.

The main problems with the developing countries in cropping are lack of machinery, inadequate control of protective chemicals, wrong fertilizers and scarcity of water supply. Best grades of cotton are irrigated,[28,29] this ensures adequate supply of water throughout the cropping season, whereas rain-growned cotton is prone to both water-logging and drought during its development. Construction of water reservoirs, artificial lakes and bore holes might be sources of irrigation to promote double cropping in the tropics. Effect of agro-chemicals can be specific; there is therefore the need to identify the weed, sucking insects, bugs, birds, bollworms and leaf rollers to assist in the formulation of the chemicals that will be safe to handle and will not adversely influence germination and growth.

Increased production makes hand picking, practised in developing countries, inadequate. Defoliation before mechanical harvesting becomes necessary. During picking of cotton, either by hand or by mechanical means, some foreign matter is bound to be picked up along with seed cotton. Machine picked cotton can be dirtier through severe contamination, these foreign matters are to be removed before ginning.

The main weakness of cotton in most developing countries are delayed and bad ginning.[31,32] There is hardly any predrying, precleaning or lint cleaning. It is due to foreign matter in the lint that spinning loss is about 12-16% in cotton from the developing countries as against 6-8% in cotton from say, the USA. The principle of predrying, precleaning before ginning and lint cleaning before baling is to do as much cleaning as possible without introducing neps or causing damage to the fibre and to improve the grade of lint so as to more than pay for the cost of cleaning with the premium of clean lint.

Cotton fibres deteriorate in quality with delay in ginning. There is an urgent need to adopt modern ginning factories compatible with volume of fibres from mechanical harvesting. The roller gin has a lower ginning capacity than the saw gin which is adequate to gin cotton fibres with a staple length greater than 32mm; with high cotton production custom-ginning might be the rule, whereby the cotton growers bring their seed cotton to the ginnery, pay the ginning charges and sell their lint and seed.

It is necessary, for research centres, to have experimental trials on the cotton grown so as to know which variants thrive best in the environment and give necessary advice for improvement.

Fabric Development:

Cotton has very good physiological and tensile properties. It has high resistance to the effects of water and heat. Its resistance to abrasion and formation of electrical charges is good. It is also good to handle. Owing to its good wearing properties, cotton finds much use in light weight, fine and frequently washed textiles. However its resilience and recovery from strain are less good, it readily burns in the air, and its resistance to shrinkage is only satisfactory. These shortcomings in the inherent properties of cotton limited its full usefulness and spurred the development of man-made fibres and their application either as a blend with cotton or as a synthetic fibres for particular end uses. An important factor affecting cotton future prospects is its ability to compete with the synthetic fibres in terms of those performance standards which the consumer regards as most desirable. Finishing capacity in the developing countries is not sufficient and the level of technology is not high. Most countries are put off by the increased cost on processing, low demand and absence of legal obligation on their part. This results in the poor quality of cloth which cannot face the competitiveness of the export market. The application of special finishes to cotton can greatly extend its usefulness, either by overcoming detrimental characteristics, like the tendency of cotton to shrink and wrinkle or by imparting new properties, such as flame resistance or water repellency. These finishes therefore improve the saleability and the aesthetic properties of cotton fabric.

Cotton is easily deformed because interchain bonds in cellulose are weak. Crease resist finish reduces the tendency of cellulosics to crease through the polymerisation of a resin within the fibre. Several crosslinking agents, notably dimethyloethyleneurea, (1, 3 bishydroxymethyl)-2-imidazolidinone are in use. These resins are applied to the fabric, dried and then reacted by heat curing. The harsh texture that is thus imparted is mitigated by applying softeners.

Cotton burns readily in air, producing Carbon Monoxide in confined places, and because of the poisonous nature of this gas, flame retardant finish is imposed, by legislation, in developed countries for such end uses as children's nightwear, protective clothing, furnishings and beddings which are prone to ready attack by fire. Flame retardant finish reduces the speed with which a fibre will burn. The flame retardants include simple soluble substances such as borax or alum and insoluble chemicals formed in the fibre by reaction, such as Stannous oxychloride or Antimony oxide. Most introduce problems of handle, toxicity or poor durability and have been largely replaced by a variety of organophosphorous compounds.

Water-repellent finish slows down the rate of penetration of water into the textile through a coating of a water repellent chemical which because of its hydrophobic nature, is unable to break down aggregated water molecules which roll about in spherical shape and are then easily shaken off from the cloth surface. The water repellency of a fabric is related to the closeness of the weave construction. In the design of fabrics for protective clothing, it is necessary to combine an adequate degree of water-vapour permeability with impermeability to water and wind. Water repellent finish is usually applied to tend fabric and fashion wear.

Compressive shrinkage is used to preshrink cotton fabrics greater than 140g/m^2, used for coats and trousers, so as to prevent shrinkage in washing. A rubber blanket is moved in opposition to the fabric through the finishing machinery, so that the filling yarns are forced together and the progressive shrinkages that would otherwise occur during repeated laundering is forestalled. In top weight fabrics for shirtings, and knits, satisfactory results are usually obtained as a side effect of the permanent press resin finish. Lack of the compressive shrinkage technique for cotton in developing countries gives room for the adoption of imported wool/synthetic blends for bottom weight fabrics.

Cotton Knitting[6] has for too long been confined to the manufacture of underwears. Man made fibres continue to dominate the knitted outwear market but cotton share of the market was around 10% in 1980.[7] The dominance of the synthetics is due largely to their inherent easy care character; for example knitting polyester is relatively easy because it can be heat set, unlike cotton yarns which respond differently to spinning, dyeing and mercerization according to its quality - yarn count, stitch length.

The IIC has successfully executed a Star-fish programme[8] for improving the quality of cotton Knit goods. In a seminar on the IIC Starfish concept in 1984, it was recognised that Starfish had demonstrated usefulness for developing new cotton knitgoods with substantial savings in time and costs, for examining product specifications, for identifying appropriate quality control measures, for guiding investment decisions and for contributing to a more efficient use of raw materials.

Clothing and Fashion Design Technology:

In developed countries, garments, based on the data drawn from various sources, represent national average body measurements. Standard size denominations are given few specifications with size ranges and fitting. This facilitates mass production of the garments - Suit, Trousers, Shirt, Skirt and Blouses - and the possibility to make an immediate purchase of these 'western' designs on request.

In most cotton-growing developing countries, the traditional practice of individuals buying a piece length of fabric and having it sewn to measurement for either western style or cultural attire is still in vogue. There are attendant disadvantages in this practice-there is delay in delivery, production is personalised and hence production cost is high, market and profitability are low, and quality may not be well coordinated. This practice restricts the demand for the national design and consumers are attracted to purchase the readily available western styles because retailers generally respond better to fabric ideas shown in garment form rather than those shown in fabric form. Most developing countries have strong taste for rich motif and patterns in print designs. Design is at best practised as a craft, there is a need for development into industrial designing.

Proposed background studies for a successful research on this project should include:

- Comprehensive market research of the national Garment Industry and various styles
- An appreciation of the practical aspects and principles involved in garment design and manufacture with emphasis on -

(i) Anthropometric measurements

(ii) Pattern drafting, grading

- Manufacturing sequence and 'state of the art' of Clothing Technology

Computer-aided design (CAD) and Computer-aided Manufacturing/ Management (CAM)[15] have emerged as a recent revolution in micro-computer capacity, colour graphics capability and the use of sophisticated scanners, plotters and printers. Computer simulation using the CAD/CAM systems may be planned as a long term objective for improved design, greater accuracy, higher productivity and better customer response.

Standardisation of the national design would:

a) encourage commercialisation of clothing manufacture based on cotton

b) Provide a strong foundation for ready made production culture

c) lead to better quality of product at cheaper price

d) create job in the clothing retail distribution

e) stimulate fashion consciousness through properly co-ordinated seasonal fashion shows to promote textile industry's healthy growth

f) enhance the establishment of clothing chain stores and also promote export market.

Improvement of Traditional Dyeing Technology:

Developing countries had, in various forms, established cotton processing techniques before the advent of modern technological processes. Spinning, Weaving and Finishing stages could be identified in the traditional processes, using cotton, as fibre source for spinning, fabricating looms and accessories from hard woods and natural colouring materials (indigo,logwood) for the colouring process. The textile auxiliaries were compounded from many sources including the use of wood ashes. Although both weaving and dyeing were slow, the practitioner had a handspme patronage of clients.

The fabrics were mostly plain weave. They could be grey, as narrow as 11.5cm, colour-woven and embroidered using extra weft and warp threads. The dyed fabrics could be single coloured or multicoloured through either a tie and dye or resist batik technique. There are several varieties reflecting the various cultural heritage among the countries, especially in Africa and South East Asia. These fabrics are still cherished and the heavily embroidered ones are reserved for important traditional and social ceremonies.

It has been found that, because of the scarce supply of some of the raw materials, and manual nature of operation, production was slow and low, the finished fabrics have some shortcomings - rough surfaces, poor washing fastness and poor air-permeability, Practitioners still abound who perpetuate the traditional technology techniques as a means of livelihood. Research centres should therefore participate in upgrading the technology. Research efforts to increase production of high quality fabrics should involve some mechanisation of the spinning and weaving techniques and better processing techniques to improve fastness properties.

Process Development

Diversification of end uses of cotton through process development is an effective way of promoting a versatile exploitation of cotton. The raw materials for development are byproducts of fibre production-waste and seed.

A) Waste Utilisation

After the long layered spinnable cotton has been freed of the cotton by ginning, the remaining shorter fibres on the seed pod are usually removed with two cuts before the seeds go for oil extraction. The first cut gives about 4% longer linters relative to the entire cotton flower, which are preferentially processed to medicinal cotton, felt and paper. The second cut gives about 8% shorter layered linters which are best suited for chemical processing to cellulose esters and ethers.

Cotton linters are the purest source of cellulosic long fibres for pulp and paper production.[13] The cotton fibre reaches the paper-maker in form of shorter fibres linters and pulverised and discarded cotton fabrics from textile mills.[14] It has the added advantage of being an annual plant which makes it readily available for use compared with other sources, unlike the pine which takes several years to mature. It is lignin-free, hence its use promotes savings in chemicals and energy use.[15] Paper produced from cotton is fine and of high quality - strength, softness, bulk density, opacity, brightness absorbency and durability.

Cotton as the purest source of natural cellulose, contains not less than 92% cellulose at 10% moisture content.[16,17] It has a high degree of polymerisation of about 4000. It is therefore available for use in the production of cellulose ethers of high viscosity greater than 50,000 mPas and high quality cellulose esters. The general scheme for the production of cellulose ethers includes alkalization, etherification and Neutralisation, Isolation and Purification, Compounding, Cross linking and Drying, Milling and sifting and finally packaging. The end uses of these ethers in various industries are determined by their properties:[18]

Thickening of aqueous or organic solutions

Stabilisation of suspensions or emulsion

Water Retention

Binding action

Action as Protective Colloid

Film Formation

Adhesiveness

The cellulose bases for the production of cellulose esters generally consists of highly purified cotton linters with an alpha-cellulose content over 99%.[19,20,21] Pretreatment of cellulose by mechanical cleaning and acid-alkaline bleaching and drying to a moisture content of 4 - 7% is followed by esterification using acetic acid or methylene chloride leading to the production of Cellulose Triacetate in the esterification process. The fibre structure can be maintained by adding sufficient amount of nonsolvents - Carbon Tetrachloride, Benzene or Toluene - to the triacetate during acetylation. It can also be processed into films or injection molding compounds.

Wastes are also generated in prospinning stages of Opening and Cleaning, Carding, Drawing and Roving. The waste generated in roving and sliver stages of ring spinning and those in comber, flat strip and carding stages of Open-end Spinning can be reprocessed. These wastes together with those generated in the blow room and sizing should not be more than 8% of the cotton input in a well managed spinning mill. The blow room wastes, which are composed of very short fibres and extraneous matters, like broken seeds, are usually discarded. Recent biotechnological advancement has revealed that such blow room waste can give a pronounced increase in yield of mushroom compared with the use of rice straw[12] which has to be fortified with protein for suitability as a mushroom culture. The blow room waste is rich in cellulose from the fibres and protein from the seeds. Mushrooms like Volvariella Volvacea and Pleurotus species that produce a lot of cellulose enzymes are known to dissolve the cellulosic materia of cotton waste to smaller carbohydrate molecules thereby producing food for their growth; whilst the seeds in the cotton waste serve as a good protein source. It has been observed[13] that using the blow room waste for the cultivation of V. Volvacea as much as 80% increase in yield of the mushroom is obtainable without the addition of plant fertilizers.

B) Seed Utilisation

Many developing countries are yet to realise that cotton is not only a source of natural fibre but also a food crop from which oil and cattle cake can be made. Cotton seed was in 1974 the fourth largest source of vegetable oil and the second largest source of oil cake for cattle feeding after soya bean. Cotton seed accounts for about 65% by weight of the whole cotton boll and at least 15% by value of harvest if properly processed. The oil extraction consists of delinting, dehulling to get the meal, crushing and extraction to get pigmented crude oil and purification for human and animal consumption. Purification involves degumming to remove the phosphatides and gums, deacidification of the free fatty acid, high vacuum steam distillation to remove undesirable flavours, partial hydrogenation to improve its stability and winterization to remove solid fractions (stearine) that otherwise would cause clouding when the liquid fat is held at refrigerator temperature. The major components are Linoleic, Oleic and Palmitic acid, and with an iodine value of about 106, it is considered to be of medium polyunsaturated content and is classified as semi drying and can be used in the manufacture of alkyd resins, used in the paint industry.

As an unhydrogenated oil, it is used in frying snack foods, when hydrogenated it is used in the manufacture of shortening. The dehulled, defatted meal containing about 63% protein is used as protein supplement in animal feeds; and also for commercial baking.

The pigmentation of crude oil is due to the presence of high levels of gossypol stored in pigment glands. The gossypol is poisonous to non-ruminants and must be removed for non industrial uses. Production of glandless variaties cotton seed would therefore be a worthwhile research exercise.

TECHNICAL SERVICES

These are essential services to a manufacturing company whose resources do not permit acquisition of the infrastructures or the skilled manpower to effectively execute.

Testing and Analysis:

These include the chemical and physical testing of raw materials and finished products[36] - cotton fibres, yarns, fabrics and dyestuffs, chemicals and processing auxiliaries. Analyses of data obtained from these tests are used to evaluate the quality and marketability of the material; to facilitate machine setting for efficient processing, and to indicate other process stages the material can be subjected to.[37] Dyestuffs, chemicals and processing auxiliaries are tested to ascertain the level of potency and thereby be able to make necessary adjustments in the recipe to obtain acceptable product.

Some of the major tests performed on cotton products are as follows -

(a) Raw Cotton - parameters give an indication of the achievable yarn properties

i. Length Measurement

- Maximum length
- Effective length (a measure of the staple length of fibre)
- % short fibres.

ii. Waste Analysis

- Clean cotton content
- Trash content

iii. Maturity Ratio

- A measure of the degree of thickening of the cotton fibre wall

iv. Micronaire Value

- A measure of fibre fineness, a value below 3 is fine. A value of 5 and above is an indication of coarse fibre.

v. Tenacity

- A measure of the Tensile strength. Strong cotton has a tenacity of 26g/ Tex and above.

vi. Pressley Index

(b) Yarn - Linear Density
Lea strength
Tensile strength
Amount and Direction of Twist
Hairiness
Evenness

(c) Fabric - ~~Thickness and~~ Weight
Tensile strength
Colour fastness properties
Weave structure
Evaluation of applied finishes
Dimensional stability

(b) Specialised Analytical Services

These are services which although may not be productive in the manufacturing process are made compulsory by legislation or can contribute to the quality of the finished product. Such services include water treatment, effluent control, dust control and standardisation. These services except standardisation, are executed by contract research, in most textile mills.

Water Treatment:

Abundant amount of water is used in wet processing of cotton fibres. The water is expected to meet some quality requirements to prevent wasteful and undesirable consequences in processing. The most commonly quoted contaminants are Colour, Hardness and the metals - Iron and Manganese.[35] Hard water forms an insoluble scum in the dyeliquor in package dyeing. Iron causes catalytic action in bleaching resulting in overbleaching and tendering of the fabric. It also causes a dulling of brighter shades in dyeing. In scouring, a part of the alkali will be used in reacting with the calcium and magnesium bicarbonate in hard water. Adequate water supply for use in textile mills should be from treated mains water supply, but in some drought affected areas of developing countries, bore-holes and rivers are the available alternatives. Bore-hole supplies are in most cases much harder and have higher levels of manganese, conductivity, dissolved solids and alkalinity than mains water and rivers. The commonest form of treatment is softening, and as a consequence there is a drastic reduction in hardness and some reduction in conductivity, dissolved solids and alkalinity. The remaining contaminants, though at relatively low levels are capable of causing faint discoloration of white cotton fabric. A pretreatment of such bore-hole water and rivers by flocculation and filtration may help to remove most of suspended materials.

The reuse of water by recycling is feasible but expensive. However multiple reuse without treatment of spent dyebath from a dyeing process is feasible with concomitant reduction in effluent charges, savings in water, fuel and chemicals. Such recycled dyeliquor is however possible for dyeing with recipes which are unaltered during the sequence and with recipes adjusted for pH and/or ionic strength.

Textile Effluent Testing and Control:

Whilst no water-borne pollution arises from spinning and weaving except in sizing, major wastes in cotton processing originate from desizing, bleaching, mercerizing, washing, dyeing and application of special chemical finishes, all of which involve the use of a considerable use of water. Water is also used in the removal of unwanted substances originating from the fibre and excess chemicals bearing all these processes. The water residues constitute textile effluent which is generally coloured, highly alkaline, high in Biochemical Oxygen Demand (BOD) and suspended solids and high in temperature, all of which can cause pollution if discharged untreated into municipal water courses.[39]

The characteristics of ~~the~~ wet waste from cotton processing is shown in Table 3 In the industrialised world, there are legislations on the level of discharge of wastes to either water courses/sea or public sewer. Most developing countries are silent on the attendant danger of textile pollution. Research centres in these countries can initiate the characterisation of such effluents and give suggestions for on-site treatment before disposal, leading to establishment of statutory limits. Periodic analysis of effluent samples is important to check compliance to legal requirements, and also, to determine a charge for municipal treatment if discharged into a sewer. The major items checked in the analysis of a textile effluent are as follows:[40]

(i) Suspended solids concentration

(ii) Total solids concentration

(iii) pH

(iv) Colour

(v) Biological Oxygen Demand (BOD)

(vi) Chemical Oxygen Demand (COD)

The general waste from washing, bleaching, dyeing and finishing accounts for about 65% of the total volume.

Usually, some form of treatment of the initial effluent on site is necessary before it can be released into either the natural watercourse or the sea or into a public sewer in order to satisfy certain permissible statutory limits. The quantity and strength of textile waste can also be reduced by good housekeeping, closer process control, chemical substitution and recovery. Caustic soda and slashing starch are recoverable chemicals, remaining waste being treated by biological means.

Dust Control:

A lot of dust is generated at the spinning and preparatory weaving stages of cotton processing. The air-borne dust particles in the workroom reduces visibility and affects the comfort of the operators and the quality of their work. It also constitutes a real fire hazard and its emission to outside atmosphere results in air pollution.[41] Respirable fine dust particles are dangerous for the lungs and can cause byssinosis. In most developed countries, there are legislations on level of cotton dust that can be generated. There are strict compliance through the installation of modern dedusting equipment. But in developing countries where manual feeding of the opening and cleaning line still operates, the operators are exposed to dust hazard. There is therefore the need, through legislation, to regulate, control, measure and resolve the problem of cotton dust.

Standardisation:

Standardisation can simply be defined as a process of specifying acceptable quality parameters of a consumer product, in consideration of the inherent properties of the local resources for its manufacture. The Standards Organisation is a statutory body aimed at protecting both the manufacturer to produce quality product and the consumer to have adequate value for his purchase. Each standard is drawn up by a techuical committee who represents the particular sector of the economy. In the processing of cotton from the lint stage to the finished fabric, many interests are involved and to ensure that these processes are carried out efficiently manufacturers use standard methods of test which relate to many essential items and stages including the construction of yarns and fabric, testing for fabric properties, choice of yarn and the type of finish.

Research centre, in its technical services activities, engage in testing and quality control of raw, intermediate and finished cotton products, and is therefore capable in participating in standard specifications and tests formulations. For textiles the majority of standards are methods of test although there are a few product specifications.

:) Establishment of Quality Control Procedures:

Quality Control (Q.C) can be defined as the operational techniques and the activities which sustain a quality of product and service that will satisfy a given need, and also the use of such techniques and activities. The aim of Q.C is to provide quality that is satisfactory, safe, adequate, dependable and economical.

A company which wants to remain competitive should therefore be concerned with control of Quality-procedures used routinely in the manufacturing process in an attempt to achieve uniformity of quality and prevent too many defective products; and improvement of Quality which pertains to procedures and techniques for achieving specific improvements in manufacturing processes where quality and production difficulties are apparent. In the establishment of Q.C. procedure consideration should be given to[42] -

(a) Control of Manufacturing Information

(b) Control of Procurement and Material stores

(c) Control of Manufacturing process

(d) Control of Finished product

(e) Control of Measuring Instruments and Test Equipment

(f) Control of Corrective Action.

The cotton processing industry consists of many segments as shown in ~~Table~~ Fig ONE. The quality control plan will defer in detail for each segment, but in establishing a Q.C. procedure some pertinent factors are common

- Place of Q.C. in the process (Control stations). The control charts are used to evaluate the need of control stations. For example the Shewhart statistical control chart of averages and ranges is used to detect signs of instability, aid in trouble shooting, detect changes in variability of the variable and detect changes in the average of the variable
- Properties to be controlled e.g. in cotton yarn - evenness, fineness, strength, hairiness are controllable.

- Frequency of control. The greater the possibility the variation of the parameter the more frequent test or controls are needed.
- Evaluation of results. The best visible evaluation method is to plot the results either in a X or R control chart.
- Spreading the result and feedback. This is precise, detailed, documented communication of results to relevant departments and management for action and feedback.
- Human factors and circumstances. Textile mill is labour intensive, and therefore there should be enough motivation for workers to do things right the first time.
- Economy of Q.C. The concepts of defect prevention and of doing any task correctly the first time will enable manufacturer to supply products to customers that conform to their requirements and also to minimize quality costs.

The organisation of the Q.C. system should be capable of selecting good products from the faulty ones and also carry out an economical quality control to assure the economic effectiveness of the company. The Q.C organisation in a cotton mill may be either limited to testing raw cotton, half products and outgoing products or it may cover all the elements of the production process. The demand on Q.C. in a cotton mill can only be met if there is understanding and effective communication between the general management and the quality department.

(d) Establishment of Process Control System

It is advantageous to develop process system concurrently with Q.C. system, as this approach will include both process and product specification.[43]

Complete process specification will include -

- A brief description of the process e.g. spinning
- List of machinery and their characteristics (card, comber, draw frame, fly frame and ring frame etc.).
- List of raw materials and referring standard of specification (cotton, effective length, mean length, % short fibre, etc.)
- Operating conditions, tolerances, maintenance schedule (temperature, relative humidity, daily, weekly, monthly maintenance)
- List of sequence of execution of process
- Tests, sampling, inspection, control stations, frequencies (in-process, raw material and yarn count)

A product specification include

- Production definition and use (cotton yarn, 14 tex for fine poplin shirt fabric)
- Product characteristics (finess, tensile strength, evenness)
- Out of limits activity (what should be done, to whom to report and the Q.C. staff entitled to stop production)
- Packaging instructions

There should be detailed control programmes concerning process and product. These include -

Name of control station (control station at the drying machine)

Property controlled (drying temperature)

Control frequency (hourly)

Person in charge (lab staff)

Method (description of the method or Number of Standard used).

(e) Technical Information

Provision of technical information is vital in Research and Development activities. It can create an invaluable pivot for effective co-operation among developing countries in technology development and dissemination. Moreover the provision of latest appropriate information from national and international sources will enable them to improve on their products and develop competitive ability for the export market. Provision of technical information should therefore focus on the use and application of knowledge concerning new products, raw materials, technologies, sources of energy, market prospects, management techniques etc, most of which, as a result of global development of science and technology and management techniques, undergo frequent changes and is scattered all over the world.[34]

As earlier emphasised, textile science and technology is a multi-faceted discipline. Neither the individual practitioners nor the single mills have access to all the existing information sources or can collect all the data they need. An industrial information division should therefore be an integral part of a research centre to collect, process, store and supply locally generated information and also serve as a viable link with international and other foreign information centres and data net-works, to collect data relevant to the industry. Both these locally generated and externally acquired information can be assembled to form a data base. Provision of technical information as an arm of technical services should therefore include Current Awareness Services, Technical Inquiry Services, Selective Dissemination of Information, Document Reproduction and Supply Service.

Current Awareness Services (CAS) should be aimed to keep users aware of latest developments, problems and problems-solving information as well as news in their fields of interest without their needing to scan the wide variety of information sources to get this information. CAS should be timely, right and relevant. It can be extended to include Selective Dissemination of Information (SDI) under which the information needs of subject specialists are noted and satisfied. Other services also include news about conferences, seminars, workshops at the research centre through a regular publication of Newsletter.

Exchange of information bulletin on new technologies, improvement on traditional technologies, as well as other results and findings achieved by the Research and Development activities of research centres, is another method of technology development and dissemination. Individual issues of the bulletin should be written in simple language, devoted solely to a particular theme and ready for commercialisation by prospective enterpreneurs who can thereafter request for a detailed report of the project.

Consulting is giving advice and providing counsel.[45] Consultancy can therefore be practised within the ambit of technical information because besides the professional skills of the consultants, the practitioners invariably have recourse to technical information to assess problems before they offer potential solutions either verbally or in writing. Advice can be given on any aspect of established project-spinning, weaving, finishing or new investment for example in the manufacture of mercerised yarn for sewing purposes. There is variation in industrial growth in developing countries, and as such there is a need for pre-investment studies[46,47] of the project to assess the overall viability of the project and to enable funding institutions or enterpreneurs to determine whether they are prepared to support it for commercialisation.

The information division will have to decide on the type of information storage and retrieval method that suits it best at any particular time bearing in mind the volume of information and data to be processed, the number of clients to be served and the type of information services to be offered. Small information centres can operate on the traditional methods of library catalogues and indexes but as volume of data and number of clients increase these traditional services have to be supplemented by acquisition of mechanical services such as Optical Coincidence Cards (Feature Cards). Both methods may be adequate for national and sub-regional services but to promote an effective co-operation among the developing countries in technology development and dissemination, computerised information storage and retrieval system may need to be employed.

This can be effected by:

(a) Agreement with established databanks which subscribe to various databases which can be searched on-line, subject to availability of necessary hardware and software together with good national and international telecommunication line. Databases on Textile Technology digest, World Textiles, Textile Patents & Trade Marks are already available.

(b) Suscription to available Compact Disc Read-only Memory (CD-ROM) for retrospective search on CD-ROM Reader.

(c) Creation of data bases on local textile technologies for network storage and retrieval using appropriate hardware, softwares and transmission line.

(f) Trouble Shooting:

This is the location and elimination of a source of trouble in a manufacturing process. Such remedial actions are possible in the processing and machine operations. Fabric faults are not readily redeemable, and this relegates the product as seconds. Examples of trouble shooting activities in cotton processing are the following:

Spinning: Soiling of yarn, fibre breakage, variation in lap weight, neppiness, hairiness, snarling, Unevenness-thick and thin places

Weaving: Barring, Crimp Variation, Warp and Weft Bow, End out, Float or Stitch.

Dyeing and Finishing: Unevenness, Poor Washing Fastness, Off-shade effect, Fibre Swelling, Fabric Shrinkage, Tailing.

In most cases, a thorough analysis of test results of the raw materials in each process, the control charts, and the expertise of the trouble shooter will help in fault identification and rectification.

3 EDUCATION AND TRAINING

Textiie Technology is a dynamic discipline which changes as fashion trends dictate. The practitioner should therefore be abreast of current developments.

The research centre should as a matter of policy encourage education and training for both its staff and textile personnel. Further training of staff will expose them to new frontiers of knowledge in their specialist field for better performance. This may be in form of participation in short-term conferences, exhibitions, or symposia on topical issues or a sabbatical attachment for a longer time to either perfect initiated processes hindered by lack of infrastructural facilities or acquire new technical know-how.

The entrepreneurs can best be intimated of new technologies, acquired or invented, through workshop training. This will facilitate their decision on commercialisation. Textile personnel are also to be trained to update their knowledge on improvement on specialised processes with a view to enhancing quality performance and increasing productivity. The local courses may be organised single handedly by the research centre or jointly with external instructors or institutions depending on the theme of the course and the availability of infrastructural facilities.

(a) Establishment of Management Training Programmes:

Establishment of management training programmes for example on (51,52) production control, labour utilisation and material flow will benefit cotton mill managers. The main objective of production control is to attain control and direction over product design, process design and material so that it can easily be decided where the products are made, how many products are made, when the products are made and how the products are made. Managing workers is more demanding for the entrepreneur than managing material resources and intangibles because human beings are dynamic; in labour utilisation for profitable operations, the entrepreneur has to consider the importance of communication, human relations, wage and remuneration and working conditions.

(b) Establishment of Specialised Technical Courses:

These are courses on strategic aspects of processing that need frequent updating arising from technological development. Such courses are run periodically.

The International Institute for Cotton (I.I.C.) annually organises five specialised training courses on cotton viz[53] -

Cotton Fibre Technology - Testing and Evaluation

Sizing and Weaving of Cotton Yarn

Cotton Knitting -

Recent Developments in Technology and Quality Control.

Wet Processing of Cotton Textiles

Cotton Textiles - Management Principles and Techniques.

The course-contents give an in-depth information on the science and technology of the topics and participation creates a forum for technology development and dissemination. These courses are only run in Britain. Such courses, if organised as regional projects would help to expand the trade in raw cotton and cotton textiles of cotton producing developing countries. I hope when proposals for such projects are put forward for assistance, the cooperation of the UNIDO will be assuring and the IIC would be ready to participate in the organisation and nurture the project to maturity.

Other specialised technical courses of urgent importance to the versatile exploitation of cotton are:-

Water analysis and treatment

Energy utilisation and conservation

Textile working hazards

Textile testing and quality control.

(c) Organisation of Overseas Training Programmes:

The developed countries are much ahead in terms of availability of experts and research equipment and machinery for cotton processing. The developing countries should therefore avail themselves of such opportunities to improve basic knowledge and skills of technical personnel and to develop specialised expertise in various fields.

Improvement in textile technology is a global problem, hence developing countries should maintain a close linkage in terms of research, exchange of information and undertaking of joint projects to solve a common problem.

Cotton Research Institutions and associations abound in Europe and U.S.A., and it is gratifying to note that, among the developing countries, renowned cotton research associations are already established in India and Pakistan.

It is possible, if the government is involved in the management of the centre, to seek financial assistance through fellowship awards from international organisations. An exchange programme between the research centre and the host overseas centre can also be arranged whereby on periodic basis, staff members can be interchanged on attachment and to undertake special research duties. The research centre can on its own sponsor its staff for short specialised courses or for higher degrees in areas of research where crucial development is desirable.

(d) <u>Establishment of Links Between Research Centres and Technical Colleges and Textile Departments of Universities</u>:

The main objectives that are achievable from a link between research centre and allied establishments are the provision of consultancy services, conduct of training courses and carrying out of applied research.

Research centres should cooperate with Technical colleges and Textile departments of universities to fulfil these objectives. Textile equipment and machinery are as varied as the disciplinary composition of textiles. The sharing of sophisticated equipment and technical expertise will benefit both parties. It is possible, by special arrangement, for research centres to organise and supervise courses and industrial projects in which the colleges lack qualified personnel. The College graduates will thereafter be better prepared for attachment to industries. Collaborative research project can also be executed between a University Department and the research centre to achieve an enviable goal, for example, cotton breeding research in a University can be successfully monitored by the research centre through application of appropriate tests. A bilateral arrangement whereby graduate students in universities can spend part of their research period in research centres will foster applied research.

ADAPTATION OF TECHNOLOGY

The textile industry in developing countries by and large, have total dependence on imports for vital spare parts for the cotton processing machinery. This cannot continue if these countries are to have maximum exploitation of cotton. Developing countries should not hesitate to collaborate and borrow technology from the developed world in order to develop indigenous industry, but this collaboration as the first should not be the last step in their technological growth. According to Sreenivasan,[54] collaboration is not a substitute for Research and Development. The best option might be to adopt the Japanese approach to industrialisation.

- Collaboration with foreign manufacturer to make a new machine
- Start research on the machine
- Modify and improve it
- Come out with better product even purchaseable by the original collaborator.

A clear advantage of this approach can be cited in the development of modern spinning machines. Japan bought the patent from Czechoslovakia for open-end spinning machine,[55] and in less than 14 years, Japan was able in 1981 to develop the air jet spinning machine. India has been able to make foreign models under licence, and through such collaboration agreements it is now able to meet 90% of her machinery requirements locally, and recently able to turn out an indigeneous ring frame.

As previously enunciated, cooperative Research and Development set up might be more advantageous to the developing nations. Co-operative research at the local level has rarely been successful in developing a patentable and highly successful process because of ownership struggle. Each manufacturer wants something original, something better than what his competitors have, and would prefer to keep it confidential until the development is patented and marketed. For the time being, research centres should have well equipped foundry facilities for the fabrication of spare parts for refurbishing the existing machinery. Research centres in the developing countries could go into more detailed machinery development when they mature into a self sustaining status of the type of Shirley Institute.

Research and Development activities are capital-intensive, and therefore should be directed to a goal where information are not available. This underscores the importance of technical information in the research centres. Trends in cotton processing technology are usually highlighted at International Textile Machinery Association (ITMA) exhibitionsand the biennial International Cotton Conferencesin Bremen. Cost-benefit analyses of carefully selected new processes or machines could be undertaken in order to assess their importance to the local industry. A case in point is the several techniques patented under trade names for fabric improvement for example -

Proban and Pyrovatex for flame retardant finish

Koratron. Sanfor set for easy care finish.

Zepel Cerol and Perlit for water repellent finish

Sanforization to produce dimentional stability through corpressive shrinkage technique.

Scotchgard, which is a fluorosilicone fabric protector which makes fabric resistant to oil, water and dry soiling, and IIC's STARFISH programme on knitwears to be able to attain uniformity of cotton knitwears with acceptable shrinkage.

Others in machinery utilisation is the IIC-Shirley Fineness Maturity Tester which is acclaimed to give unbiased maturity evaluation; and the Open-end Rotor which is capable of producing coarser yarns than Ring Spinning. If the cost-benefit study of a new process or machine indicates commercial viability, a technical evaluation of the new development should be undertaken, taking into account the local conditions and needs. Such a study would normally mean the acquisition of the new equipment or the setting up of a simple process line in the centre. Once the study has been completed, mill representatives can be invited to examine and evaluate the new system for their own particular requirements.

SUMMARY

Research Institutes in Developing countries can play a prominent role in the versatile exploitation of cotton through an aggressive programme on fibre and fabric development, waste and seed utilisation, supplemented by other auxiliaries activities in technical services, education and training, which are capable of forging effective cooperation among them in Technology Development and Dissemination. The countries should therefore, through research, be able to exploit their basic resources, their abilities in terms of improving their returns and income from cotton. Increase in yield, product and quality and development work aimed at improving the competitiveness and extend the range of cotton products should be the preoccupation of research centres in the developing countries.

FIGURE 1: FLOW CHART FOR COTTON PROCESSING

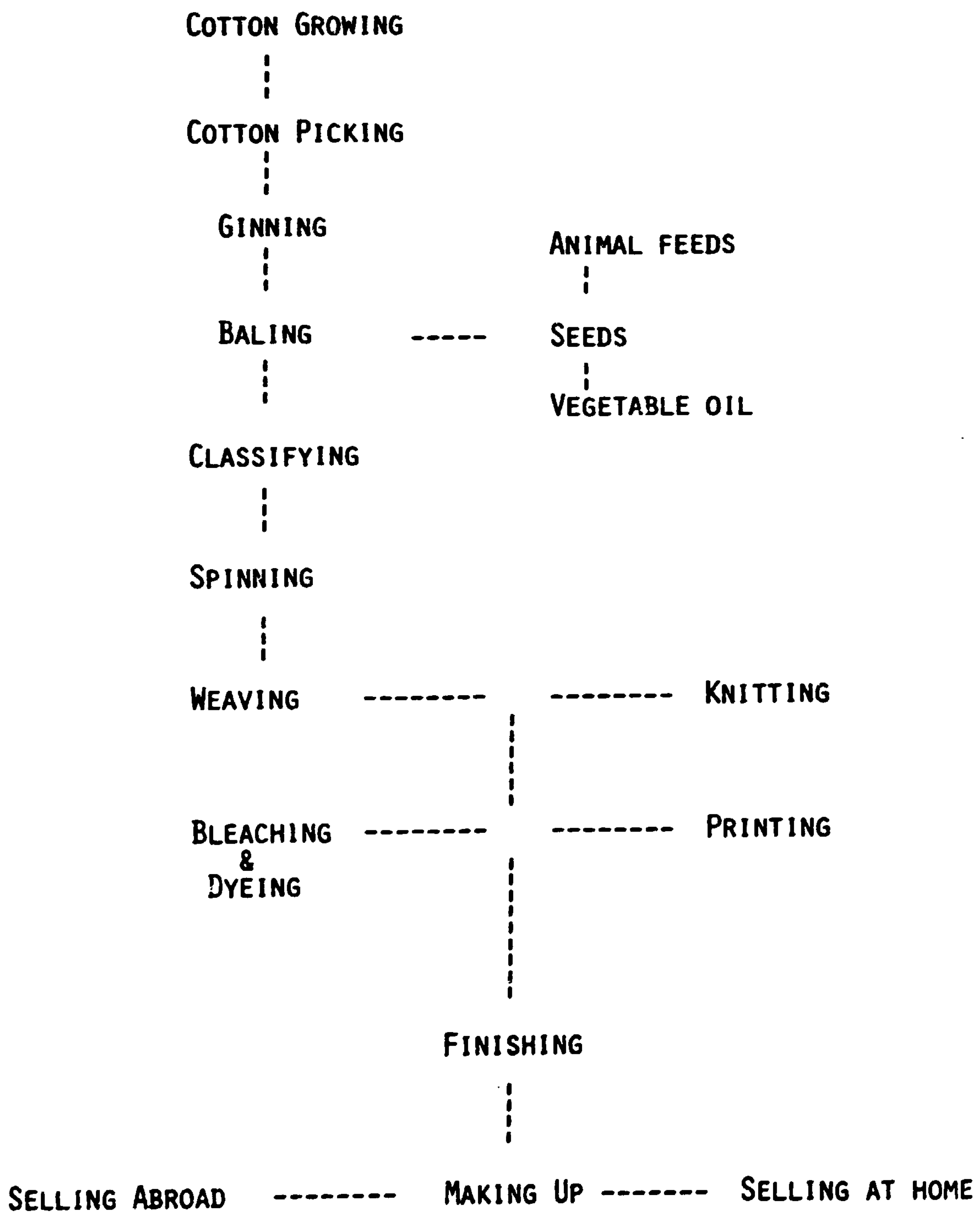

TABLE 1: WORLD COTTON PRODUCTION ANALYSIS 1984/85

	Cultivated Area (1000 ha)	Production (1000 ton)	Average Yield (kg/ha)	Potential Arable Land Resources (mha)
China	6900	6075	730	N/A
U S S R	3338	2537	784	270
U S A	4233	2894	684	N/A
India	7402	1428	193	N/A
Latin America	4055	1827		570
Asia/Oceania	11570	3678	318	735
Africa	3656	1201	329	N/A
WORLD	33954	18423	492	2944

Compiled from: [1] Cotton World Statistics, ICAC ,Quarterly Bulletin, Washington.

[2] Study and Trends in World Supply and Demand of Major Agricultural Commodities, OECD Paris 1976.

TABLE 2: WORLD PRODUCTION OF DIFFERENT COTTON STAPLE 1984/85

Staple Type	Length (mm)	Production 1000 bales	% of World Production	Major Producing Countries
SHORT	Under 20.6	831	1.5	Afro Asian Countries
MEDIUM	20.6 - 25.4	10,065	18.1	Afro Asian Countries Latin America
MEDIUM-LONG	26.2 - 27.8	32,018	57.7	Peru, Greece
LONG	28.6 - 33.3	9,539	17.1	USSR, India, USA Egypt, Peru, Sudan
EXTRA-LONG	34.7 and above	3,050	5.6	USSR, USA, India Egypt, Peru

SOURCE: ICAC ,Wahington DC ,USA.

TABLE 3: Effluents in a Cotton Processing Mill

Process	Pollutants	Characteristics
Desizing	Starch	HighBOD, high total solids
Scouring	Caustic soda, soap Colour, Detergent	HighBOD, high alkalinity, high Total solids, high Temp
Bleaching	Toxic Chlorites Caustic soda	HighBOD, Alkaline, high solids
Mercerisation	Caustic soda	LowBOD, alkaline, Low solids
Dyeing and Printing	Dyes, Colour Pigments, Thickners.	HighBOD, High solids, neutral to alkaline, Coloured
Finishes		Low pH.

REFERENCES

1. K. Screenivasan: Textile Horizons 5/2 29 1985
2. Majeed A, Yunus M: Textile Horizons 5/2 32 1985
3. Majeed A, Yunus M: Textile Horizons 2/5 21 1982
4. S. C. O. Ugbolue: Textile Horizons 11/12 32 1982
5. International Institute for Cotton: Programme for a National Textile Centre
6. H. M. Taylor: Textiles 1979 pp 64
7. M. A. Taylor: Technology of Textile Properties, 2nd Ed, Forbes Pub Ltd, London 1985
8. Cotton Technology 3/84 Aug 1984
9. Aladeselu I.: Technological Improvement of Traditional Indigo Dyeing in Nigeria
10. Aladeselu I & Balogun M.D.: Improvement in Traditional Weaving Technology.
11. Joanne B. Eicher: Nigerian Handcrafted Textiles, Univ. of Ife, Nigeria, 1976.
12. Dougal Pleasance: Textile Horizons 5/6 21 1985
13. Julius Grant et al, Paper & Board Manufacturing, 3rd Ed. 1978, British Paper & Board Industry Federation.
14. James Casey: Pulp & Paper, 2nd Ed. 1960, Intersci Pub. N. York.
15. Bjoorn E. O. Woodpulp 1st Ed. 1954, Ab Svensk Travaru-Tidning, Sweden.
16. A. J. Turner: J. Text. Inst. 40 973 1949
17. High Polymers 2nd Ed. Vol.5: Cellulose and Cellulose Devivatives Parts 1-IV, Intersci N.Y. 1954.
18. R. L. Davidson (ed): Handbook of Water Soluble Gums & Resins, McGraw Hill 1980.
19. Ullmann Encyclopedia of Industrial Chemistry 3rd Ed, 1987ff
20. H. Temming, H. Grunert: Temming Linters, 2nd Ed. 1972, P. Temming Gluckstadt
21. Buffel M.: Cotton et Fibres Tropicales Vol.XXXIV Fasc 2, 1979.
22. KhannaP, Garcha H.S: Utilisation of Paddy Straw for the cultivation of Pleurotus spp - Mushroom Newsletter for the Tropics 2(3) 5-9 1982
23. N. O. Banjo: FIIRO, Private Communication
24. S. A. Heap: Melliand Textilberichte 61 1980
25. A Humberston: Textile Month Feb 1980
26. African Textiles June/July 1987 pp7
27. M. Afzal & I Afzal Textile Horizons 5/2 36 1985 - Packaging, Ginning.
28. M. Afzal & S. Ahmad: Textile Horizons 5/11 32 1985 - Cotton Production.

29. M. Afzal & S. Ahmad: Textile Horizons 5/10 34 1985 - World Cotton

30. Jean Canquil Tex. Horizons 4/10 38 1984

31. African Textiles, April/May 1988

32. First IIC Cotton Breader/User Conference, Manchester July, 1970.

33. H. M. Taylor: Textiles 1979 pp 64

34. M. A. Taylor: Technology of Textile Properties

35. Cotton Technology 3/84 Aug. 1984 - Starfish

36. E. Lord - The Characteristics of Raw Cotton Vol.II Part 1 - Manual of cotton spinning Coulson A.F. & Tordoff M (Eds), The Textile Institute 1961.

37. J. E. Booth: Principles of Textile Testing Newness - Butterworths, London 1979.

38. Water Quality Requirements and Waste Water Recycling in the UK Textile Industry: Textile Research Council Publications, 1978.

39. Nemerous N. L.: Liquid Waste of Industry - Theories, Practices and Treatment, Addison - Wesley Pub. Co., 1971.

40. C. M. Reed: Textiles, 1982 Vol.11 No. 2

41. The Working Environment in the Textile Industry - Dust in the Cotton & Allied Fibres Sector: Shirley Institute.

42. J. M. Juran et al: Quality Control Handbook, 3rd Edition McGraw Hill.

43. Davies O. L. & Goldsmith P. L.: Statistical Methods in Research and Production, Longman 4th Ed. 1980.

44. Introducing FIIRO Indices: FIIRO 1987

45. Ron Tepper: Become a Top Consultant - How the Experts do it: John Wiley & Sons, N.Y. 1985.

46. Manual for the Preparation of Industrial Feasibility Studies.

47. A. D. Harverd: The Evaluation of Investment Proposals - Project Appraisal Checklists for the Textile Industry: The Textile Institute 1983.

48. European Space Research Agency Information Retrieval Services.

49. Dualog Information Retrieval Services.

50. Dow Jones News - Retrieval Tests-Search Services.

51. Smolik D. P.: Material Requirements of Manufacturing Van Nostrand, 1983.

52. Jooley D. F.: Production Control Systems and Records 2nd Edition, Gower Pub. Co., 1981.

53. International Institute for Cotton: Specialised Training Courses Cotton Technology. 5/86 1986.

54. K. Screenivasen Textile Horizons 6/2 1986.

55. H. Deussen & L. Neuhaus: ITS Textile Leader No. 1
May 1988 pp. 5

56. Cotton Technology 3/82 July 1982 - Proban.