

# Chapter 30

## Diverse Uses of Cotton: From Products to Byproducts



**Hassan Munir, Fahd Rasul, Ashfaq Ahmad, Muhammad Sajid, Salman Ayub, Muhammad Arif, Pakeeza Iqbal, Amna Khan, Zartash Fatima, Shakeel Ahmad, and Muhammad Azam Khan**

**Abstract** Cotton is a multifaceted crop of which wholesome or all parts individually can be used for their byproducts in addition to their domestic or economic uses. It provides lint raw material to an ever-increasing textile industry, cotton seed oil for culinary purposes, and edible oil and protein-rich oil cake residue for livestock. Cotton can benefit human being through its sticks, fibers, seed, and oil as the primary products, whereas several secondary products are manufactured by utilizing these

---

H. Munir (✉) · F. Rasul · M. Sajid · S. Ayub  
Department of Agronomy, University of Agriculture, Faisalabad, Pakistan  
e-mail: [hmbajwa@uaf.edu.pk](mailto:hmbajwa@uaf.edu.pk)

A. Ahmad  
Department of Agronomy, University of Agriculture, Faisalabad, Pakistan

US.-Pakistan Centre for Advanced Studies in Agriculture and Food Security, University of Agriculture, Faisalabad, Pakistan

M. Arif  
Department of Agronomy, University of Agriculture Peshawar, Peshawar, Pakistan

P. Iqbal  
Department of Botany, University of Agriculture, Faisalabad, Pakistan

A. Khan  
Department of Agronomy, Bahauddin Zakariya University, Multan, Pakistan

Department of Agronomy, University College of Agriculture, University of Sargodha, Sargodha, Pakistan

Z. Fatima  
Department of Agronomy, Bahauddin Zakariya University, Multan, Pakistan

S. Ahmad  
Department of Agronomy, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan, Pakistan  
e-mail: [shakeelahmad@bzu.edu.pk](mailto:shakeelahmad@bzu.edu.pk)

M. A. Khan  
In-Service Agriculture Training Institute, Sargodha, Sargodha, Pakistan

components of cotton. Cash crop appraisal is, however, based on its multifaceted uses, and a significant proportion in value added in agriculture is well established through cotton textile, hosiery made-up, and raw and fine products of cotton apart from its use in many surgical products.

**Keywords** Textile · Fuel · Fiber · Lint · Cash crop · Seed

## 30.1 Introduction

Cotton is distinguished as a source of natural fiber since the very early human civilization due to its need to provide basic clothing and hence was identified as an important plant species for mankind (Fryxell 1979; Ahmad et al. 2014, 2017, 2018; Abbas and Ahmad 2018; Ahmad and Raza 2014; Ali et al. 2011, 2013a, b, 2014a, b; Usman et al. 2009). At present, cotton is among the top fiber crops that are being grown on a vast area belonging to nearly 50 nations across the globe. The regions of cotton cultivation comprise of temperate to tropical conditions with efficient commercial cotton production (Smith and Hirth 1988; Amin et al. 2017, 2018; Khan et al. 2004; Rahman et al. 2018; Tariq et al. 2017, 2018; Usman et al. 2009). Cotton is presently considered among the top 20 important crops where its appraisal is different from other crops as it is not a staple crop (Wendel et al. 2010). Cotton ranks first among fiber crops across the globe. Its fiber is known as “king of the fibers” which has the ability for being naturally absorbent, permeable, soft, and viable as well as durable with no skin rashes and allergies when meeting human skin. For being a natural thread, cotton lint-based fabric is never undesired for its origination from waste material as compare to chemically made threads in which a lot of waste material is involved during different steps of manufacturing. Apart from its fiber appraisal, cotton is among the top ten crops for its appraisal as oilseed, a rich source of edible oil. In addition, cotton is being modified in terms of its genetics, and transgenic cotton is counted among the crops with greatest area under cultivation across the globe (FAOSTAT 2012). Fiber staple of cotton is worth to be knitted or woven into a variety of fabrics, for example, corduroy, velvet, jersey, velour, and chambray. Furthermore, cotton is used at a large scale in making fishnets, archival papers, in binding of books and stationery, food packaging, feed seedcake, pillows, and quilts. After the extraction of oil from cotton seed, the remaining part which is known as “cotton seed cake” is being fed to cattle and is especially a rich source of energy for ruminants. Cotton seed left over considered as waste after extraction of oil is named “banola (Urdu), wareva (Punjabi), and seed cake (English).” Cotton seed oil is used in cooking after blending it with different other edible oils in a variety of goods like margarine, cosmetics, pharmaceuticals, rubber, soap, emulsifier, fattening, vanaspati ghee, and plastics. The short fiber residue of cotton seed named linters left as waste after ginning are used to produce products like bank notes, X-ray films, swabs, cotton buds, bandages, etc. In this chapter, an attempt has been made to

colligate the major uses of products of cotton and its byproducts covering all portions of the cotton plant, i.e., raw, refined, and finished goods.

## **30.2 Raw Uses**

### ***30.2.1 Cotton Sticks***

Cotton was cultivated on approximately 2,489,000 hectares in Pakistan, and the production was 10,671,000 bales during the fiscal year 2016–2017 (Economic Survey of Pakistan 2017). Cotton stick is the major residue that contributes threefold of the lint weight obtained from cotton plant. In rural areas of Pakistan and many agrarian economies of the world, cotton sticks are mostly appraised for fuel. The amount of cotton crop residues, called with different names, i.e., cotton straw, cotton sticks, cottonwood, etc., usually volumes from 5 to 7 tons/hectare (Silanikove and Levanon 1986). Hence, cotton sticks are referred as the biofuel for domestic energy consumption starting from the stove to kiln; however, bioenergy reactors or gasification chambers can be the source of utilization of these sticks in this energy scarce arena.

### ***30.2.2 Baskets***

Making baskets from different parts of cotton benefits not only at domestic level, but it is also being utilized for marketing a number of vegetables, fruits, and other industrial products. Because of the strength of cotton plant sticks, their rigid parts are used to make strong baskets. Good and fine quality fibers can also be used in making enormous art products like wall hangings, gift packings, and closet boxes.

### ***30.2.3 Fences and Cages***

Making fences is another efficient use of cotton stick. Semi-dried cotton sticks can be flexible for being knitted like a woven web, or it can be moistened for the said purpose to make it flexible. Such fences are cost-effective for the small households in addition to keeping pets and birds by making cages with same sticks.

### **30.2.4 Cotton Bolls**

Cotton lint grows in a fluffy round and sound clumps (Locales) and is called boll. These fluffy fiber clusters or bolls are living cells with outer walls surrounding the cytoplasm. The outer wall of cotton fiber is made up of several layers of microscopic fibers mainly composed of cellulose and microfibrils. In raw conditions, the fiber is an almost pure cellulose sheath with a fine coat of wax which makes it hydrophobic or “waterproof.” The top-notch utility of cotton is to make fine fiber and knit the textile. Linters are undersized fibers called fuzz on the seed coat; those can be used as source of cellulose in order to make plastics, explosive material, and many other products. These fuzzy fibers are not being utilized for making cloth but help make lining used for making furniture in addition to quality paper manufacturing. Furthermore, bumpers, dashboards, and other plastic-oriented car or vehicle parts and mattresses are made from this fuzzy material. Cotton fiber is naturally either white or colored. There are varieties that produce brown, khaki, yellow, and greyish-green fibers. The American Indian natives usually utilized colored cotton, while in modern and industrialized countries, the development of chemical dyes increased demand for colorless lint.

### **30.2.5 Cotton Lint/Fiber**

High durability has made cotton renewable; hence, its fiber can be used in a variety of man’s ways (Chen et al. 2007). Lint from cotton plant is twirled and then woven into fabrics, i.e., chambray, velvet, velour, corduroy, jersey, and flannel. Sixty percent of the world’s net cotton harvest is utilized in making cloth, while the rest is used in industrial products and home furnishings. Most renowned cotton products include t-shirts, denim jeans, towels, socks, bedsheets, and underwear etc. Fiber is also used in tentage making, car tires, ropes, fishnets, and book bindings. Its fiber is used in different home textiles, i.e., rugs, blankets, diapers and tampons, window coverings, and face masks etc. Fine fiber can be used in the production of currency, papers, stationery items, art papers, degrees, and document folders etc.

### **30.2.6 Cotton Locule**

Locule means a cavity of the ovary in which ovules develop or preserve. Locules carry the cotton seeds in them which can be utilized in numerous ways. Three products including meal, hulls, and oil were obtained after the crushing and isolation of cotton seed. Oil is used for salad dressing and cooking and as vegetable shortening. The meal and hulls are used as feed for poultry, fish meals, and feed for livestock as well as fertilizer separately or in combinations. Cotton trash in the form

of leaves and stalks can be mixed with soil to trigger its fertility status for being a source of organic matter. Cotton seed is also used in high protein concentration for making baked food products. As far as the aesthetic purposes of locules are concerned, these can be used in interior decoration and can be made scented and colored using dyes and fragrances.

### 30.3 Cotton Seed

More than half of the cotton (cotton seed) consists of seed, a beneficial byproduct gained during production of fiber. One ton of cotton seed can contribute to 1/3 of seed coat, while nearly 20% oil can be extracted from it, and half of this seed after pressing can even be used as animal meal (Cotton Australia 2018). Cotton seed meets the protein need of half of a billion people and many billions of animals across the globe. The most common utilizations of cotton seed are oil for cooking and feeding the livestock animals. Cotton seed is crushed or pressed to get cotton seed oil with a number of utilizations starting from domestic up to industrial avenues. While processing the seed of cotton, cleaning is done as first step, and this continues even up to the extraction of pharmaceutical or industrially important compounds such as gossypol. Removing dirt, inert matter, plant debris, and short fine fibers is among the cleaning procedures to get fine cotton important for making quality paper. Technically, paper composed of both small and long staple having fibers is more durable as it resists mishandlings easily. Even printing currency is worth based on certain blends of cotton and linen, such as 1/4 linen and 3/4 cotton blend is used to print dollar bills that costs 9.6 cents/dollar size bill (Kavilanz 2011). Cotton seed can be cooked as meal and is commonly used to feed livestock and cattle as it's a rich source of energy. Seed oil can also be used in making of various industrial goods, i.e., margarine, soap, emulsifiers, pharmaceuticals, cosmetics, rubber, candles, water proofing, etc. Cotton seed oil has a profound quality that it is free of cholesterol; it is having high amounts of polyunsaturated fats and has massive amount of antioxidant (vitamin E) which increases the shelf life of chickens, pigs, and rabbits, among others.

### 30.4 Lint Uses

#### 30.4.1 Raw Fabric Making

Fabric initially woven from the cotton thread is named grey cloth. Such weaving is highly dependent on spinning process in which staples of cotton are spun and cotton thread is being made (Smith and Hirth 1988). Process involved in fiber making comprising of conversion of raw cotton to thread is called "spinning," and the other where the thread is changed into fabric is called "weaving." Textile manufacturing is

based on basic steps such as spinning and weaving of cotton. These processes have become technically advanced and are now done by blending precious materials such as the addition of feathers, beads, bird feathers, etc. Such processed products are valued in the elite community of the society since long (Follensbee 2008). Raw cotton is used in medical field for making medical swabs and bandages and in other related products and surgical affairs, because it can easily be sterilized and can also be used to cover or wrap the wounds.

### ***30.4.2 Fine Cotton (or Chintz)***

Fine cotton is 100% cotton fabric as well as fine and basic cotton. Fine cotton has a plain weave, but as compared to the basic cotton, it is lower in weight and softer too as it is generated from fine yarns. Various types of fine cotton are produced, i.e., dyed, bleached, and printed. When it is at a temperature which is not more than 60 °C, it ensures the long-lasting or permanent color.

Glazed calicos are termed chintz and those were imported from India subcontinent for use as clothing stuff. These glazed chintz are fine enough to be printed and decorated and can be stuffed with material from bird feathers and can also be used for making drawings, flowers, etc., with half tone designing. A number of uses of chintz are found in households like bedlinen, window decorations and shades, and installation with delicate clothing having resistance to stains of different origin particularly from dirt. Furthermore, at times these chintz are parts of a dress of feminine gender and kid garments particularly during summers.

### ***30.4.3 Cotton Rope and Twine***

Cotton ropes are an important commodity for domestic as well as for industrial uses. Ropes are being used from knitting charpais (Indian woven bed) to making anchor supporting ropes. From tying to knotting and from binding to making spirals, every flexible binding is based on use of cotton ropes. Twine is a light weight string or strong thread composed of two or more than two smaller strands lashed and then got twisted together. Natural twine is used in various forms like sewing upholstery, making rugs, jewelry making, packaging, weaving nets, wrapping things, critical household applications, food services, meat packing, advertising, and assorted industrial uses. It is also used to tie up a turkey, roast, and various poultry or meats prepared for rotisserie, grilling, or oven. Just keep it away from the open flame. Furthermore, it is used to tie up stuffed chicken breasts and meat roll ups, holding up the delicious ingredients inside. One can tie parcels or herb bouquets and gift tags or presents using a twin.

### **30.4.4 Textiles**

Textile products are used by all of us and not just for aesthetic reasoning. We use them for protection against hazardous elements, to improve our quality of life, for safety purposes, and even for technical reasons. Textiles are highly esteemed commodities like bullion and emerald and were signified when used by status quo in the old era.

Textiles are classified as described by Bergan (1987).

#### **30.4.4.1 Clothing**

For being rich, elite community of the society used cotton garments in the ages when it was real-time scarce due to low production and less yield potential of cotton varieties. Still its fineness in the merit of its worth and cost of cloth varies with it; hence, consider it well regarded among the fibrous crops such as yucca and maguey. Clothing made from cotton is having additional uses in the household, such as kitchen napkin, hand gloves, and covers.

#### **30.4.4.2 Armor Manufacture**

Textiles were an important element of armors natively called “ichcahuipilli” in Mexican civilization from where upland cotton originated. In many civilizations, battles and wars were ranked among the most substantial sacramental and sacred inferences, and combatants were exceptionally stasured. Battle armory was designed with ample use of cotton clothing in combination with bird fluffs so that combatant could carry them easily for being lighter in weight.

## **30.5 Sociopolitical Significance**

In Asian environment, silk route was also named textile route and was based on long travel associated with business activities as well as supply of the basic needs to humans in far flung, less privileged areas by crossing Pamir heights and through the Himalayas. A trajectory of wearing precious, fine, and attractive clothes was highly respected since the dark ages, and people were dealt on the basis of what they had worn. Even today, clothes are the symbol of recognition when the world has become a small village and people are interacting across the borders frequently. Textiles and fine cloth were part of the decorative clothings worn by idols and gods in the old civilizations of Euphrates or in the Mesoamerican Myths.

## **30.6 Economic Commodity**

As far as the bartered trade system of the past is concerned, textiles remained among the top precious commodities to be bartered. Such exchanges were historically reported against spices in India before Christ. For being a light weight commodity, cotton clothings were carried for longer distances for ease in travel and were marketed with high prices in order to get grains and other precious commodities in many folds by weight. Even today, cotton made-ups are being exported as costly commodities and are a source of heavy foreign exchange earnings in the matter of financial status of any nation or country across the world.

### **30.6.1 Bags**

In daily routine life, cotton bag is an important and handy product that if made from natural cotton fiber will completely serve as eco-friendly; hence, cotton is completely biodegradable in nature. The cotton bag material is free of any environmental hazard and made of pure fiber. These bags can easily be washed when they are dirty and can be used again and again for a long time. The surface of cotton bags is very suitable for designing or printing and, therefore, can be used as promotional material. Furthermore, these bags can be used for packing, shopping, etc. Customers like to get a cotton bag in order to carry lightweight items like gifts, garments, etc., due to the smooth and light nature of the fabric.

### **30.6.2 Rugs and Carpets**

Central and Western Asians developed carpets first as coverings for beaten/broken earth floors. From old times, carpets covering the floors of houses and tents as well as mosques and palaces were made from cotton thread. In the homes of elite eastern families, floor coverings serve an aesthetic as well as a pragmatic function. Rugs are often arranged in a traditional arrangement, partially to allow for simultaneous display; the size of carpet and shape are determined by the selected place within that arrangement.

### **30.6.3 Towels**

Towels are a basic everyday need to sponge out the wetness. These are necessarily required from their need while working in kitchen to taking shower in the bathrooms in addition to other cleaning purposes. Towels are made up of good quality cotton



material with high absorbance and durability. Cotton-made towels are destined for their softness and their property for not infecting skins with any allergy. However, they are quickly washable as well as their cleanliness is near to excellence too. They are good on skin because they are not made from any petrochemicals.

#### **30.6.4 Paper**

While manufacturing paper, durability, resilience, and price affordability are always kept in mind. Hence, making paper for longer durations, in superior quality for a variety of objectives such as printing, dyeing, painting, etc., and avoiding age-based deterioration are among the targets. Cotton-based paper luckily has all these characters; however, variation is found from lot to lot and patch to patch. Many of the important documents are being written on paper made from cotton since the very past. Today, important documents, registries, agreements, and govt. sector archives are being executed using quality cotton paper; even academic degrees and manuscripts are being printed on such papers with cotton as constituent with varying compositions from 25% to 100%. Light penetration and crossing is one useful method to assess the quality of paper; hence, holding paper in the direction of light can help us understand how good that paper is. Market value in paper industry is ruled by acid-free paper across the world for being the most precious one; hence, offset paper is a term used for getting white, colorable, printable, and durable paper for official and durable needs.

#### **30.6.5 Hosiery**

Hosiery is a stuff which is worn by human as an expounded outfit, as vests, linings, and undergarments. These are the products which are categorized on the basis of denier or opacity. Five to 15 lower denier measurements explain a tendency to become absorbent that can be fragile as per its look, where forty and above denier stuff is impenetrable to light. Hosiery articles are among the largest cotton commodities being consumed regarding dressing, sports, and aerobics purposes.

#### **30.6.6 Surgical Uses**

In addition to cotton dressing and clothing uses as garments, surgical appraisal of cotton is one important avenue of cotton utilization. In old times natural fiber is used in many processes. One of the earliest examples is the use of fibers in healthcare facilities for wooden dentures. Cotton fiber has been used in healthcare due to its softness, purity, hypoallergenic purity, and absorbency properties. Cotton can also

be sterilized by all three major sterilization methods such as steam, gamma radiation, and ethylene oxide. Undocumented use of cotton seed as food remained for long in the Mesoamerican civilizations. Roasting of seed for edible purpose is still part of rural households in scarce areas of the region. In addition, cotton seed use for abortion of men semen is also known. The families with edible use of cotton oil were having less birth rate that later proved in the form of sterility and retarded potassium absorption to a serious extent. Certain studies were also found that birth control can be ensured by dietary use of cotton seed or oil in reduced concentrations for those men who wish no more children in the days to come (Coutinho et al. 2000).

Cotton seed has a gland termed as “gossypol gland” responsible for secretion of an alkaloid substance “gossypol” with high anti-nutritive significance. During late 1980, human immunodeficiency virus (HIV) has emerged as real time threat to mankind for which a number of treatments were considered for their potential impact on reduced epidemiology of this virus disease. Gossypol was found to be effective for both traditional mean of cure as well as its significance as substitute medicine (Polsky et al. 1989; Ratsula et al. 1983).

Injuries based on unlucky incidence are part of human and animal life for being warm blooded in nature. Saving blood by stitching the wounds is one empirical solution to avoid excessive blood loss. Statures used for this purpose at once help life sustain under any time of injury or surgery. Cotton thread used for the purpose is one most suitable as it has the tendency to be used in pure or in blended form related to the kind, nature, and extent of injury. Many thread types are in practice today with dissolvability or non-dissolvability in the human or animal body. Thus, pure cotton such as original catguts (polydioxanone) or cotton-blended threads such as caprolactone, proline polyglycolic acid, polylactic acid, etc., for saturating the wounds are key tools of almost all surgeons today. In addition, a number of polymer-based threads are also used for surgery purposes with absorbable character.

Blood choking and coagulation is one needed attribute to immediately relieve the patient from hazard. For the purpose, cotton gauze or sponges are being employed by the surgeons. Being biodegradable and absorbent to slurry type secretion and blood, such gauzes help to act like sponges and dry wounds to initiate the healing process. During surgery sponges called gauze sponges with different sizes. It is also worth to mention that the nonwoven material or gauzes help remediate more efficiently than the ones being made with woven lint of cotton. Another advantage of cotton-based gauzes is that we can make them sterile with little effort as compare to other materials. Latest technology has suggested use of some blended materials for the same purpose; however, the significance of cotton-based gauzes is still valid and superseded them.

Healing bigger wounds or injuries are highly dependent on cotton-based bandages particularly in case of major operative procedures. Bandages are mainly designed to restrict the movement of injured part of the body. Bandages are part of the dressing and hence support the procedures undertaken for improving skin tissues and abrasions. Other uses of bandage are based on their types such as “elastic bandages;” those are used to provide support or to reduce the swelling on an uneven part of human body. Bandages used tightly can help reduce the flow of blood to the

suburbs of a crack or wound and hence help give tissue a chance to recover in case of heavy bleeding conditions. A wide range and types of bandages such cloth slips and flexible bandages are available in the market; those can be improvised keeping in view the conditions of the wound as well as the wound location and purpose of improvisation. Absorbent cotton is usually a bleached, non-lubricated fine piece of sheath available in different dimensions. Absorbent type of bandages is often in direct contact of human body; hence, these should be free from any risk of human health and meet the pharmaceutical parameter. Absorbent cotton is also termed as wool cotton. Excessive use of it in surgical traumas named it as “surgical cotton” too. Cotton wool is used mainly in nursing home, dispensaries, hospitals, etc., because it has high absorbency power, due to absorbent. Today, baby diapers and other absorbent type of cotton commodities are popular for daily life use and consume a lot of capital.

### ***30.6.7 Biodegradable Packaging***

The step which combine the fungicide inside a cast and gin waste called a “tool” where the two-component combine to result in spongy material same in the appearance of thermopore sheet. Such thermopore or polystyrene type spongy material obtained from cotton provides a cheap and environment-friendly alternative to get things packed. Volume of this type of intervention is as larger as \$2 billion in the market.

### ***30.6.8 Embroidery***

Cotton is spun manually (by hand) for its fine-tuned utilization as stuff for embroidery of dresses. In Pakistani environment, needed work-based embroidery is very popular; hence, the use of this sort of six-stranded, twisted thread is highly demanded here. Quality stitch is the base of such popularity in such embroidery, and their use is dated back to sixteen century. Few more uses are also mentioned below:

- Matte-Finish cotton is a French type used on borders of the cloth often named as French border cotton.
- Two-ply and spiral, twisted cotton thread is named pearl cotton with a variety of thickness starting from 3 to 16 finca, i.e., from heaviest to finest, respectively.

## 30.7 Conclusion

Cotton is a multifaceted crop of which wholesome or all parts individually can be used for their byproducts in addition to their domestic or economic uses. Cotton can benefit human being through its sticks, fibers, seed, and oil as the primary products, whereas several secondary products are manufactured by utilizing these components of cotton. Cash crop appraisal is, however, based on its such multifaceted uses, and a significant proportion in value added in agriculture is well established through cotton textile, hosiery made-up, and raw and fine products of cotton apart from its use in many surgical products as mentioned in above paragraphs. The team of authors foresee that the use of this silver line thread can, however, be a savior of human life in future climate change scenario from high temperature, skin dryness, and respiratory infections, a need of today and the days to come.

## References

- Abbas Q, Ahmad S (2018) Effect of different sowing times and cultivars on cotton fiber quality under stable cotton-wheat cropping system in southern Punjab, Pakistan. *Pak J Life Soc Sci* 16:77–84
- Ahmad S, Raza I (2014) Optimization of management practices to improve cotton fiber quality under irrigated arid environment. *J Food Agric Environ* 2(2):609–613
- Ahmad S, Raza I, Ali H, Shahzad AN, Atiq-ur-Rehman, Sarwar N (2014) Response of cotton crop to exogenous application of glycinebetaine under sufficient and scarce water conditions. *Braz J Bot* 37(4):407–415
- Ahmad S, Abbas Q, Abbas G, Fatima Z, Atique-ur-Rehman, Naz S, Younis H, Khan RJ, Nasim W, Habib ur Rehman M, Ahmad A, Rasul G, Khan MA, Hasanuzzaman M (2017) Quantification of climate warming and crop management impacts on cotton phenology. *Plants* 6(7):1–16
- Ahmad S, Iqbal M, Muhammad T, Mehmood A, Ahmad S, Hasanuzzaman M (2018) Cotton productivity enhanced through transplanting and early sowing. *Acta Sci Biol Sci* 40:e34610
- Ali H, Afzal MN, Ahmad F, Ahmad S, Akhtar M, Atif R (2011) Effect of sowing dates, plant spacing and nitrogen application on growth and productivity on cotton crop. *Int J Sci Eng Res* 2(9):1–6
- Ali H, Abid SA, Ahmad S, Sarwar N, Arooj M, Mahmood A, Shahzad AN (2013a) Integrated weed management in cotton cultivated in the alternate-furrow planting system. *J Food Agric Environ* 11(3–4):1664–1669
- Ali H, Abid SA, Ahmad S, Sarwar N, Arooj M, Mahmood A, Shahzad AN (2013b) Impact of integrated weed management on flat-sown cotton (*Gossypium hirsutum* L.). *J Anim Plant Sci* 23(4):1185–1192
- Ali H, Hameed RA, Ahmad S, Shahzad AN, Sarwar N (2014a) Efficacy of different techniques of nitrogen application on American cotton under semi-arid conditions. *J Food Agric Environ* 12(1):157–160
- Ali H, Hussain GS, Hussain S, Shahzad AN, Ahmad S, Javeed HMR, Sarwar N (2014b) Early sowing reduces cotton leaf curl virus occurrence and improves cotton productivity. *Cercetări Agronomice în Moldova XLVII(4):71–81*
- Amin A, Nasim W, Mubeen M, Nadeem M, Ali L, Hammad HM, Sultana SR, Jabran K, Habib ur Rehman M, Ahmad S, Awais M, Rasool A, Fahad S, Saud S, Shah AN, Ihsan Z, Ali S, Bajwa AA, Hakeem KR, Ameen A, Amanullah, Rehman HU, Alghabar F, Jatoi GH, Akram M,

- Khan A, Islam F, Ata-Ul-Karim ST, Rehmani MIA, Hussain S, Razaq M, Fathi A (2017) Optimizing the phosphorus use in cotton by using CSM-CROPGRO-cotton model for semi-arid climate of Vehari-Punjab, Pakistan. *Environ Sci Pollut Res* 24(6):5811–5823
- Amin A, Nasim W, Mubeen M, Ahmad A, Nadeem M, Urich P, Fahad S, Ahmad S, Wajid A, Tabassum F, Hammad HM, Sultana SR, Anwar S, Baloch SK, Wahid A, Wilkerson CJ, Hoogenboom G (2018) Simulated CSM-CROPGRO-cotton yield under projected future climate by SimCLIM for southern Punjab, Pakistan. *Agr Syst* 167:213–222
- Bergan FF (1987) Cotton in Aztec Mexico: production, distribution and uses. *Mexic Stud* 3 (2):235–262
- Chen Y et al. (2007) Potential of agricultural residues and hay for bioethanol production. *Appl Biochem Biotechnol* 142(3):276–290
- Cotton Australia (2018) Cotton Australia Annual 2018. Australian Cotton Industry Statistics, New South Wales
- Coutinho EM, Athayde C, Atta G (2000) Gossypol blood levels and inhibition of spermatogenesis in men taking gossypol as a contraceptive. A multicenter, international, dose-finding study. *Contraception* 61(1):61–67
- Economic Survey of Pakistan (2017) Cabinet Division. Ministry of Finance, Govt. of Pakistan, Islamabad
- FAOSTAT (2012) Searchable online statistical database. Food and Agriculture Division of the United Nations, Rome. Available at: <http://faostat.fao.org/>. Accessed Apr 2019
- Follensbee BJA (2008) Fiber technology and weaving in formative-period gulf coast cultures. *Anc Meso* 19(1):87–110
- Fryxell PA (1979) The natural history of the cotton tribe (Malvaceae, tribe Gossypieae). Texas A&M University Press, College Station, TX
- Kavilanz P (2011) Dollar bills are made of cotton. CNN-Money. Available at: [http://money.cnn.com/2011/03/08/news/economy/dollar\\_cotton\\_prices/](http://money.cnn.com/2011/03/08/news/economy/dollar_cotton_prices/). Accessed Mar 2019
- Khan MB, Khaliq A, Ahmad S (2004) Performance of mashbean intercropped in cotton planted in different planting patterns. *J Res (Sci)* 15(2):191–197
- Polsky B, Segal SJ, Baron PA, Gold JW, Ueno H, Armstrong D (1989) Inactivation of human immune-deficiency virus in vitro by gossypol. *Contraception* 39(6):579–587
- Rahman MH, Ahmad A, Wang X, Wajid A, Nasim W, Hussain M, Ahmad B, Ahmad I, Ali Z, Ishaque W, Awais M, Shelia V, Ahmad S, Fahad S, Alam M, Ullah H, Hoogenboom G (2018) Multi-model projections of future climate and climate change impacts uncertainty assessment for cotton production in Pakistan. *Agric For Meteorol* 253-254:94–113
- Ratsula K, Haukkamaa M, Wichmann K, Luukkainen T (1983) Vaginal contraception with gossypol: a clinical study. *Contraception* 27(6):571–576
- Silanikove N, Levanon D (1986) Cotton straw: composition, variability and effect of anaerobic preservation. *Biomass* 9:101–112
- Smith ME, Hirth KG (1988) The development of prehispanic cotton-spinning technology in western Morelos, Mexico. *J Field Archaeol* 15(3):349–358
- Tariq M, Yasmeen A, Ahmad S, Hussain N, Afzal MN, Hasanuzzaman M (2017) Shedding of fruiting structures in cotton: factors, compensation and prevention. *Trop Subtrop Agroecosyst* 20(2):251–262
- Tariq M, Afzal MN, Muhammad D, Ahmad S, Shahzad AN, Kiran A, Wakeel A (2018) Relationship of tissue potassium content with yield and fiber quality components of Bt cotton as influenced by potassium application methods. *Field Crop Res* 229:37–43
- Usman M, Ahmad A, Ahmad S, Irshad M, Khaliq T, Wajid A, Hussain K, Nasim W, Chattha TM, Trethowan R, Hoogenboom G (2009) Development and application of crop water stress index for scheduling irrigation in cotton (*Gossypium hirsutum* L.) under semiarid environment. *J Food Agric Environ* 7(3–4):386–391
- Wendel JF, Brubaker CL, Seelanan T (2010) The origin and evolution of *Gossypium*. In: Stewart JM, Oosterhuis DM, Heitholt JJ, Mauney JR (eds) *Physiology of cotton*. Springer, Dordrecht, pp 1–18