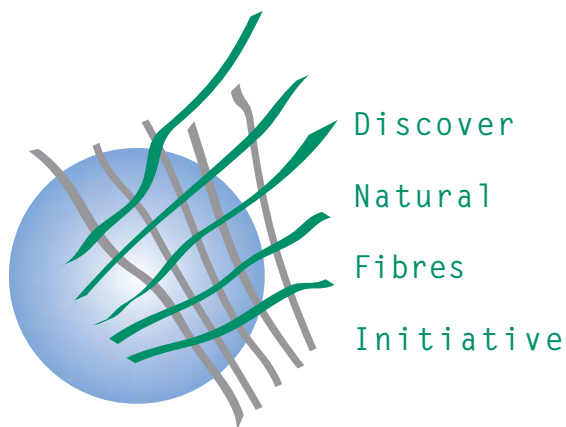




THE ICAC RECORDER

International
Cotton
Advisory
Committee

Technical
Information Section

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Update on Cotton
Production Research

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Introduction

The world yield for 2009/10 is estimated at 726 kg/ha, 41 kg/ha less than in 2008/09. Yields in 2010/11 are expected to improve to about 759 kg/ha. The record yield of 797 kg/ha was achieved in 2007/08. Recent performance seems to indicate that cotton has entered into a period of no growth or slow growth in yields. Similar periods of stagnation occurred in the past, most recently during the 1990s. However, each period of stagnation has ended with the development of a new technology that boosted yields to a new level of potential.

Increases in production are achieved either by expanding area or by increasing yields. Cotton and other crops compete with each other, and world cotton area has remained level within a range between 29 million and 36 million hectares since the 1950s. Therefore, all the increase in world cotton production over the last six decades has come from increases in yields through the application of new cotton technologies.

Cotton is prone to stress, especially from insects and weeds. Biotechnological advances may be able to tackle this pressure. Agronomic practices have been improved and adopted in consonance with the demands of local growing conditions. Nevertheless, constraints will always exist. With the world yield having reached a new plateau of about 770 kilograms per hectare, a new breakthrough technology capable of improving yields across countries and regions in a sustainable manner is needed. While numerous concepts are under developments, it is not known when a new breakthrough technology will surface. The first article entitled 'Cotton Yields: Once Again Reached a Plateau' discusses the implications of little or no gain in the world yield in coming years.

The second article is on cotton breeding in the USA. In the U.S., as well as in all other countries, cotton breeding started conventionally without taking into consideration the hereditary basis of specific traits. Early breeders knew that heredity was more important than environment in affecting plant growth and yields, but they still relied on phenotypic breeding until Mendel's laws were discovered. The science of genetics converted phenotypic breeding into classical breeding based on certain principles and not just on phenotypic expressions.

There are 20 public sector breeders in the U.S. engaged in the development of elite germplasm. Fifteen teams are located at state universities, while five belong to the U.S. Department of Agriculture (USDA). Each breeder follows his/her own methodology to induct heterozygosity, screen segregating generations (as a single plant or in bulk populations), select desirable plants (based on breeding objectives), develop a homozygous (at least phenotypically) population, test promising genotypes/lines/strains against standard varieties and decide which genotypes to put forward for registration as germplasm or release as a variety (in the case of private breeders). A procedure followed by Dr. Fred M. Bourland of the University of Arkansas, Keiser, Arkansas is described in detail. Dr. Bourland is the 'ICAC Cotton Researcher of the Year 2010.' A lot of breeding work is also going on in the private sector; only private seed companies release commercial biotech varieties.

Advocates of cotton extol the advantages of cotton over products made of chemical fibers. The third article 'Why Natural Fibers are Better than Synthetic Fibers in Clothing: Scientific Basis,' contributed by Dr. Malgorzata Zimniewska of the Institute of Natural Fibres and Medicinal Plants, Poland, provides scientific evidence of why cotton is better than chemical fibers in clothing applications. Dr. Zimniewska conducted trials on two groups of people wearing natural and polyester apparel. Her tests demonstrated that the forearm muscles of test subjects wearing polyester clothes exhibited changes in the pattern of motor unit activity. She observed fluctuations in the test subjects wearing polyester were the result of desynchronization in muscle motor units that may lead to fatigue. Another test conducted by Dr. Zimniewska demonstrated that subjects wearing garments made of chemical fibers experienced greater oxidative stress. Consequently, there are more allergies observed among people who use textile products made from chemical fibers. Dr. Zimniewska also found that chemical and natural fibers in bed linen have dramatically different physiological effects on the human body.

World Cotton Research Conference-5

The World Cotton Research Conference-5 will be held in Mumbai, India, from November 7-11, 2011. Pre-registration is available online only. Pre-registration is free, and only those who are pre-registered will receive the full registration package for the WCRC-5. Additional information and pre-registration are available at <http://www.icac.org/meetings/wcrc/wcrc5/english.html>.

Cost of Production of Cotton

The Technical Information Section undertakes a survey of the cost of production of raw cotton every three years. The latest report containing data for 2009/10 has been published. The report contains data from 34 countries and can be purchased from the ICAC at publications@icac.org. The data include cost of individual inputs and operations, including harvesting and ginning. The report also provides information on value

of seedcotton, lint and seed for calculating the net cost of production of seedcotton and lint per kilogram.

ICAC Publishes a New Book

Six years after the publication of the book *Cotton Facts*, the Secretariat has published a new book *Cotton: Technology for the 21st Century*. The book has 16 chapters, each contributed by highly respected and internationally recognized authors from across the world. The book begins with the origin of the cotton species and ends with a provocative look at how world production and demand may change in the 21st century. The overall approach in the book is not to provide information on work already done, but instead the book is devoted to future trends in ever-changing cotton production technology and research. Pest control, sustainability, biotechnology, fiber quality measurements, yarn processing and dyeing/finishing form substantial parts of the book. The book can be ordered at publications@icac.org.

Cotton Yields: Once Again Reached a Plateau

Cotton yields vary among regions within a country, across countries and among regions in the world. The highest yields are achieved in Australia where, on three occasions during the last five years, the national yield was over two tons of lint per hectare. Israel had been the highest-yielding country in the world for many decades until 2000/01, year after year with few exceptions, but now it ranks second in productivity globally. Some of the world's producing regions consistently produce higher yields compared to others, despite the fact that research on cotton may be more advanced in comparatively lower-yielding countries or regions. Variation in yields among neighboring countries support the contention that production conditions override genetic factors in determining higher yields. The genetic capability to produce higher yields, in consonance with input use and production technology, becomes a factor only after yields have reached a certain base level. Cotton yields in the world have reached a plateau, and it will take the development of a new technology to regain the past momentum.

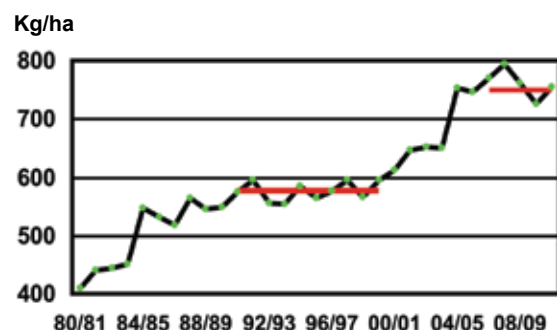
World Average Yields

The most recent ICAC estimates indicate that the world average yield for 2009/10 will be 726 kg/ha, that is, 41 kg/ha less than in 2008/09. The ICAC is expecting that the 2010/11 yield will improve to about 759 kg/ha. So far, the highest world yield ever was 797 kg/ha in 2007/08. Taken in the context of the yields actually achieved since, it would seem that cotton yields in 2007/08 were exceptionally high and that a more realistic potential, given current varieties and production technology, would be in the vicinity of 750 kg/ha. The latest trend in

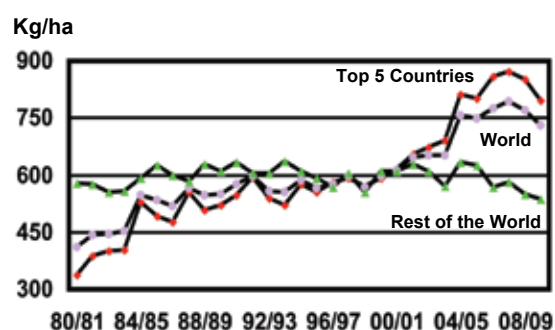
world yields indicates that cotton has entered into a period of no growth or slow growth in yields. The current situation is similar to what the cotton industry faced as in the early 1990s when the world yield varied only slightly and hovered around 570 kg/ha until 2000/01, the year when they finally broke the 600kg/ha barrier. In the mid-1990s, it was biotechnology, in the form of insect-resistant and herbicide-tolerant varieties that came to the rescue, and in the first decade of the 21st century, after 11 years of stagnation, cotton yields started to increase. How long the current period of slow growth or stagnation will last is uncertain, but there have been similar stagnations in the past and after varying periods, technological innovation stepped in to help push yields up again. Afzal (1986) discussed crop yields at length in his book *Narratio Botanica* and he also talked about the contribution of biochemistry to the improvement of yields long before the introduction of biotech cottons. The current view is that the only apparent route to improved yields would seem to be biochemical breakthroughs in the form of new biotech cottons. However, there does not seem to be any such breakthrough coming to maturity in the next few years to boost the trend in world cotton yields.

World yields between the early 1950s and 1991/92 increased at a rate of 2%, or 8 kg/ha per year. Extending the period to the current stage would have the effect of averaging out the stagnation period indicated in the chart in the next page. The impact on yields during the 1980s was the result of the adoption of insecticides in many countries, a movement that started earlier but gained momentum during 1970s. Yield increases continued for many years because countries were slow in adopting the new technologies. Biotech cotton has

WORLD COTTON YIELDS



LONG TERM TREND IN COTTON YIELDS



proved to be one of the fastest technologies to be adopted in the history of agriculture, and that is why the impetus from the adoption of biotechnology has slowed in a comparatively short time. Long-term world yield data show that there were other periods of slow growth, or even of no growth, prior to the adoption of insecticides. What has changed now is that the adoption of fertilizers and insecticides, the development of higher harvest index varieties and of biotech cotton have increased the response to emerging technologies. Any new technology capable of producing better performance data, whenever it is developed, will be adopted rather quickly and, as before, the new momentum will be spent in a short period of time. With the potential to minimize the insecticide use, and despite apprehensions about the technology itself, biotech cotton fits perfectly into the history of agricultural technology advance.

Yield Impacts in Five Major Countries

The top five cotton producing countries, China, USA, India, Pakistan and Brazil, have a major impact on world average yields. These five countries, whose average combined yield was less than the world average until 2000/01, accounted for 75% of world cotton area in 2009/10. The following chart shows that the average yield of the rest of the world, a total of more than 75 countries, has almost never surpassed or remained over 600kg/ha lint for any sustained period of time. Seasonal variation is apparent in the five major cotton-producing countries, as well as in the rest of the world's cotton producers. The following chart shows that all the increases in world average yields have been driven by increases in yields in the top five producing countries. However, the declining trend in world average yields over the last three years is a cumulative effect of the top five cotton producers, together with those of the rest of the world's cotton producers. Cotton yields started to decline in the rest of the cotton producing countries three years earlier than in the top five. Each of the countries in the top five has commercialized biotech cotton, and most of the cotton in these countries, is produced with

biotech varieties. There does not seem to be any single factor capable of boosting yields in these five countries over the next few years. The same may be said about the rest of the world's cotton producers, five of which have commercialized biotech cotton, most with no apparent impact on yields.

Prior to the introduction of biotech cotton, yields increased as a result of eliminating or minimizing the effects of a given yield-limiting factor. Whenever a yield-limiting factor is removed, yields increase. Yield-limiting factors may be intrinsic to the plant itself or external (such as nutrient deficiency, insect damage, etc.). Cotton breeders resolved the intrinsic factors by developing varieties capable of producing higher yields under a given set of production conditions and by developing early-maturing, short-stature varieties. There were a number of inherent limitations, such as photorespiration, that were beyond the control of researchers and still remain unresolved. External limitations, such as nutrition deficiency, were resolved so successfully that the cost-benefit ratios from new technologies were many times higher than the benefits derived from the removal of other constraints. Biotech cotton was not a solution to a yield-limiting factor, and that is why it did not increase yields in all the countries where it was adopted on a commercial scale. In those countries where biotech cotton had no positive impact on yields, benefits may have accrued in the form of lower costs. However, the environmental benefit afforded by insect-resistant biotech cotton is wherever it is used. With respect to further increases in yields, it may safely be said that fine tuning the use of available technologies will continue to have a beneficial impact on yields in the five largest producing countries and in the rest of the world's cotton producers, but future improvements will not be enough to produce increases in the world yield anywhere close to 2% per year.

Average Yields by Region

Some countries continue to produce higher yields than others for a number of reasons: better research, growing conditions comparatively better suited to cotton, lack of abiotic stresses, and more accurate implementation of the technologies

Average yield in Neighboring Countries – 2008/09

Region/countries	Yield (Kg/ha)
North America	
Mexico	1,235
USA	911
South America	
Argentina	404
Brazil	1,446
Central Asia	
Kazakhstan	562
Uzbekistan	769
Asia	
China	1,27
India	526
Pakistan	688
West Africa	
Burkina Faso	390
Mali	429

recommended for producing higher yields. It has also been noted that cotton yields vary greatly across borders. In the above table, there are some examples of the significant differences that may exist between countries with common borders.

The table above shows that differences in cotton yields in neighboring countries may be in the order of as much as 30%, except in West Africa, where yields in Mali are 10% greater than in Burkina Faso. The latest data from these countries indicate that the difference in yields between Mali and Burkina Faso will be 5% in 2009/10.

Brazil accounts for over 60% of the total cotton area in South America. Cotton yields increased in almost all countries in South America during the last three decades, and the yield for 2009/10 in South America will be equal to the yield in the highest region for the first time in decades; the highest region includes Iran, Iraq, Israel, Syria and Turkey.

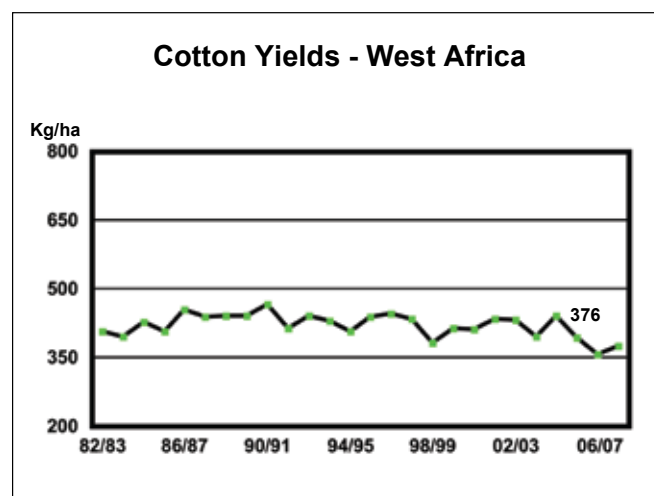
Cotton yields in the Southern African countries have increased very little, if at all, in the last twenty some-odd years. Southern Africa is also the lowest yielding region in the world. There are many factors responsible for the lower yields in the region, with poor input supply and lack of effective technology dissemination heading the list of factors possibly responsible for lower yields in Southern Africa.

Cotton yields started to decline in the countries of the former Soviet Union as they transited to independence after 1991. The main reasons given to explain that drop have been: disruption of the input supply system, distribution of land to the private sector and slower development of production technologies. This region has the potential to achieve higher yields, and yields may yet recover if the current constraints on the production system are taken care off.

The countries of West Africa have not had increases in their cotton yields in over 25 years. The initial impact of synthetic fertilizers seems to have dissipated as a result of a failure in coping with the problem of deteriorating soil fertility. The

countries are beginning to come to grips with this realization and are reverting to organic fertilizers. Their varieties are known to be high yielding, they have one of the highest ginning out-turn ratios in the world, and together they have successfully tackled the crucial problem of bollworm resistance to insecticides. Production conditions in the region are similar, and developments in one country can benefit most of the other countries in the region. Burkina Faso commercialized biotech cotton in 2008/09, and an increase in yields is expected. It is estimated that about 30% of the area in Burkina Faso was planted to biotech varieties in 2009/10, but there was no impact on the national average yield because of draught. Since yields in West and Central Africa have not increased in a long time, there is a high-unrealized potential for regional improvement. The first step in that direction, however, would be to identify the limitations and start working on possible solutions, one by one. The limiting factors in the West and Central African regions are not new, and it would be useful to conduct trials to quantify the relative weight of each limiting factor to be able to formulate recommendations and assign resources effectively.

Among the countries of Southern Asia, India has achieved the greatest gains in yields since 2002/03. Many factors contributed to the increase, including the adoption of insect-resistant biotech cotton. However, it seems that for the time being cotton yields in India have reached a plateau, and the country is looking at ways to recover the pace of recent gains in yields, but there do not seem to be any easy options. Pakistan more than doubled cotton yields between 1981/82 and 1991/92. Since 1992/93, Pakistan has been struggling to maintain yields in the face of severe attacks, first by the leaf curl virus disease and more recently by the mealy bug. Pakistan seems to have overcome the leaf curl virus disease caused by Gemini viruses, thanks to its strong breeding program. The latest reports suggest that Pakistan has also had the good luck to find a parasitoid capable of controlling the mealy bug. Both pests have been contained, but not eliminated, and that is why cotton yields continue to vary drastically from year to year.



No sustained increasing trend is expected in Pakistan's cotton yields unless the damage caused by leaf curl virus disease and the mealy bug are eliminated.

Biotech cotton resistant to bollworm has finally been officially approved, and the Government of Pakistan has also signed a memorandum of understanding with Monsanto to test stacked gene biotech varieties. It is hoped that those varieties will be resistant to the leaf curl virus disease and that they will bring the mealy bug under better control, but if they do not succeed, biotech varieties may not have any impact on yields. Judging from yield increases in neighboring India since 2002/03, hopes have been running high, but there is no way that similar increases could be achieved in Pakistan. The reason is the same as the one mentioned above: biotech cotton does not eliminate a constraint, but instead it is a substitution of one method of insect control with a different, environmentally friendly, method of insect control.

Consequences of the Lack of Increases in Yields

Based on previous trends and on the current situation, it seems that the period of slow growth in world average yields will last at least a few more years. As has already been mentioned, further progress in the adoption of technologies already available to producing countries might sustain some countries from year to year despite unfavorable circumstances. In others, it might push the average up slightly if supported by favorable weather conditions. In the event that cotton producers fail to maintain the momentum achieved as of 2000/01 for a goodly number of years, many aspects of cotton production and marketing will have to change. In some cases, the impact could be significant enough to inadvertently drive research down new avenues.

- Cost of production per hectare continues to rise because of increases in the cost of inputs. However, if production costs are compensated by increases in yields, then ultimately the cost per kilogram of cotton will remain stable. On the other hand, a lack of increases in yields will push up the cost of production per kilogram of lint.
- Farmers' net income from cotton will be affected by continued increases in the cost of production without any corresponding increases in yields. Consequently, farmers' motivations to lower the cost of production will tend to take precedence over the ambition to increase yields. The result would be a situation similar to the one prevailing in the 1990s.
- Emphasis on sustainable methods of production could continue increasing. Researchers (breeders) are already doing their best to produce varieties with higher yields. It is quite possible that breeders will increase their emphasis on better quality. However, farmers in countries where they sell lint are going to increase their focus on fiber quality so that they can earn more money for the same amount of lint.

- In many countries, cotton producers contribute funds, in one way or another, for production research. In a few countries, contributions from growers are matched by their respective governments. Countries where contributions for cotton research are based on cotton production may actually have to deal with reduced budgets. Having exhausted the possibilities of traditional approaches to the improvement of productivity, people will increasingly shift their emphasis to non-traditional research. On the other hand, if biotech research succeeds in making breakthroughs in yields, it might get greater attention from policy makers.
- If yields do not increase and cotton area remains stable, production is going to stagnate around the current production level of 24-25 million tons. In this situation, increases in demand could push cotton prices higher. Higher prices would cause cotton's share of fiber use to decline.
- Higher cotton prices would affect international trade and cotton consumption in many ways. With respect to subsidies, higher prices will minimize direct payments to cotton growers, wherever they are made now.

A New Approach to Improve Yields

In the USA, researchers from the Agricultural Research Service (ARS) of the US Department of Agriculture have found that a naturally occurring class of plant hormones called cytokinins can help increase cotton yields during drought conditions. It is already known that cytokinins are a class of plant growth hormones that promote cell division, or cytokinesis, in plant roots and shoots. They are primarily involved in cell growth and differentiation, but also affect apical dominance, axillary bud growth, and leaf senescence. According to Campbell *et al.* (2008) cytokinins are involved in many plant processes, including cell division and shoot and root morphogenesis. In particular, they are known to regulate axillary bud growth as well as affect apical dominance. These effects are a result of the cytokinin to auxin ratio, which Campbell *et al.* (2008) termed the direct inhibition hypothesis. This theory states that the auxin, originating in the apical bud, travels down shoots to inhibit axillary bud growth. This, in turn, promotes shoot growth, and restricts lateral branching. During the process, cytokinin moves from the roots and into the shoots, eventually signaling lateral bud growth. When the apical bud—the major source of auxin—is removed, the axillary buds are liberated from inhibition. This allows the plant increased lateral growth, making the plant bushier.

In cotton, cytokinins stimulate the growth of the main plant stem and branches. Dr. John Burke, director of the Cropping Systems Research Laboratory, Agriculture Research Service of the USDA, Lubbock, Texas, found that applying cytokinins to cotton crops could increase yields in water-limited environments with reduced or no irrigation. About half the cotton produced in the USA is grown in the arid high plains

of Texas. Commercially produced cytokinins are routinely applied in apple and pistachio orchards to promote fruit growth. Young cotton seedlings have small root systems, making it difficult for them to reach available soil water. Cytokinins trick the young plant's water stress defenses, prompting it to quickly build a bigger root system to access deep soil moisture. Cytokinins also stimulate the growth of a protective wax on the surface of the plant that helps reduce water loss. The experiments conducted by Dr. Burke and his team concluded that one application of cytokinins produced a 5-10% increase in yields under water-limited conditions. Additionally, tests determined that cytokinins neither helped nor hinder yields under fully irrigated or rainy conditions, making it safe for use in all weather environments. There is also no extra work involved for the grower because cytokinins can be applied when conducting normal weed-management practices early in the season. To be effective, cytokinins should be applied at a relatively low concentration to cotton seeds or to cotton plants at an early stage of development. The report listed in the references below says that the Agriculture Research Service is working closely with commercial companies to make this material available to cotton growers in the future.

Similarly some other chemicals have been tried. One such chemical, which is already registered for use on cotton, is called plant health regulator. It is based on harpin, a protein occurring naturally in numerous plant pathogenic bacteria. It is claimed that the harpin protein triggers the plant's natural defense mechanisms. The plant growth regulator activates genes that influence cell growth, flower initiation, fruit set and size. As a consequence photosynthesis, root biomass, nutrient uptake and plant health are significantly improved. While all the effects are reported to improve yields, trials have also revealed a beneficial effect in suppressing nematode reproduction on cotton roots. Some improved versions contain active components from more than one harpin protein, thus improving the efficacy of application.

Conclusions

Increased cotton production may be achieved either by expanding planted area or by increasing production per unit area. Cotton faces economic competition from other crops, which constrain increases in planted areas. The best option for increasing world cotton production is to increase productivity per unit area by applying new cotton technologies that may be biotechnological, chemical or of any other sort. Cotton is prone to external stresses. The greatest threat is from insects and weeds. Biotechnological advances maybe able to tackle this pressure. Agronomic practices have been improved and adopted in consonance with the demands of local growing conditions. Certain constraints will always exist. What is needed is a breakthrough or a technology capable of improving yields across countries and regions in a sustainable manner. The options are there, but exactly when this technology will surface is not known.

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Cotton Breeding in the USA

Breeding has played a greater role in cotton development, bigger than any other discipline, and this is so in the USA also. Breeding can rightly be called the hub around which all other disciplines revolve in order for cotton to progress. Cotton breeding reached maturity earlier in the U.S. than in other countries, and breeding in the U.S. experienced many stages before reaching the current level. One reason the U.S. has led in cotton breeding is because a large share of world production has been in the U.S. According to Kearney (1909) of the US Department of Agriculture, U.S. cotton production in 1908 was estimated at almost 3 million tons, and all other cotton producing countries accounted for 1.8 million tons. Hence the U.S. produced 62% of the world total. Kearney (1909) also estimated that the total value of cotton fiber and seed produced in 1909 was US\$840 million. About 70% of

U.S. production was exported in 1909 thus providing raw material to almost half of the textile industry outside the USA. The size and value of cotton early in the 1900s made cotton the most important field of research for breeders. This article discusses the evolution of cotton breeding in the U.S. and what the current procedure is to develop varieties.

Conventional Breeding

In the U.S., as well as in all other countries, cotton breeding started conventionally without taking into consideration the hereditary basis of specific traits. Early breeders knew that heredity was more important than environment in affecting plant growth and yields, but they still relied on phenotypic breeding until Mendel's laws were discovered. One of the best-known type of cotton that American breeders experimented

with extensively was Sea Island cotton brought from the Bahamas in 1785. Records indicate that even in the 17th century people brought cottons from different parts of the world and grew them for domestic use, the same as is currently happening around the world. But the development of the saw gin and textile machinery in the 18th century opened the way for the Industrial Revolution and caused a huge increase in demand for cotton, so growers started paying more attention to improvements in yield and quality. Moreover, beginning in the early 20th century, the development of instruments to quantitatively measure cotton fiber properties spurred breeders to develop varieties with length, strength, and fineness characteristics that are more amenable to textile processing.

Breeders used a phenotypic breeding approach until the science of genetics was born in the early 20th century and Mendel's laws of segregation of characteristics and independent assortment were accepted. The birth of the science of genetics converted phenotypic breeding into classical breeding. Even now, a qualified breeder, or in fact any individual, can breed and develop varieties by selecting better-looking plants with bigger bolls, a larger number of bolls, a short stature compact plant, etc., from the field and testing their fiber quality in a lab. The difference between an individual farmer's selection and the selections made by a talented trained breeder is that a qualified breeder will utilize the knowledge of genetics to develop varieties that are adapted to specific environmental conditions and to the specialized requirements of different segments of the cotton industry.

Cotton Varieties Planted

Over 100 cotton varieties are planted every year in the USA. Most of the varieties are biotech, and almost all are from the private sector. The Delta and Pine Land Company, now owned by Monsanto, dominated the U.S. cotton planting seed market for many years. FiberMax varieties became popular during the last 7-8 years in areas previously picked by

strippers. The favorable characteristic of FiberMax varieties is their superior fiber strength. Because of a reorganization of the seed industry, Bayer CropScience now owns FiberMax and Stoneville varieties, and for the last three years FiberMax and Stoneville together were grown on more area than the varieties owned by Deltapine.

Cotton Breeders Tour

Cotton Incorporated, a private company owned by U.S. cotton farmers and importers of cotton products, organizes a cotton breeder's tour every other year. Breeders from across the U.S., both private and public, participate. The tour is usually conducted at peak fruit formation stage to early boll maturation and boll opening stage. Researchers visit cotton variety trials, farmers' fields and university and the private sector research labs. Researchers from outside the U.S. have also participated in the program recently. Close to 60 scientists from Australia, Brazil, China, Colombia, India and the U.S. participated in the 2009 tour. The group had a session in College Station, Texas, to discuss molecular marker characterization of germplasm in the collection, and heard about three databases currently in use in the cotton community. A cotton germplasm bank is maintained by the USDA-ARS Southern Plains Agricultural Research Station, Crop Germplasm Research Unit, based in College Station, TX. Participants in the 2009 tour also visited the Norman Borlaug Center to hear about cotton sequencing efforts and current projects sponsored by Cotton Incorporated involving seed gossypol reduction (Chaudhry, 2010). The tour also stopped at the Texas AgriLife Extension and Research centers in the cities of College Station, Corpus Christi, and Harlingen. Participants observed Monsanto, Bayer CropScience, and Dow/Phytogen research and agronomic plots in the area. The cotton breeders' tour provides a unique opportunity for breeders to meet and discuss their programs face to face, a key to the success of variety development in the USA.

Area Planted to Brand Name Varieties by Company

Company/Brand	Area Planted (%)									
	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10
Deltapine	39,0	30,7	32,2	33,1	38,4	43,2	47,9	42,9	41,5	39,3
Bayer CropScience - FiberMax				15,6	24,3	25,3	26,7	29,3	32,1	34,5
Phytogen	0,6	1,6	1,8	2,1		2,6	2,2	3,3	4,1	7,2
Stoneville	12,1	12,1	13,1	13,6	12,2	13,9	12,2	15,4	14,2	11,5
Dyna-Gro								1,4	1,5	1,2
All-Tex			4,2	3,1	2,1		1,8	1,7	1,8	1,4
Americot								2,2	2,7	3,2
Paymaster	31,6	37,1	26,2	21,3	11,2	6,8	2,7			
AFD Seed					3,3	3,0	2,5			
CPCSD	2,4	2,1				1,3				
Sure-Grow	8,3	7,8	7,2	5,4	2,4					
Aventis	2,1	4,5	10,5							
Others	3,9	4,1	4,8	5,8	6,1	3,9	4,0	3,8	2,1	1,7

Source: Cotton Varieties Planted, 2000-2009.

Notes: Stoneville became Bayer CropScience - Stoneville from 2008/09 on.

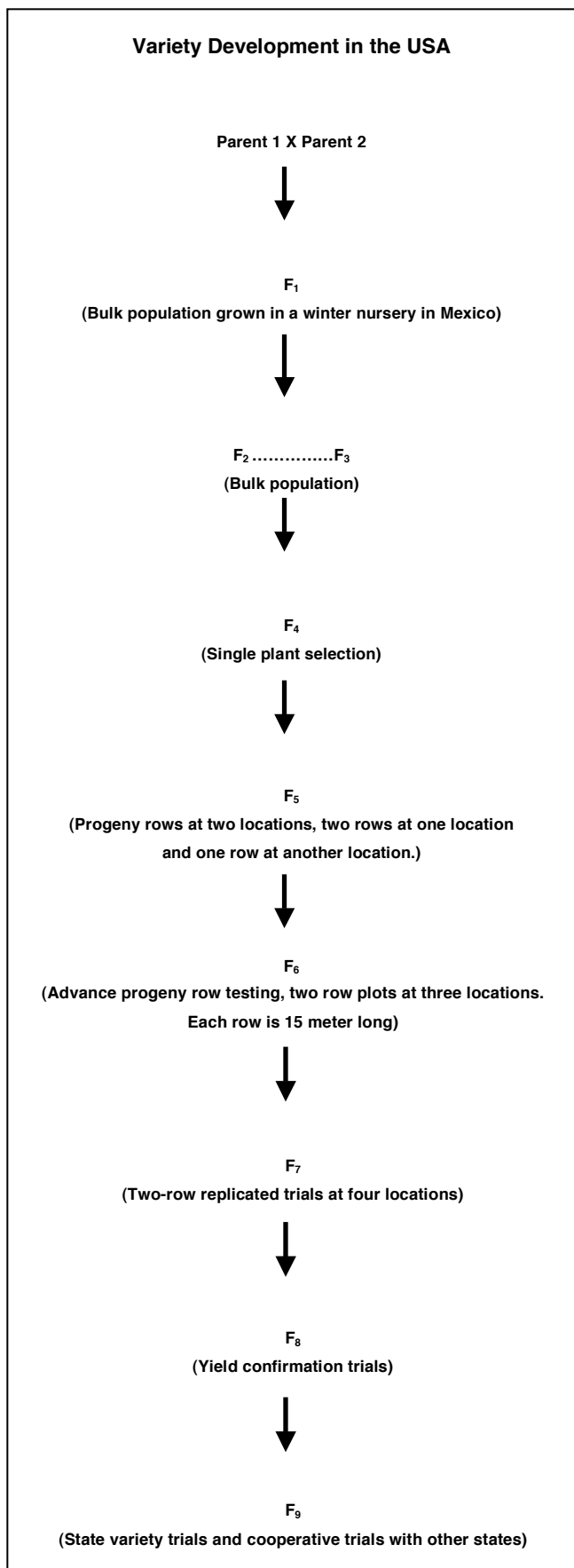
A Typical Variety Development System in the USA

There are at least twenty strong cotton breeding teams in the USA, fifteen at state universities and five from the USDA at four different locations. The following universities are actively engaged in programs to develop germplasm. Additional research may also be undertaken at other locations within a university system.

Auburn University, Auburn, Alabama
 Louisiana State University, Baton Rouge, Louisiana
 Mississippi State University, Mississippi State, Mississippi
 New Mexico State University, Las Cruces, New Mexico
 Texas A&M University, College Station, Lubbock, Texas
 University of Arkansas, Keiser, Arkansas
 University of Georgia, Athens, Georgia
 North Carolina State University of, Raleigh, North Carolina

The Agricultural Research Service, US Department of Agriculture, has four active breeding programs in Arizona, Mississippi, South Carolina and Texas. The USDA Mississippi program has two breeders working independently of each other. Similarly, the Texas A&M University has three breeding teams working to develop new cotton varieties.

The approaches and methods used by cotton breeders differ with specific breeding objectives, available equipment and facilities, and the level of personnel and financial support. Each breeder follows his/her own methodology to induct heterozygosity, screen segregating generations (as single plant or as a bulk populations), select desirable plants (based on breeding objectives), develop a homozygous (at least phenotypically) population, test promising genotypes/lines/strains against standard varieties, and decide which genotypes to put forward for registration as germplasm or release as a variety (in the case of private breeders). It is not the objective of this paper to vet which of these procedures is superior. A procedure followed by Dr. Fred M. Bourland of the University of Arkansas at Keiser is described in detail here. Dr. Bourland is "ICAC Cotton Researcher of the Year 2010". More details about his program and prior work done at the station can be found in Bourland (2004).



Important Notes:

F_1 – The number of crosses made may vary year to year, but on average 20 seeds of each combination are sent to the USDA-ARS Cotton Winter Nursery in Tecoman, Mexico. The USDA-ARS, National Cotton Council of America, and the Mexican Institute of Forestry, Agriculture and Livestock Research, which is Mexico's ARS equivalent, have jointly operated the facility since its inception 60 years ago. Selfing is done on the F_1 plants to avoid contamination. F_1 seed is returned to respective breeders for F_2 generation to be grown in bulk. Almost all state breeders and some private breeders who do not have their own facilities also utilize the winter nursery to save one year. However, breeders have to pay to use the winter nursery, and Cotton Incorporated covers the expenses for state breeders most of the time through project funding.

F_2 & F_3 – Bulk population is grown for two years. No single plant selections are made, but plants visibly not conforming to the target genotype are rouged out to avoid unnecessary testing of large populations and to minimize the risk of losing desirable plants while taking seed samples from the bulk. For example, if a breeder is focused on frego bract, he/she will eliminate the normal bract plant.

F_4 – F_4 population is grown from bulk F_3 seed, but single plant selections are made at maturity stage. Single plants are screened for yield, and for the first time plants are tested for quality characteristics. Poor performing plants, in quantity or quality, are rejected.

F_5 – F_5 seed is planted in progeny rows at two locations, one with two rows and the other with only one row per progeny. One row trial is picked by machine while one row from the two-row trial is picked by machine and the second row by hand. A first yield assessment is made from the progenies harvested from F_5 generation. Fiber quality is also checked.

F_6 – About 200 progenies from all combinations are grown in two-row plots at three locations. Each row is 15 meters long (50 feet). Picking is done only by machine. Quality assessment and rejections based on quality measurements continue.

F_7 – Lines/genotypes are named as strains. Replicated yield trials are planted at four locations with two rows and four replications. Rows are 15 meters long. The number of trials depends on the number of entries, but if there are 72 progenies, which is usually the target for this generation, progenies are divided into four separate trials.

F_8 – The best F_7 generation strains are planted in 2nd year trials usually called "strain test." On average, there are twenty entries per trial including two checks. Seed of selected strains is multiplied so as to put them in regional trials the next year.

F_9 – The best F_8 generation strains are evaluated for a third year in replicated strain tests and are entered in regional trials conducted at the state level along with materials from other breeders. Seeds of selected strains are also supplied to cooperating breeders in other states.

Purpose of Developing New Genotypes and Arrangements with Seed Companies

Private seed companies currently own almost all the cotton varieties planted commercially in the USA. The private seed companies own all biotech genes that have been identified for use in cotton so far, and neither USDA breeders nor state university breeders are legally entitled to insert biotech genes into their germplasm. Thus, the main purpose of public sector breeders in the USA is to develop genotypes that are liked by seed companies. Breeders, whether state or USDA-ARS, are not usually involved in releasing varieties since the commercial cultivation of biotech varieties in the country. Currently there is a limited market for non-biotech varieties. Even though public breeders cannot release varieties and varieties they develop will be not adopted directly, public breeding work is still important. The main objectives of cotton breeding by state and USDA breeders are:

- to extend the science of cotton breeding via enhanced technology, selection criteria, genetic diversity, and understanding of inheritance and interactions of traits;
- to participate in cooperative research with other disciplines, which extends knowledge about the cotton plant;
- to hire trained breeders who then train new cotton breeders and influence students;
- to develop germplasm for the furtherance of a wider genetic base through release of novel germplasm lines;
- to fill niches/alternatives not covered by private companies; and
- to enhance the profitability of cotton production within a state or region.

Some breeding programs like the one at New Mexico State University have a direct agreement with private companies to insert biotech genes for the company. State and USDA breeders develop breeding lines that are registered with the U.S. government. Once a breeder has developed a homozygous promising genotype, the breeder prepares a proposed release notice and submits it to the department head, who reviews the application and submits it to the plant materials release committee. The name of the committee may be different in different states but the objective is to begin the evaluation process to make sure that the new line is distinct from already available lines and deserves to be processed for registration. If the genotype is found to be good for registration, the breeder will prepare the invention disclosure form and submit it for further processing. Thereafter, patent documents are prepared and lawyers get involved to avoid any legal implications in the future.

Cotton Breeding in the Private Sector

For a long time until the release of biotech cotton, private seed companies had tough competition in the development of superior varieties. But, since the adoption of biotech varieties, farmer's preferences have changed. Biotech genes imparting resistant to insects or tolerance for a herbicide became the highest priority in selecting a variety to be cultivated. To some extent, even yield and quality features became secondary choices, particularly because existing varieties were released as biotech varieties. Such an approach slowed the variety release process and affected fiber quality. Meredith, Jr. (online) concluded that fiber quality values are not significantly correlated with value per hectare. In contrast, the correlation of value (\$/ha) with yield/acre is more than 0.9. The strong association of yield with value (\$/ha) and the weak association of fiber quality with value in \$/ha explains why many growers continue to plant high yielding, short staple length and high micronaire varieties. It also explains why commercial breeding companies continue to release these types of varieties.

Meredith also stated that examples of breeding programs that have been successful in developing high fiber quality varieties are the Acala program in California, ARS Pee Dee germplasm program in Florence, SC, and the FiberMax breeding program from Australia. These three programs had several factors in common:

1. Set high priorities on both yield and fiber quality;
2. Broadened the genetic base, beyond crossing the "best X best";
3. Stayed with the program.

Commercialization of biotech cotton impacted the planting seed industry in at least two prominent ways. First, companies that owned biotech genes started acquiring planting seed companies so that they did not have to seek and rely on a seed company to sell biotech genes. Consequently, seed companies, including once the largest cotton planting seed company in the world, Delta and Pine Land Limited, changed hands. The second transformation stage is not completed yet. The seed industry is passing through a stage where biotech companies' primary interest is to sell biotech genes, which has reduced emphasis on breeding their own varieties. Private seed companies may not have recognized it, but the development of

their own varieties is their long-term interest, and eventually this is likely. It is fair to expect such a change because for example in the USA, many state and USDA breeders with very strong breeding programs are developing elite germplasm that can be used by biotech/seed companies. State and USDA breeders develop a germplasm line, and when it has proved its worth for higher yield and quality, seed companies can buy the lines and insert biotech genes of their own choice and market them under their own brand names. The breeder retains the right to the original non-biotech germplasm line but not to the transformed biotech variety. This is something which is already happening and is going to increase. Seed companies usually negotiate royalties based on the anticipated market but may also use the line in their own breeding programs. The varieties released under brand names do not give credit to the original breeder's work.

Seed companies and private breeders have usually not been open about the parentage of commercial varieties. Propriety rights on all biotech genotypes have further limited access to pedigree information about varieties. Companies have exclusive licenses for transformed lines, and the biotech/seed company is responsible for making transformations, all seed increases, protection of released varieties, and marketing of the transformed line. Consequently, propriety rights have narrowed the base for breeders.

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Why Natural Fibers are Better than Synthetic Fibers in Clothing: Scientific Basis

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Abstract

New and more sophisticated technologies are being introduced in the textile industry that make production processes more efficient, more productive, allow for introduction of a new assortment of textile products and new fibers to improve the properties of clothes. However, as scientists develop technological novelties, they cannot forget about human sensitivity, because it is a human who will wear clothing products. No product should have a negative effect on the human body. Each new technology using new chemicals should be evaluated for safety in direct contact with human skin. Research related to evaluate the effects of clothing on human physiology conducted at the Institute of Natural Fibers and Medicinal Plant (INF&MP) proves that garments made of natural fibers create a more human-friendly environment compared to garments made of synthetic fibers.

The influence of clothes, which were covering transiently the human forearm muscles, on the activity of motor units of these muscles was investigated at the INF&MP. The results of electromiographical studies of two groups of people wearing natural and synthetic apparel showed that covering tested forearm muscles with synthetic clothes changed the pattern of motor unit activity temporally. The observed fluctuations were the result of desynchronization in muscle motor units that may lead to a higher tendency to fatigue when wearing synthetic garments. Another part of the research studied the influence of different types of clothes (in given conditions, during rest or exercise), to oxidative stress and how the organism's defense mechanism change. One of the ways to test the ability of an organism to defend itself against the reactive oxygen species is to measure the 'Total Antioxidant index Status (TAS).' This parameter signals the total ability of tissues to neutralize an exactly determined amount of reactive oxygen species. Results showed that garments made of synthetic fibers can be a reason of oxidative stress of a wearer organism. Due to considerable amounts of man-made fibers in clothes and bed linen, there are more allergies observed among people who use different textile products made from man-made fibers. According to studies conducted at the Institute of Natural Fibres and Nara Woman's University, Japan, it was found that man-made and natural fibers in bed linen have dramatically different physiological effects on the human body. This physiological influence is connected with different effects on the level of α -globulin produced in the human body in different conditions created by bedding made of different fiber compositions.

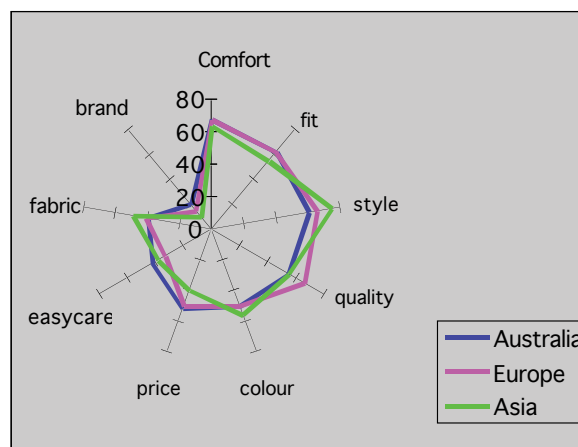
Introduction

Natural fibers provide high comfort, a positive influence on the human body, and environment protection. For ages, natural fibers have provided protection and comfort against weather conditions. Clothing comfort is a complex and hazy subject, hard to define in simple words. Most of this is a result of comfort being a set of personal/individual feelings. However, one can define comfort as all the physiological human body reactions to the conditions related with an environment-cloth system. For an everyday consumer, a state of comfort is similar to "freedom from pain and from discomfort; a neutral state"[9].

Comfort is a key aspect in the process of clothing selection for many consumers. Results of market analysis conducted twelve years ago are still valid. Figure 1 shows some results from a study on the perceptions of the importance of various attributes of clothing worn in the work place, which covered a number of national groups from Europe, Asia and Australia.

The main trends among the national groups are similar. From the nine dimensions listed, comfort, fit, style, color and quality were rated more important than others, which suggests the need for an effective methods for evaluation of the overall wear performance of clothing.

Fig. 1. Consumers' Requirement of Clothing

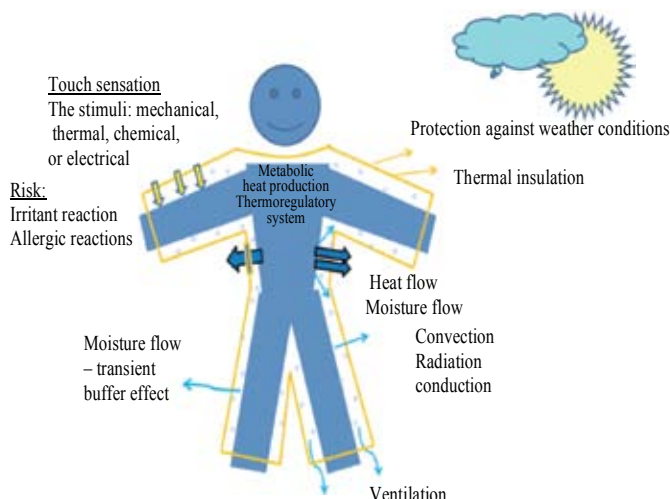


(Y.Li. *Wool Sensory Properties and Product Development*, Textile Asia, 1998, Vol. XXIX, 5),

The “skin – clothing” system is the key factor when discussing a comfort formula.

The “skin – clothing” system is an open system that is always in a state of dynamic interaction with its surrounding environment in physical, sensory, physiological and information means.

Fig. 2. Comprehensive Clothing Interaction With Human Body



Heat and moisture movement between the body and its surroundings is a result of processes that run on the surface of the skin and lungs, processes that arise from conduction, convection, radiation and evaporation. The contribution of numerous processes to the whole system differs for various surrounding conditions.

Fig. 3. “TOUCH: Special Nerves Help Babies and Lovers Feel Pleasure, Softy”



Source: The Washington Post, July 30, 2002 (by Shankar Vedantam)

“Human body has a special set of nerves for feeling pleasure at a mother’s caress or a lover’s embrace. While the thick fibers rapidly shoot electrical signals to the somatosensory cortex of the brain and convey information about contact and pressure, the thin slow fibers connect to the insular cortex and convey the emotional context of the touching. The fast fibers indicate, when we are touched and how strong the touch is. The slow fibers signal the fine aspects of the touch.” In a similar way,

the touch receptors placed in skin transmit information to the brain concerning stimuli from clothing. The nerve ends collect the stimuli from skin exposed to clothes and send the information to the brain. This way they stimulate certain processes in the body. Depending on the type of clothing, stimuli can be pleasant or not.

Other than stimuli directly received by fast and slow fibres of nerves placed on the skin, there are many other factors influencing the complex impression of each user about clothes.

Aspects of comfort, as well as the hygienic properties of clothing, have been the scope of many studies. Traditional tests on physical-mechanical characteristics of textile products are not enough to develop an objective evaluation of textile properties. In the tests described we have tried to go further. The aim was not to measure comfort itself, but to measure the changes on human physiology caused by the clothing common in everyday life. The studies covered the following topics: the influence of bed linen on the quality of sleep, and the influence of garment on parameters of the body, specifically, oxidative stress, the activity of sebaceous glands, and the tendency for tiredness. The research was conducted under an agreement with the Commission of Bio-ethics of the University of Medical Sciences in Poznan. The clothing was evaluated by wear tests in everyday conditions. Young volunteers wore the tested garments for specific times. Two groups of raw material were investigated: natural cellulosic fibers and polyester fibers. Natural cellulosic fibers: cotton and linen are characterized by very similar properties, because the main component of their chemical composition is cellulose (Table 1). Garments made of both fibers show a high ability for moisture absorption and ensure breathability, which significantly improves comfort for wearers in everyday steady conditions without physical effort.

Table 1. Selected Properties of Natural Cellulosic Fibers

Fiber	Cellulose Content [%]	Density g/m ³	Moisture Content in 65% Relative Humidity of Air [%]
Cotton	88–96	1,5-1,6	8
Flax	71	1,5	10

Sleep and Natural Fibers

The study was conducted in the Laboratory for Physiological Influence of Cloth on Human Body. The laboratory is air-conditioned, which guarantees stable temperature and humidity at levels required for experiments. The experiments on the influence of bedding on sleep conditions were done in cooperation with Nara Women University, Japan and Karol Marcinkowski University of Medical Sciences in Poznan, Poland. A comparative test was conducted on bedding made of natural (100% linen, 100% cotton) and synthetic (100% PES) fabrics. Some of the most important fabric features are shown next table.

Table 2. Properties of Tested Fabrics

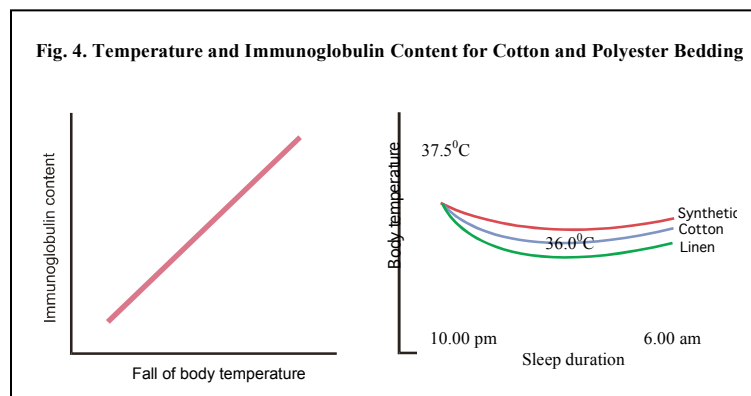
Fabric	Surface mass g/m ²	Hygroscopicity at 65% Humidity	Hygroscopicity at 100% Humidity	Resistance Ω	Heat Resistance Km ² /W
100% linen	152.3	7.0	16.2	5.5×10^9	12.2
100% cotton	141.4	6.4	15.1	1.2×10^9	10.6
100% PES	138.6	0.3	1.5	1×10^{12}	7.5

Experimental Methodology

Young males slept for 8 hours in linen and cotton bedding, followed by sleep in polyester bedding. The environmental conditions were strictly defined for each experiment to avoid any accidental differences in results. Air temperature 20°C, humidity 50%, sleep duration from 22.00 till 6.00 in springtime. The men were of similar age and healthy. Skin and inner body temperature, as well as levels of immunoglobulin A, were measured during the experiments. Temperatures were measured every 10 minutes. The level of immunoglobulin A was measured through saliva analysis.

(IgA) A class of antibodies often formed as a dimer (i.e., two antibody molecules attached to each other end to end) that is secreted into bodily fluids such as saliva. IgA protects the body's mucosal surfaces from infection.

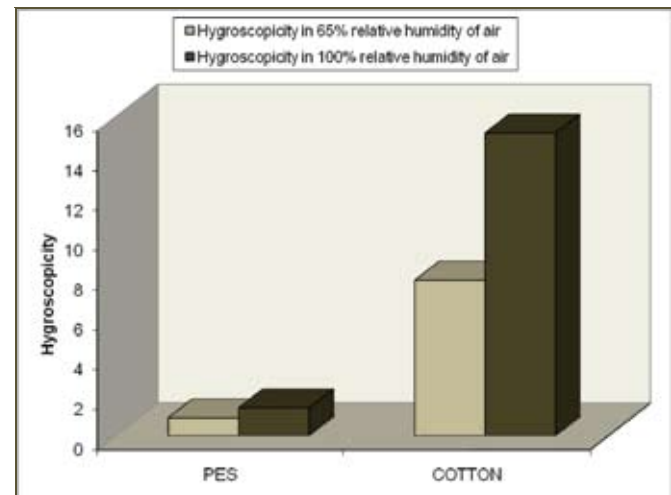
Body temperature decreased during sleep in typical physiological ways. However, results showed that the decline in temperature is the largest during sleep in linen or cotton bedding in comparison to sleep in polyester bedding, as shown in Figure 4. Also, the level of immunoglobulin A content is higher when sleeping in natural fiber bedding than for sleeping in polyester bedding, which means a deeper sleep, quicker human body regeneration and better rest takes place in natural fibers bedding; the human immune system grows stronger.



Sebaceous Gland Activity Under the Influence of Cotton Pajamas

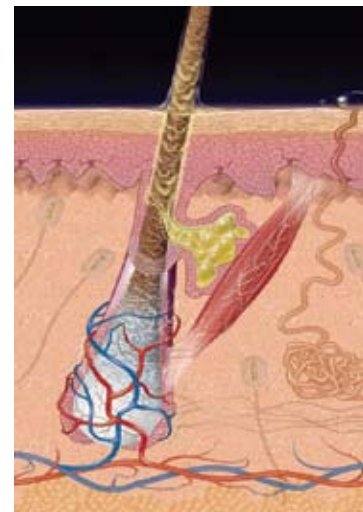
Tokura *et al.* [23] described different adaptability of sebaceous glands activity to two types of clothing with hydrophilic (cotton) and hydrophobic (polyester) properties. Humans have evolved wearing clothing with hydrophilic properties.

Fig. 5. Higoscopicity of Cotton and Polyester Fabric



The sebaceous glands are located approximately 0.5 mm under the skin surface. The sebaceous glands are distributed over almost the entire body, with the exception of the palms and soles of feet. The number of glands per cm² of skin and their size varies considerably. The most number and the largest sebaceous glands are found on the scalp, up to 800 per cm². Secretions of each sebaceous gland forms a thin film over hair and the surface of the stratum corneum, which may spread up to the upper layers of the stratum corneum. Thus, water permeability is reduced and the resistance to acid, lye and bacterial contamination is increased.

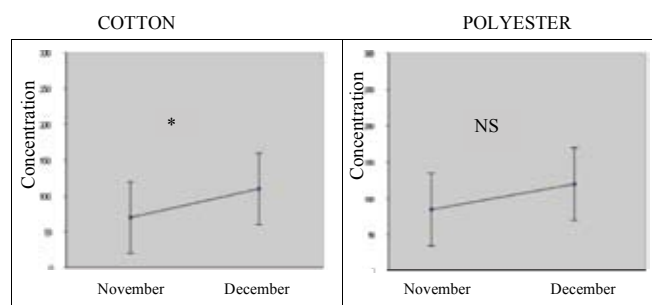
Fig. 6. Copyright © 2000 - 2003 Skin Care Forum



Within the study, ten female adults wore cotton pajamas with hydrophilic properties and ten female adults wore polyester pajamas with hydrophobic properties during night sleep for a month. The pajamas were worn directly on the skin. The authors collected sebum from the back skin and samples of blood for the measurement of Natural Killer Cell Activity two times at the beginning and at the end of each experiment.

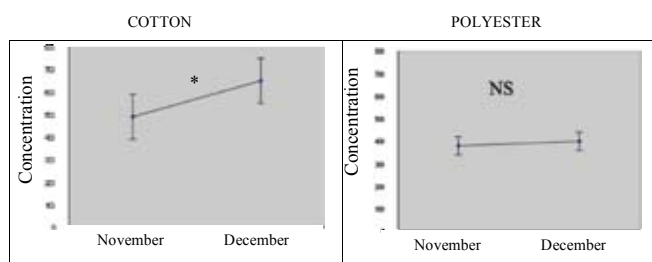
Squalene, waxester and triglyceride being derived from sebaceous glands of each volunteers back skin increased from the start to finish of the experiment significantly in the case of sleep in cotton pajamas, but they did not change significantly for volunteer sleeping in polyester pajamas (Figures: 7-9).

Fig. 7. Average SQ (Squalene) Sleep in Tested Pajama; [$\mu\text{g/ml}$]



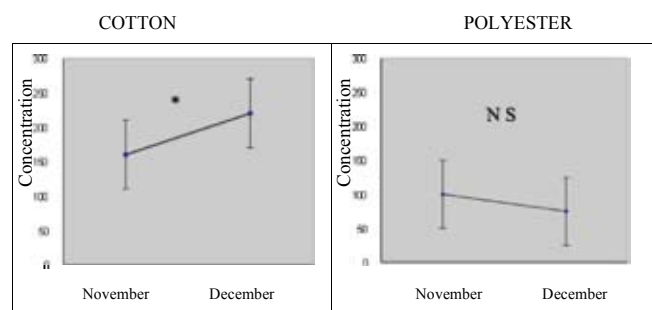
(* Significant)
(NS=Non significant)

Fig. 8. Average TG (triglyceride) – Sleep in Tested Pajama; [$\mu\text{g/ml}$]



(* Significant)
(NS=Non significant)

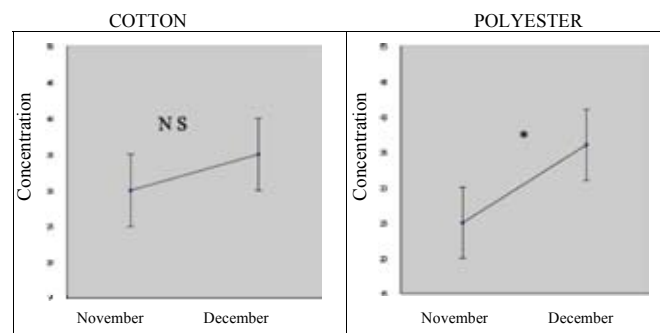
Fig. 9. Average WE (waxester) – Sleep in Tested Pajama; [$\mu\text{g/ml}$]



(* Significant)
(NS=Non significant)

Prof. Tokura maintained that Natural Killer Cell activity increased significantly when volunteers were sleeping in polyester pajamas (Figure 10). This indicates that the subject wearing polyester pajamas was more stressful during night sleep. Stress could decrease the level of androgen. Its reduced level could also suppress sebaceous gland activity.

Fig. 10. Average NK Cell (Natural Killers) Activity in Pajama [%]



(* Significant)
(NS=Non significant)

Constant skin cover by clothing with hydrophilic properties (cotton) could enhance sebaceous gland activity. This indicates that skin as a defense barrier against attack from surrounding agents could function more effectively. Synthetic clothing (with hydrophobic properties) would suppress natural and seasonal increments of sebaceous activity.

Parameters of Oxidative Stress of the Human Organism Under the Influence of Natural Fiber Clothing Material

The objective of this part of the study was to investigate if everyday clothing can influence the parameters of oxidative stress of a human body. Shirts made of natural and polyester fibers were used as a tested material in the study of effects of apparel on measures of oxidative stress. The shirts were characterized by the same construction and model with long sleeves. Characteristics of textile metrology parameters of the tested clothes are shown in Table 3.

Time Constant in ms units is the time required for 67% discharge of electrostatic charges gathered on a cloth surface.

Conditions for the measurement of Time Constant were as follows:

- Upper limit of time constant potential – 150V
- Lower limit of time constant potential – 50V
- Air humidity – 55%
- Air temperature – 20°C

Table 3. Properties of Tested Clothing

Material	Hygroscopicity		Surface Resistance [Ω]	Electrostatic Discharge Time Constant [ms]	Heat Resistance [Km^2/W]
	65% Air Humidity	100% Air Humidity			
100% Linen	9.3	17.1	1.5×10^9	56	14.8
100% PES	1.0	1.3	6.5×10^{11}	1891	5.4

Lower values of surface resistance and time constant of electrostatic discharge for linen fabric compared to values measured for polyester clothes shows that linen clothes do not allow for gathering electrostatic charges on their surface. Men wearing polyester garments are exposed to the danger of a constant influence of an electrostatic field and rapid discharges in contact with conducting materials.

Methods

The tests were conducted on 6 healthy, untrained, similarly built males of age 19-23. The control group was people wearing linen garments; the tested group was the same people wearing polyester clothes. The people stayed in a climatic chamber (Laboratory of Physiological Testing at the INF) at a temperature 20°C, 50% relative humidity of air and air movement smaller than 0.5m/s.

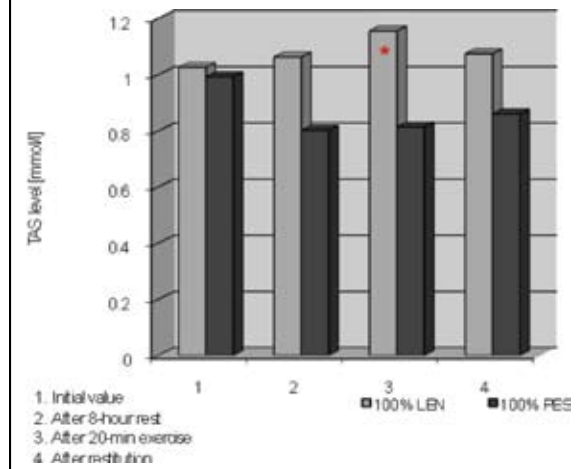
The evaluation of the physiological parameters of volunteers wearing tested shirts were conducted during resting time for 8 hours, moderate physical exercise for 20 minutes, and after post-exercise restitution, until blood pressure and pulse stabilized. The physical activity was on the level of 75 W according the cyclometer (Hellige). In the period before rest, before exercise, after exercise and after restitution, the blood samples for biochemical assessment were taken. TAS (Total Antioxidant Status) was measured using the colorimetric method (Randox Laboratories Ltd. GB). The authors of the study received the permission of the Bioethical Commission at the University of Medical Sciences in Poznan for conducting this study.

Results

The purpose of the study was to determine whether staying in different types of clothing in given conditions, during rest or exercise may be the cause of the oxidative stress and to see how the organism's defense mechanisms change. One of the ways to test the ability of an organism to defend itself against the reactive oxygen species is to determine the Total Antioxidant Status (TAS) [4]. The Total Antioxidant Status provides information about the total ability of tissues to neutralize an exactly determined amount of reactive oxygen species (ROS).

The results of TAS level testing in people wearing linen and polyester clothes in controlled conditions are shown in Figure 11.

Fig. 11. The TAS Level in People Wearing Linen and PES



The results showed that the TAS value is lower for individuals wearing polyester garments compared to people wearing linen clothes in each stage of the experiment. The difference in TAS value is statistically significant after moderate exercise. The results indicate that the antioxidative reserves are higher, resulting from increased amounts of reactive oxygen species, in individuals wearing polyester clothing. It is supposed that the polyester garment may cause higher production of ROS, which reduces the antioxidative reserves of the organism. Changes in the parameters of the antioxidative system of a body under the influence of polyester clothing may reflect the oxidative stress, i.e., a disorder in physiological defense mechanisms against the reactive oxygen species.

Natural Fiber Clothing and Muscle Tension

Everyday clothing can influence human muscle tension, which can be a reason for an increase in fatigue. That was confirmed by the experiments done by the Institute of Natural Fibres in cooperation with University of Medical Sciences in Poznan [18].

Experimental Methodology

The studies were performed on ten volunteers wearing garments made from linen, double layer linen, polyester and blends of both fibers in the Laboratory of Physiological Influence of Textiles on Human Body under stable conditions: air temperature of 21°C $\pm$ 2.0°C, relative humidity 55% and air movement less than 0.5m/s. Volunteers, only men of similar age, height, weight and constitutional conditions, were not exercising. Humidity and temperature of back skin under each type of clothing were recorded every half an hour, according to the scheme shown in Figure 12.

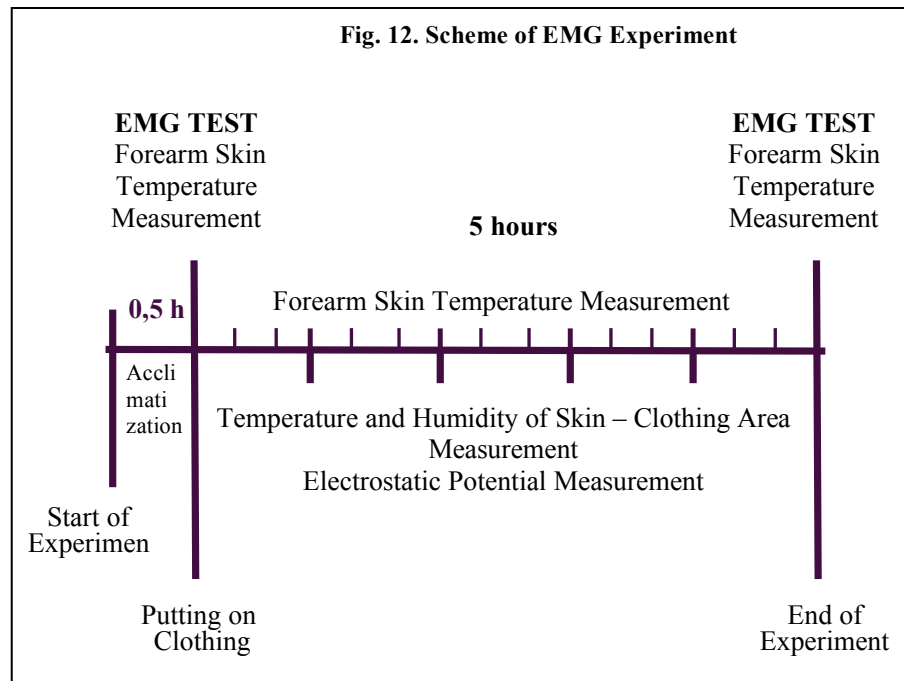
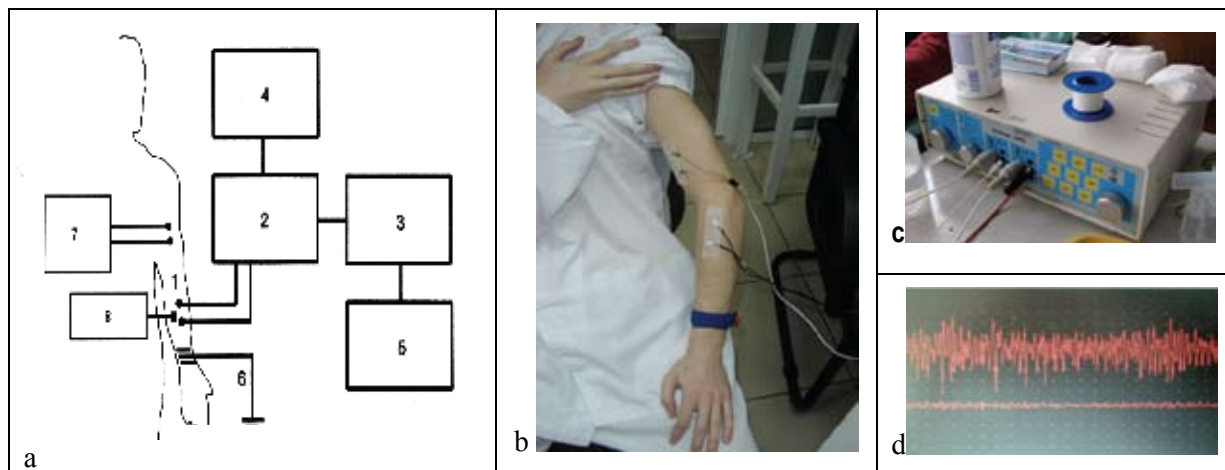


Fig. 13. Experimental Arrangement Used During Tests Performed in this Study



The electromyographic (EMG) parameters of muscles were gathered before exposition and after five hours of wearing each garment. The exposition duration with each garment was similar and was strictly connected with biological rhythm of the day [1]. The circadian cycle of the muscles efficiency coming from the fatigue-relaxation rhythm was also considered in these studies [5,6]. Therefore, the period of the day, between 2.00 pm and 9.00 pm, when tests were performed, was chosen to adjust changeable activity to the optimal period of muscle motor unit efficiency of a healthy human. The circadian cycle of the temperature rhythm is, in the general, the same as above.

The analysis of more than 2,000 EMG records was conducted in order to demonstrate the main objective of the studies. The EMG device recorded the level of muscle tension on the surface of each forearm during activity and static performance of volunteers, which is shown in Figure 13.

a) 1 – Surface bipolar recording electrodes, 2 – AC amplifier, 3 – Personal computer, 4 – Loudspeaker connected to the amplifier, 5 – Printer, 6 – Reference electrode, 7 – Stimulating bipolar electrode, 8 – Thermometer measuring temperature over the skin [7];

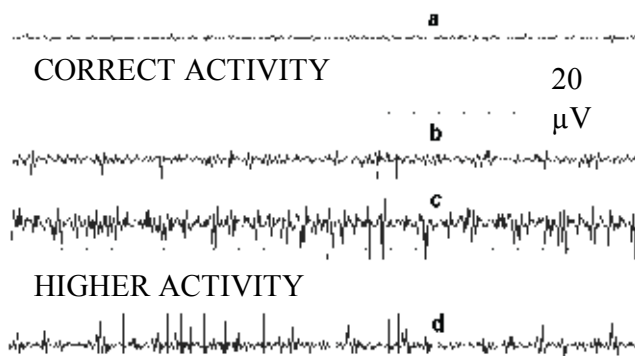
b) EMG surface electrodes placed on the volunteer forearm;

c) EMG apparatus; d) EMG record.

Results

The muscles always have some tension while at rest (without brain control). Stimuli are sent constantly from the brain to cells of movement and then to muscles with a frequency 2 – 6 Hz. But temporarily covering the forearm muscles with different types of clothes can change some electromyographic parameters monitored in the form of electrical signals with the characteristic potential. Examples of electromyographic records taken at a resting state from volunteers wearing tested clothing are shown in Figure 14.

Fig. 14. Examples of Global Electromyographic Records Taken at Resting State from a Forearm of Volunteer Wearing



- (a) 100% linen clothing;
 (b) 100% double layer linen clothing;
 (c) 50% linen 50% PES clothing, (d)-100% PES.

The recorded changes in EMG records in the resting state were divided into four main groups. The first group, marked in Figure 14. as 'a' comprised the EMG records taken before covering bodies with clothing, after covering bodies with the clothing made of 100% linen and 75% linen/25%PES as well as done in the control group – they are standard records. The second group, marked in Figure 14 as 'b', comprised records of forearm muscle activity after covering the body with 100% double layer linen fabrics, garments with higher thermal insulation properties. This record was characterized by the presence of few additional single potentials of low frequency. The third group, presented in part 'c' comprised records of forearm muscle activity after covering the body with clothing made of 50% linen and 50% PES and; 25% linen and 75% PES. The typical results for this group are high amplitude potentials grouped in high frequency series or volleys. The intensification of this phenomenon and appearing irregularities in frequency of action potentials with different amplitude occurred in EMG records taken from subjects wearing clothing made of polyester fabrics for five hours. The record of this phenomenon is shown in part "d" of Figure 14.

The statistical analysis indicates that covering the body with clothing causes changes in users' muscles tension shown

by electromyographic activity. Clothing made of fabrics of 100% linen, and 75% linen and 25% PES, result in very slight changes of muscle EMG parameters in the wearers. These slight changes are caused by a natural increase in skin temperature as a result of covering the body with clothing and are not a desynchronization of motor units. The increase of skin temperature observed in the case of a double layer linen clothing results in changes in the amplitude of EMG records both in the resting state and during voluntary movement. These changes cannot be regarded as desynchronization of motor units. However, clothing made of polyester fabrics produce substantial changes in muscle EMG records of the wearers after covering the body with this kind of clothes for five hours, which indicates the occurrence of desynchronization of motor units. The presence of electrostatic charges on the surface of clothes made of polyester fabrics is a reason for increases in mean value of potential frequency action of motor units in the resting state. The phenomenon of sweating intensification in people wearing clothes made of polyester fabrics causes changes in motor units activity in EMG amplitude in the resting state and amplitude and frequency during voluntary movement. The threshold value of polyester fiber content in blends with natural cellulosic fiber is 25%. Clothes made of natural fiber fabrics with polyester content of no more than 25% do not cause desynchronization of motor units in healthy muscles.

Conclusions

- The studies conducted in everyday conditions without physical effort showed that garments made of natural cellulosic fibers like cotton or linen have a positive influence on physiological parameters of the human body: level of immunoglobulin A, sebaceous gland activity, parameters of oxidative stress and muscle tension. The result contrast with the results from polyester clothing, which may have an unfavorable influence on the human body.
- The lowest body temperature and increase of Immunoglobulin A during sleeping in cotton or linen bedding proved that such raw materials have a positive influence on human rest and sleep quality.
- Wearing cotton pajamas positively influenced the activity of sebaceous glands that improve resistance to skin diseases.
- The lower level of total antioxidative status in individuals wearing polyester garments showed that this probably is an effect of increased production of reactive oxygen species, which are responsible for oxidative stress. It means, that polyester clothes can be a source of oxidative stress in certain conditions. Clothes made of natural cellulosic fibers do not cause the increase in reactive oxygen species and oxidative stress.
- Wearing polyester clothes can be a reason for

desynchronization of muscle motor units and thus, an increase in fatigue in users. Clothing made of natural cellulosic fibers positively influences the human body, ensures well-being and does not cause fatigue.

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