

Roadmap to sustainable cotton production

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Abstract: Cotton is natural-fibre that is mostly used in clothing and textile industry. It almost covers 50% of the textile market worldwide. It has been used for various textile products, such as bath towels, robes, denim, shirts, socks, T-shirts, bed-sheets, etc. The Organic cotton farming has emerged as a solution to overcome serious environmental effect of conventional cotton. The organic cotton is cultivated under natural conditions without the use of inorganic fertilizers, herbicides, insecticides or fungicides, etc. Cotton production due to its high demand is the backbone of Pakistan's textile industry. The use of genetically modified cotton all over the world has become the emerging trend all over the world. During 2002, Bt cotton was first introduced to increase the yield because it had potential to resist boll worms attack. The introduction of organic cotton (by ecological restrictions and global eco-friendly market dynamics) is the alternate of conventional cotton industries where biological processes play an important. Bio modification of synthetic and natural fibers with enzyme-based processes move towards a more bio based economy may end up in depleted renewable resources and environmental degradation.

[Rashid B, Haider T, Yousaf I, Rasheed Z, Ali Q, Javed F and Husnain T. **Roadmap to sustainable cotton production.** *Life Sci J* 2016;13(11):41-48]. ISSN: 1097-8135 (Print) / ISSN: 2372-613X (Online). <http://www.lifesciencesite.com>. 7. doi:[10.7537/marslsj131116.07](https://doi.org/10.7537/marslsj131116.07).

Keywords: cotton, natural-fibre, clothing, textile industry, genetically modified cotton

Introduction

Synthetic fibre production has been increased but cotton is still the most important fibre crop due to its global significance so it is well known as "Queen of the fibre plants". More than 80 countries are known for cotton production so cotton covers 2.5% of the total cultivated land all over the world. Cotton has also commercial value as it is crucial component for its producers to earn through foreign exchange [1,2]. Cotton also constitutes the major portion of cash crops cultivated all over Pakistan. Cotton and its products are exported which constitutes 62% of the foreign exchange earnings. It contributes about 28% of the earnings from the exportation of major crops. Due to enhanced cultivation and developed industry for the preparation of cotton made-ups, it provides employments to large population i.e. about 40% individuals are employed by cotton industry alone. Cotton seed also provide edible oil which constitutes 60% of total edible oil consumption [3].

Although cotton is a natural fibre but due to increase consumption of synthetic chemicals and fertilizers (applied to about 99% of cultivate cotton) to increase the yield of the crops so to enhance industrial productions, the cotton goods sold today do not justify the natural fibre label. Cotton crop is vulnerable to insect attack all over the world by more than 230 species of insects [4]. Cotton is the major consumer of agrochemicals because it is the crop majorly produced and also more prone to attacked by insect pests so it is found that 16% of the world's insecticides are consumed for the single cotton crop. Agrochemicals

constitute about 50% of the total cost utilized globally for seed cotton production [5]. Professor Doug Murray studied the use of pesticides on cotton and stated that among the most hazardous pesticides in practice are the one used in cotton fields. Pesticide Action Network statistics estimated that about one fourth of a pound of chemicals is utilized to produce single t-shirt as a pair of jeans get produced by using two third of a pound of chemicals [6]. Global use of toxic pesticides and chemicals is greatly affecting the ecosystem and environment. Extensive use of chemicals is disturbing the biological balance as more and more pesticide resistant species are emerging which is responsible for changing insect pattern. All this resulted in the increase in production cost. These chemicals also enter into water bodies and air so causes water and air pollution and hence decreases the biodiversity [1,7]. Organic cotton is the solution of all emerging problems. It is the cotton which is cultivated under natural conditions i.e. no inorganic fertilizers, herbicides, insecticides or fungicides, etc. are used. It is certified by a documented certifying organization. Organic production systems preserve biological diversity in agriculture as the use of fungicides and pesticides is reduced to an extent that supports various life forms. This also helps to preserve as well as replenish the soil fertility. Organic cotton is also known as natural cotton, clean cotton, green cotton or environment-friendly cotton [8].

Comparison of organic Cotton with Conventional cotton

Organic cotton production systems utilize biological substances rather than chemicals which are major focus of growing farming systems. The use of inorganic fertilizers is prohibited for cultivation of organic cotton and replaced by organic manure including farmyard and green manure, composite, cotton seed meal, fish meal, cake, leather meal or gypsum, etc [9]. Also the herbicides and pesticides of the botanical origin are usually used such as ipomea, neem cake etc. While chemically synthesized pesticides, insecticides and herbicides are used for conventional cotton production. The use of chemical defoliants is also avoided in harvesting of organic cotton [10]. Besides its significance in clothing chain, organic cotton is also a major component of food chain whereas the pesticide residues from seeds of conventionally grown cotton residues into the fatty tissues of animals and thus contaminate the meat and dairy products and pose a risk to consumers. Organic cotton is economic and has reduced cost of production as it eliminates the cost for the use of agrochemicals for its cultivation [11]. However the yield of organic cotton is less than that of conventional cotton and so organic cotton fabric costs much higher. Organic

cotton production prohibits the use of toxic chemicals so not only farmer enjoys a healthy environment but it also prevents environmental pollution. Soil also remains fertile as its composition is not destroyed by chemicals. Organic cotton production also eliminates the need for the treatment of water contaminated with chemicals as organic treatment process require just simple nontoxic dyes instead of hazardous chemicals e.g. chlorine, toxic finishes or bleach etc. [11,12].

Production

Organic cotton production system is a complex system as it require stable environment and farmers are required to manage the stable farm conditions to sustain and optimize the yield. This requires a heavy investment to maintain soil fertility. Organic cotton is majorly produced in the areas which grow cotton as the major cash crop or its cash crop [13]. Certified organic cotton is cultivated in 22 countries all over the world and in ten producers, India ranked first followed by Turkey, Syria, Tanzania, China, United States, Uganda, Peru, Egypt and Burkina Faso respectively. The region wise production of organic cotton in 2008/2009 is given in table 1 as under:

Table 1: Organic cotton fibre production in 2008/2009

Region	Production 2007/2008 (Metric Tons)	Production 2008/2009 (Metric Tons)
SE Asia	73,908	107,800
Middle East	52,753	49,450
Africa Non CFA	5,455	6,610
China	7,354	3,489
USA	2,716	2,729
West Africa	1,069	1,612
Latin America	1,590	1,614
North America	761	936
Central Asia	194	428
EU	72	85
Total	245,872	175,113
Total in Bales	668,580	802,601

Source: Organic Exchange.

Organic Exchange (OE) mentioned some statistics about cultivation of organic cotton in their Fourth Annual Organic Cotton Farm and Fiber Report 2009. In the growing season by the 2008/09, organic cotton grown on 625,000 acres (253,000 hectares) with the help of 222,000 farmers. This yielded 175,113 metric tons (802,601 bales) cotton in July 2009. U.S Organic Trade Association (OTA) reported that in 2009 the grower of organic cotton increased the acreage of plantings by 26% over than the preceding year i.e. 2008. Now the organic cotton represents the 0.76% of the worldwide cotton production. Organic cotton fibre yields around 690 kg ha⁻¹. Farmers are now concerned much with the average yield of organic

cotton and also pondering to employ organic cotton sector which gives better yields [14].

The role of cotton in Pakistan

Pakistan is also in the list of major producer of cotton worldwide as it ranks fifth in this regard and the largest exporter of cotton yarn. It is the third chief exporter of raw cotton and ranks at the fourth position as the cotton consumer. About 15% i.e. over 3 million hectares of the cultivable land is covered by cotton in this country. Cotton and its products contribute about 10% of gross domestic product (GDP), 60% of foreign exchange earnings to the economy of the country. The cotton yield (Table 2) is found to be lowered during 2010-11, as the crop was cultivated 2,689 thousand

hectares area, which was 13.4% less than preceding year (3,106 thousand hectares). The production is estimated at 11.5 million bales, 11.3% less than that of last year's i.e. 12.9 million bales and also 17.9% less than that of target's i.e. 14 million bales [15]. The reduced cultivation and the resulting decreased cotton

production is attributed to extensive floods, Cotton Leaf Curl Virus (CLCV) attack and damage to crops caused by sucking pest/insect in core and non-core area, fruit shedding cause by excessive rain and shortage of water due to canal closure during flood in certain areas [13,16-19].

Table 2. The year wise cultivated area, production and yield of cotton

Year	Area (000 hectors)	Production (000 tonnes)	Yield (Kg / per hectors)
2006-07	3,285	11,720	645
2007-08	3,054	11,655	649
2008-09	2,820	11,819	713
2009-10	3,106	12,914	707
2010-11	2,689	11,460	725
2011-12	2,830 (P)	13,500	730

Source: State Bank of Pakistan Annual Report FY11.

Cotton production is the backbone of Pakistan's textile industry. Textile sector comprises about 521 textile mills, 11.3 million spindles, 8,000 looms in the mill sector and over 260,000 looms in the non-mill sector, 27,900 shuttle less looms, 1,200 knitwear units, 5,000 garment units (with 160,000 industrial sewing machines), 750 dyeing and finishing units nearly 1,200 ginner, 300 oil expellers, and 15,000 to 20,000 local, small scale oil expellers (kohlus) [15]. There is an emerging trend for the use of genetically modified cotton all over the world. Bt cotton was first introduced in 2002 through an informal sector as a means to increase the yield because it had potential to resist boll worms attack. However, number of factors interferes while working with genetically modified crops which affect the yield [20]. When reviewed, two factors were found to significantly affect the economics of cotton industry. These are widespread use of agrochemicals and yield stagnation i.e. no improvement in yield. Insecticides and fertilizers are extensively used among all agrochemicals. Synthetic fertilizers are efficient enough that there is no such means to replace them and cotton crops could only benefited by the use of inorganic fertilizer to fulfill the needs of nutrients. Insecticides are major agrochemicals used in cotton production among all pesticides.

In January 2000, an organic cotton project was initiated by King's Group. Now it produces 80,000 Kg of organic cotton lint. It also exports garments of organic cotton to the customers in U.S and Europe in accord with their specific requirements. The project is going well in the small village of fertile Lasbela district in the province of Baluchistan. The village is 80 km North West from Karachi and is easily

accessible from Karachi by a major highway. Due to its fertility, high quality cotton is yielded. Cotton is cultivated on 3000 acres of land using organic agriculture procedures. Pakistan's cotton yield is not increasing in last few years due to several factors. Some of the major factors for stagnant production of cotton are: excessive rains in sowing season, damage to flowers caused by high temperature in at flowering stage, delayed harvesting of wheat so less area is available at the time of planting, viral (Cotton Leaf Curl Virus) and pest attack and lack of advanced technology in major cotton growing areas of Punjab and Sindh [13].

The Textile policy is trying to increase the value addition of bales, textile exports, give budget for machinery and technology, enhance the fiber mix quality to increase the product quality, increase the ICT use and making strong to the cluster. Textile policy needs to make strategies and then act upon them. According to ministry, in the next 5 years, the scheme of finance bill 2014-2019, including disadvantage of local taxes, decrease in markup rates etc., might be continued.

Organic cotton product and prospects

The introduction of organic cotton (by ecological restrictions and global eco-friendly market dynamics) is the alternate of conventional cotton industries. Now a day, many brands are using organic cotton lines for their cloths. A few of good companies are; Nike, Coop Switzerland, Otto, Patagonia etc. Now a day, organic cotton is a reliable selection. Recently it is reported that, In U.S, since few years, there is two times more increase in growth due to the organic and eco-friendly textile sales. Many companies are making plans to use either pure organically produces cotton or mixed it

with small percentage of conventional cotton. The more use of domestic and international organic cotton is doing by many companies [21].

Processing

Greater than 50 developing countries are growing cotton. The more cotton is produced by U.S, China, India, Pakistan and Uzbekistan. The more usage of chemicals e.g. pesticides and fertilizers is affecting the life on earth by affecting the soil and water. Nitrates are produced from nitrogen fertilizers and causes methemoglobinemia (blue baby) syndrome in the children. In California, the emission of volatile organic compounds (VOC) has increased to 11 million pounds and pesticides related diseases are on third number in California. Recently, 13 pesticides are registered to be used for cotton, causes death of birds. The more dangerous outcome of using these pesticides is that; fish and wild life are unable to reproduce [22]. Following are the steps to grow cotton from seeds;

- 1) Cotton fibers spinning
- 2) Harvestation
- 3) Cleaning
- 4) Manufacturation;
 - a) Cotton fabric spinning
 - b) creation of bolts of cotton fabric by knitting
 - c) fabric dye
 - d) Making smooth fabrics
 - e) Making garments

Step 1. Planning and growing

For growing organic cotton, people work with nature and to enhance the production, the organic farmers use the systems which are biologically based. Organic farmers are trying to manage the hazardous weeds and insects to keep the ecological balance and to secure the environment. 18 countries are growing organic cotton worldwide [23].

The soil

Healthy soil is necessary for organic farming. The soil not only acts as a growing medium for plants, but also a living system for keeping the soil healthy and productive. Synthetic fertilizers can be replaced by compost, efficient nutrient recycling, cover crops and frequent crop rotation [23].

Weed control

Weeds spread can be controlled by hoes and other mechanical implement, rotation of crops, efficient use of irrigation water, intercropping, using mulches and also by adjusting the densities of plants and planting dates [24-29].

Pest control

Farmers can reduce the likelihood of insects, birds or mammals that cause damage to crops by biological diversity. The predator insects, crop rotation, biological pesticides like neem oil and intercropping can be used to control the pests by the farmers [24,30-32].

Step 2. Harvesting

Conventional harvested cotton

Only the chemical woes continue after the toxic disaster of growing season. To make the picking easier, herbicides are used to make defoliate cotton plants during harvesting. The consequences are that the ground water and rivers are get polluted with potentially carcinogenic compounds. The ground is compacted by the large harvesting machinery that reduces the soil productivity [33].

Organic harvested cotton

Organic cotton is usually picked by hand without using machinery, defoliant or chemicals, especially in developing countries and it reduces the waste [33].

Step 3. Cleaning and ginning

There are many processes involved in the manufacturing of cotton fiber into fabrics and garments i.e. cleaning, spinning, knitting, weaving, dyeing, cutting, assembly, and finishing. In the manufacturing of cloth fiber, several cleaning steps are involved. Fiber producers receive processed pants and then remove plant material and waste by dividing and carding the lint. Waste is the mixture of soil, leaves, stems and lint. Cotton is an important source of food and it consists of 40% fiber and 60% seed by weight. After ginning, the fiber is processed in textile mills, while the by-products and seeds are used as food source. The cotton seed oil is commonly used in making of cookies, potato chips, salad dressings, baking products and other processed foods [34,35].

Conventional cotton by-products

The conventionally grown cotton has pesticides residues in the tissues of animals and these end up in meat and dairy products [22].

Organic cotton by-products

The cotton grown organically can be used for production of organic food and it is also valuable in clothing chain [22].

Step 4. Manufacturing

- a) Spinning
- b) Weaving
- c) Knitting
- d) Dyeing
- e) Finishing

Conventionally manufactured cotton

To get soft fibers, the conventionally manufactured cotton is chemically processed and most of the pesticides and herbicides are washed away. There are different chemicals, oils and waxes which are being used in manufacturing. The chemical residues cause problem to multiple chemically sensitive people.

In spinning cotton fibers, when spin into yarn, they remain untouched by chemicals. For easier weaving, the yarn receives a sizing after spinning. Fabric is bleached after weaving. Hydrogen peroxide

and chloride are used for bleaching purpose. At this step, instead of using petroleum scours, formaldehyde, anti-wrinkling agents, chlorine beaches or other unauthentic materials, the manufacturers use the natural alternatives such as natural spinning oils which helps for spinning, potato starch which helps for sizing, hydrogen peroxide helps in bleaching, low-impact dyes and earth clays help in coloration, natural vegetable, minerals inks and binders help for printing on organic cotton fabric. These natural alternatives have decreased the hazards which are caused by manufacturing of conventional cotton fabric [36].

Limitations

The increasing interest of large brands and retailers in the organic cotton sector might bring several challenges to the sector in the coming years because it is not yet well recognized by the International cotton community. Organic cotton must counter the overall sustainability challenges like soil fertility, water management, the hard weather conditions, food security and land competition. The areas where the use of synthetic inputs is much high in conventional farming, the conversion to organic is more difficult and expensive. The products of 'in-conversion farming' cannot be sold as 'organic' and don't get much market value, which is the major barrier to adopt the organic agriculture[37]. Likewise, in many areas in the world, organic cotton production is not yet established as a cost-effective alternative for conventional farmers. Moreover it is technically difficult to attain proper yield and income in Organic agriculture. Another hurdle is the growing importance of GM cotton and the cost to separate the fields to prevent its cross contamination. As the fiber, thread, fabrics and garments of Organic cotton cannot be distinguished from conventional and GM cotton, so the main barrier for Organic cotton production is to find its market that will pay value-added costs of production, labor cost, challenges and competition from International organic cotton organic cotton production has not been extended to other countries because of many reasons. During the 1990s, nineteen countries attempted to produce organic cotton but many of them have to stop its production because of the economic reasons. As Insecticides are dangerous to apply, have long-term effects on the pest complex, and harmful effects on the environment so they are needed to be eliminated from the cotton production system [38]. That's why many counties had been pushed out of the cotton production because of the intense dependence on pesticides. In 2002, the Organic Fiber Council of the Organic Trade Association contacted all organic cotton farmers in the USA and tried to collect information to identify the problems with organic cotton production in the USA, through a survey. The two main issues focused in survey were:

1. cost of production of organic cotton vs. conventional cotton
2. price premium on organic cotton

According to the survey, the main problems faced by organic cotton producers are weed management and defoliation due to the prevention of herbicides usage, insect control and seed treatment which is not allowed in organic production [39,40]. In the USA, defoliation is a serious problem in organic cotton than handpicked cotton because organic cotton has to be picked by machines. The following aspects have limited the development of organic cotton production. If organic cotton production is to expand than Proper measures must have to be adopted to encourage suitable production practices. Some of the following points may be specific to cotton, but most others will apply to general organic production.

Suitable Varieties

In all nineteen countries mentioned above the production of current varieties have been replaced with organic cotton. Commercially grown varieties have been tested and developed for high input conditions. Under such conditions, any genotype has not been performed [41].

Production Technology

For the production of conventional cotton the best use of inputs and production practices is required. The availability of technology package might differ in different countries might differ, but in most of the countries, it is freely available and delivered directly to the farmers' doorsteps by the extension service. This technology package comprises of complete guideline for a producer, from start to all the way until the cotton is sold, to achieve maximum yield including guidance from variety selection, soil preparation, planting time weeds elimination, watering, insect control, picking and storage of seed cotton [42]. Similarly farmers need advices for the production of organic cotton as well; otherwise there can be a high risk for their investment. Unluckily, advice available for organic cotton is far less than the technology packages of conventional production. Furthermore, the removal of fertilizers, pesticides and other agrochemicals would make organic cotton more difficult to grow and organic cotton growers don't have sufficient advice on suggested production practices [43].

Lack of Information on Cost of Production

Unfortunately, under a variety of production conditions information available on cost of production of organic cotton is also very less as compared to the conventional production. That's another reason for farmers to be reluctant to adopt organic cotton production [44].

Application of Biotechnology in the Processing of Textile Fabrics

In the last few years the field of Biotechnology, has made rapid developments in genetic engineering due to which the *in vivo* production of commercially important conventional as well as novel metabolites and transferring of genetic material from one organism to another have been made possible. The technical advancement in the life sciences enables Industrial biotechnology to develop commercial products or to incorporate in the industrial practices. The use of Enzymes in the agriculture, food, leather, paper and textile industries has enhanced the product quality and significantly reduces the cost and environmental pollution. The impetus of biotechnology to produce modified fibers and improving the yields of existing fibers is being studied. Using large-scale fermentation equipment biocompatible and biodegradable biopolymers are now being manufactured for the production of Novel fibers [45]. Natural biological fibers synthesized from natural raw materials having properties of synthetic fibers have penetrated the textile industry. To achieve a sustainable bio based economy in textile manufacturing, chemical processes have been replaced with enzymatic methods. A critical requirement to support a sustainable development of our society with little environmental impact is the exclusion of a large variety of waste and other contaminants from the environment. Biological processes play a major role in this context. Otherwise, the move towards a more bio based economy may end up in depleted renewable resources and environmental degradation [36]. The use of enzymes in fiber production has made the way for exploring new opportunities in the textile industry. But for the bio modification of synthetic and natural fibers with enzyme-based processes, further research is needed to be done [46].

Environment-Friendly Textile Processing Using Plasma and UV Treatment:

In textiles industry a large quantity of water is required as a wet chemical processing medium which is ultimately discharge as a waste matter polluted with left over dyes and other toxic chemicals. On the other hand, if this processing medium is replaced with plasma and UV photons then it can be well used for Nano scale surface engineering of a variety of fabric substrates. The use for Plasma- and UV photons for surface activation, oxidation, etching, surface roughness, and polymerization of substrates have also improved the water and oil absorbency, coloring, printing and antistatic properties. By UV treatment specialty fabrics with one side hydrophilic and other hydrophobic side could also be produced. Conversely, pinhole-free hydrophobic textiles can also be developed by *in situ* plasma reaction after the fragmentation of a precursor molecule in the plasma zone. In plasma and UV methods, a minimum amount

of chemicals and energy is required as only the surface of the sample is modified furthermore shorter processing time, elimination of multistep procedures and less waste matter treatment results in minimized cost of the final product. In addition, plasma and UV-treated samples need less dyeing time, temperature and dye bath accessories to accomplish similar or better shade as compared to the untreated samples [21,23].

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11/25/2016