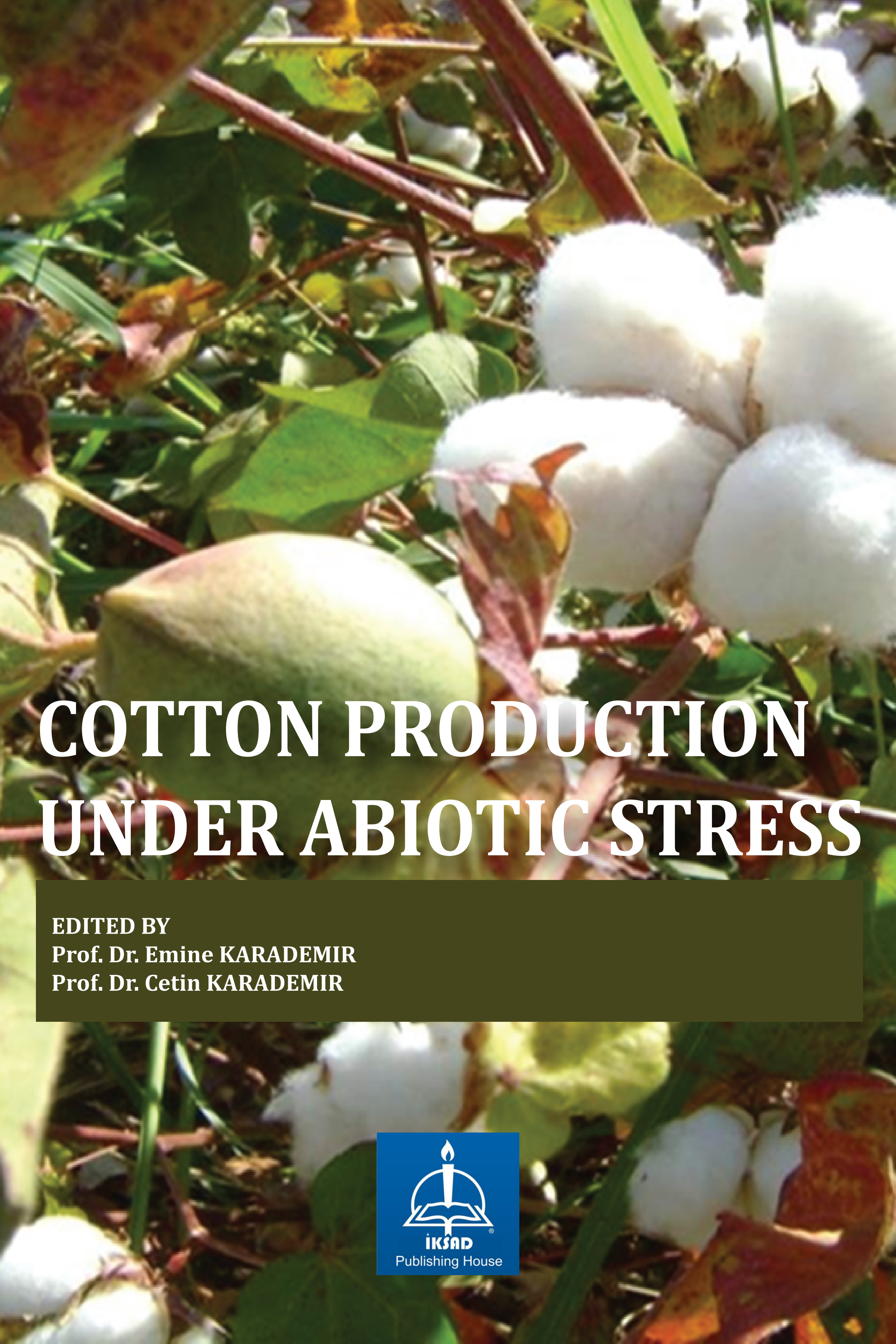

COTTON PRODUCTION UNDER ABIOTIC STRESS

EDITED BY
Prof. Dr. Emine KARADEMIR
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PREFACE

Cotton is one of the most important strategic fiber crops in the global textile industry and plays a significant role in the industrial and agricultural economy of the country. Turkey has an important place in terms of cotton yield and production in the world. Cotton is not only providing raw material for textile industry, but also its by-products have economic development of Turkey. However, global warming which is effective throughout the world and consequently high temperature and drought stress leads to reductions in cotton yield and fiber quality. Climate change probably will affect cotton production in world especially through changes in temperature, rainfall and carbon dioxide concentration.

In Turkey, cotton production has been negatively affected by unfavorable climate conditions from time to time and in recently years, the reduction and the erratic distribution of rainfall negatively affects the yield of cotton and cotton farming. Approximately 60% of Turkish cotton production comes from Southeastern Anatolia Region, where the high temperature is effective (particularly in July and August). If the high temperature accompanies with drought it causes significant decreasing on cotton yield and quality parameters, plant cannot reach its genetic potential, therefore, the environmental stress has significant effect on plant growth.

It is known that greenhouse gas emissions in the atmosphere trigger global warming, it is estimated that the effect of increases in this greenhouse gas in the atmosphere will be slow but permanent in the future. Atmospheric CO_2 concentration will likely exceed by the latter half of the next century (21. Century), and the mean global temperature has been predicted to be 1.5 to 5.9 °C higher than today, and the extreme weather conditions occurring in a development season will increase. It is expected that our country will be negatively affected by increased high temperature and also global warming. The best way for mitigating the negative effects of environmental stresses are development of abiotic stress tolerant cotton varieties and growing them in cotton production areas.

This book reviews various studies and discusses the findings of different experiments carried out to assess impact of climate change on cotton growth and development, physiology and yield throughout the world. We presented some suggestions to reduce the negative effects of climate change on cotton production. We are very thankful to the authors for their valuable contributions and the IKSAD publication house.

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CHAPTER 1

IMPACT OF CLIMATE CHANGE ON COTTON GROWTH AND YIELD

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INTRODUCTION

Cotton is the most significant fiber crop in the world, with an area of 32 million hectares under cultivation (Sami-Ul-Allah et al., 2015). Cotton belongs to the Genus *Gossypium* and the family Malvaceae. Among fifty species of the *Gossypium* genus, 45 are diploid and 5 are allotetraploid. Among these species, only *G. hirsutum* and *G. barbadense* are tetraploid, whereas *G.arboreum* and *G.herbaceum* are diploid, which are presently cultivated (Malik et al., 2014). Cotton plants exhibit a wide range of morphological characteristics, from perennial herbs to small trees (Wendel*et al.* 2009). Basically cotton is a perennial plant but since a long time, it has been cultivated as an annual crop. *G.hirsutum* is grown in bulk all over the world. *G. barbadense* comes in second, it is mostly grown for its high staple length. Also, it is mainly reported to be grown between 37^{o} N and 33^{o} S longitudinal band (Chaudhry and Guitchounts, 2003).

Cotton requires 105-125 days to reach full maturity under normal conditions. Further, cotton also requires suitable conditions in terms of temperature, heat, light, and soil moisture as well. Additionally, the dry season is critical for the bolls to open correctly and be harvested. Due to the vertical tap root system, it is more prone to be affected by water stress or water lodged conditions. It can be grown in areas with an annual rainfall of 700 mm approximately (Ton, 2011).

Cotton can withstand environmental challenges to some extent by using "compensatory growth," for example, if a flower bud is lost, the plant can help to offset instantly by developing a new bud (Sement, 1988).

The cotton plant responds to change in the environment at any stage from emergence to maturation. Extreme climatic conditions can harm the crop at any stage, and it is hard to predict how plants will respond to these changes.

Cotton is the king of fibers is an industrial commodity of worldwide importance. It is one of the important commercial crops playing a key role in the economic and social affairs of the world. The Arabic word Qutun or Kutun has given rise to the English word cotton. Similarly, it is Kateon in Dutch, cotton in French, cotton in Italian, and algodon in Spanish. Despite the recent setbacks, cotton continues to remain the backbone of the Indian rural economy, particularly in dryland areas. Besides being a monetary spinner, it is an employment generator as its cultivation provides the employment to 200 man days per hectare.

Around 60 million people rely on its cultivation, commerce, and processing for a living. The current crises in cotton revolves around the main issues such as rising cost of production, hiked use of pesticides without adequate pest suppression, inability to enhance the production during the bountiful monsoon due to ineffective water management, deterioration in genetic purity of the multitude of cotton cultivars, ineduate price paucity of infrastructure to ensure value addition products at farmers level (Mayee et al., 2002). Given the present market scenario, cotton growers need to reorient their approach to the package of practices that they follow to cultivate cotton. Wasteful input use with wishful thinking of more harvest needs to be dissuaded.

1. TYPES OF COTTON

The genus *Gossypium* is place in Malvaceae family, tribe *G. hirsutum*, *G. barbadense*, *G. herbaceum*. Among them, *G. herbaceum* and *G. arboreum* (n=13 chromosomes) are called old worlds cotton cultivated in tropical and sub-tropical regions. The other two species with (n=26) are grown in the new world. The species *G. hirsutum* (American upland type) is commercially grown throughout the world. The long staple Egyptian and sea Island species are grown with highest area under *G. hirsutum* (36%) followed by *G. arboreum* (17%) and *G. herbaceum* (10%). The area under *G. barbadense* is less than 1.0 %. The remaining 36% of the area is with hybrids.

1.1. Origin and distribution

The *G. barbadense* seems to have evolved in South America as wild species, which later evolved into cultivated species. The native perennial *G. barbadense* has given rise to Tanguis cotton, which are ratooned and present 90% of the Peruvian crop. Cytological studies indicate that all four species are monophytetic (evolved from a single intersecific hybrid combination). *G. hirsutum* must have moved from the center of diversity near the border of Mexico and Guatemala. Cotton is the most important vegetable fiber cultivated in about 60 countries in the world. The countries such as Russia, USA, China, India, Brazil, Pakistan, Turkey, Egypt, Mexico, and Sudan account for about 85% of the total cotton production.

1.2. Climate

Cotton is a warm-weather crop and the cultivated species are not limited to the tropics. Adopted cultivars are successful in regions where the frost-free period is less than 180 days. Cotton is a short day plant but day-neutral cultivars also exist. It is grown around the world in tropical latitudes and as far north as 43^{o}N in the USSR and 45^{o}N in China. In India, cotton is grown from 9^{o} to 31^{o} N. There is a linear relationship between heat units and cotton production. The required grown degree days are 2000 to 2640 over the base temperature of 10^{o}C (Waddle, 1984). For Asiatic cotton, temperature requirement during vegetative phase is 21^{o} to 27^{o}C, and below 15^{o}C it makes hardly any growth. The optimum temperature for germination is 32^{o} to 34^{o}C. Studies in India revealed that at optimum soil moisture conditions, cotton can be grown in a temperature range of 43^{o} to 46 ^{o}C but for *G. hirsutum* the upper limit is 42 ^{o}C and for *G. barbadense*, it is 37 ^{o}C. Optimum night temperatures are reported to be ranged from 15^{o} to 20 ^{o}C.

Cotton can be grown from sea level to an elevation of 1200 to 1500 m but the low temperature at higher elevations limit its productivity. As a rainfed crop, it can be grown in regions receiving 500 to 2000 mm rainfall. Well distributed rainfall of 900 to 1000 mm during the vegetative phase helps in better growth and yield. Cloudy weather results in boll shedding. A minimum of 4hours of bright sunshine is a prerequisite. A light intensity of 400 to 500 Cal cm^{-2} day^{-1} appears to be ideal for cotton crop.

1.3. Soils

Major soils on which cotton is grown are alluvial soils, black cotton soils, red sandy loams to loams and larerites. Cotton is grown as arainfed crop in deep black cotton and medium black soils, and as an irrigated crop it is also grown in alluvial and other light soils. It does not stand waterlogging. Cotton crop is considered moderately acid-tolerant and the critical pH range is 5.5 to 6.0, and the upper limit is 8.5. The crop is considered saline tolerant, and the salinity threshold (initial yield decline) is about 7.7dSm^{-1}. The main criterion for suitability of soils within the ideal pH range is a depth of at least 60 cm, and freedom from prolonged waterlogging. Deterioration of the quality of soil as a natural resource base is evident in the traditional cotton belt. High external input-based cropping has degraded the soil-water system, depleted soil organic carbon, the productivity of the soil, and resulted in secondary salinization and waterlogging in some canal irrigated tracts.

2. CLIMATE CHANGE EFFECT ON COTTON CROP

There are many reasons of climate change such as the increase in greenhouse gases, including fluorinated gases, CO_2 and many others factors are involved. These variables have an impact on the ecosystem by altering temperature, rainfall patterns, and seasonal patterns. Climate change is now considered a global phenomenon. It is noticed in practically every country on the planet, but underdeveloped countries are more vulnerable to it due to their limited ability to cope with significant climatic change.

Another factor is that developing countries rely heavily on their agriculture industry, which is in direct contact with nature. Usually, climate changes are uneven and have a minor effect globally but geographically these may be drastic for some regions or countries. As mentioned earlier, most of the losses are suffered in the developing countries of arid and sub-humid regions. Some of the key factors are subsistence agriculture and a lack of financial resources to adopt new technologies. However, it is evident that climate change can cause severe damage to global food security and have adverse effects on the livelihood of people all around the world (Ali et al., 2017).

Overall climate changes have impacts over crops. Among various environmental changes, heat and water stresses are considered to be the most important. Heat stress may affect the crops at developing phases (by effecting the physiological growth of the plant) as well as at maturity or productive (by affecting the fruit development) stages. This may be the cause of low yield and decrease of the quality of the crop as well. Similarly, water stress may cause potential damage to the crops' yield by various ways. Such as, due to water stress there may be a reduction in crop reproduction stage, leaf area may be reduced and the stomatal openings may be closed to mitigate the water loss. However, water stress is accompanied by heat stress and can reduce the yield of crops (Adhikari et al., 2015). Global warming and climate change trigger major changes in the sector of agriculture by affecting crops yield and their quality (Sharma, 2014).

Cotton is grown all over the world, and is the main agriculture crop of so many crops. According to Hebbar et al. (2013) cotton has no effect of change in climate. However, to some extent it can resist drought and high temperature but it is sensitive to water availability. Water stress may be another limiting factor in reduced cotton yield in the future. Low temperature may promote the yield slightly but shorter growing seasons may have effect on cotton crop (Chen et al., 2019). It has been documented that if there is 1% increase in temperature, the cotton yield increases relatively to 3% but further increase in temperature is not favorable for cotton. Rainfall is also a climatic factor which affects the cotton yield, and if there is 20% reduction in precipitation, the cotton yield will decrease to 4% according to a research. But as compared with the temperature, the rainfall has less impact oncotton crop production. The decrease in yield causes low income to farmers as well (Diarra et al., 2017).

However, sometimes change in the climate may be helpful for crop yield in some regions. Such as, according to Chen et al. (2015) in the study revealed that change in the rainfall amount decreased the cotton yield in some provinces of China, while in some this was helpful to increase the crop yield. Temperature and precipitation may be harmful and useful as well depending upon the region. The details on the impact of these factors is dicused below:

2.1. Temperature

For specific regions, the increase in temperature may lead to a longer growing season with more or sufficient rainfall. On the other hand, it can also cause a decrease in rainfall with a shorter growing span. The higher temperature may affect different regions in various ways. Especially at flowering and boll formation stages. An increase in temperature is reported to decline the boll maturation period which decreases crop yield and quality parameters such as fiber fineness and fiber length (Adhikari et al., 2015). An increase in temperature is very helpful for those countries in which temperature is low at the time of sowing which is a hurdle for plant germination.

While in cotton-producing areas where the temperature is already high, more increase in temperature will be harmful to cotton plants. Though the high temperature may have positive effects on cotton yield in those regions where the fruiting period is in between two phases of decreased temperature. However, it is also not possible to completely void the effect of increased temperature because it is the main reason for fruit loss due to shedding in cotton plants (Reddy et al., 1997). Temperature changes also alter the boll development processes as well. It has been observed that cotton boll growth significantly decreases at 32^{o}C. However, cotton production is viable in the hotter environment as well till now (ICAC, 2009).

2.2. CO_2 level

If a cotton plant is exposed to increase CO_2 levels, the level of photosynthetic activity will rise. Thus, plant will develop better and will increase the lint yield. Vegetative growth is fostered by increase in photosynthetic rate which will later on increase the lint yield. However, higher level of photosynthesis will increase the demand of inputs for plant growth. In the areas where water availability is not sufficient this may exert negative effect on yield (ICAC, 2007). In the presence of abundant atmospheric CO_2, weeds will also increase more vigorously. So, at the seedling stage cotton may have competition with weeds for growth in the early stage of life. However, cotton can compete with weeds more effectively under conditions where there is enough water and nutrition (Kaynak, 2007).

Weed control will then become more critical to achieve optimal cotton plant development and yield. Due to the increase in temperature, precipitation and drought will be hard to control pests which is critical for optimum crop yield. Carbon dioxide may also have an impact on the effectiveness of pest management tools.
Wu et al. (2007) reported that the genetically-modified *Bacillus thuringiensis* (Bt) cotton shows less Bt-toxin after exposure to elevated CO_2, which might affect plant-bollworm interactions. In another study, Karl et al. (2009) stated that higher temperatures reduce the effectiveness of certain classes of pesticides (pyrethroids and spinosad).

2.3. Drought

Availability of water in adequate quantities is a prerequisite for normal vegetative growth and development of cotton plants for producing lint yield as per the varietal potential of the specific cultivar (Radin et al., 1992; Iqbal et al., 2020). In dry soils, the availability of nutrients and uptake by the root system of cotton tends to decrease significantly which adversely alter the physicochemical composition of the xylem sap (Bacon et al., 1998; Schurr and Schulze, 1996; Reddy et al., 2020).

Mild drought conditions may increase the pH of the xylem sap under the influence of the reduced uptake of nitrates and ultimately cause a significant increase in apoplastic pH (Gollan et al., 1992; Schurr et al., 1992). In addition, water scarcity negatively influences the water content of the leaf which reduced the photosynthesis as well as water-use efficiency in cotton plants (Egilla et al., 2005).

The changing climate scenario has multiplied the intensity as well as the frequency of different abiotic stresses such as heat, salinity, and drought. However, in recent years, drought stress (DS) has emerged as one of the most lethal and growth hampering factors that has led to a serious decline in cotton production worldwide. It manifests itself as a result of persistent hot and dry spells owing to the lack of rainfall in various cotton-growing regions of the globe. The DS tends to curtail various vital physiological processes such as photosynthesis and metabolism of carbohydrates for the synthesis of starch and sucrose along with disruption of several enzymes (sucrose synthase, vacuolar invertase, *etc*.) activities that hamper fiber development in cotton (Koudahe et al., 2021).

Additionally, cotton plants subjected to DS record significantly poor translocation of assimilates from leaves towards reproductive tissues which result in poor pollen functioning and reproductive failures which ultimately lead to inferior fiber quality. The effects of DS on the growth, lint yield, and quality of different genotypes have been found to be serious as well varying under different agro-climatic conditions (Ayele et al., 2020). The pronounced decrease in turgor has been regarded asone of the prime effects of DS that significantly influences the rate of cell growth as well as its volume.

This phenomenon constitutes the most sensitive effect of DS that reduced growth and development rate of stem and leaves, along slashing the stomatal diameter. The DS adversely impacts the photosynthetic process directly or indirectly through disruption of the carbohydrate metabolism. Under DS, not only decreases the photosynthesis rate significantly, but also inhibits the flower development. In addition, DS triggers bud fall in cotton and promotes competition among vegetative and reproductive plant parts for carbohydrates. It has been reported that the development of leaves in cotton under DS is more sensitive compared to stomatal functioning and the rate of photosynthesis. The DS also causes a serious reduction in carbon uptake that leads to a decrease in the rate of boll formation in cotton plants (Qian et al., 2020).

The transgenes and QTL-based molecular breeding approaches might be put into use for the development of drought-resistant genotypes of cotton having the potential to higher lint yield and fiber quality of cotton. Additionally, foliar application plant growth regulators in optimized doses, and soil application of different mineral elements may aid in developing DS tolerance, enhancing fiber yield, and improving the quality of cotton through effective response to DS by optimizing physiological processes (Mahmood et al., 2020). Different advanced genomic tools and molecular approaches may aid to expedite the breeding of cotton genotypes having potential to respond favorably under suboptimal environmental conditions especially drought and heat. However, it is need of time to study various physiological factors and processes along with the isolation of genes that can confer tolerance against the heat and drought stresses along with boosting lint yield and quality (Saranga et al., 2001).

In this context, the interactive effects of genotype and environment need to be studied for designing genomic research under changing climatic conditions. This scenario demands an integrated approach by the coherent merger of crop physiology and molecular genetics for understanding the underlying complex genotype×environment interactions, and thus exploring new avenues of crop improvement to cope with global warming and climate change. At the same time, basic research to explore the drought nature under particular site conditions needs to be conducted (Imran et al., 2019). Thus under changing climate, it is the need of the time to understand various external abiotic stresses such as drought for boosting lint yield and quality under different agro-climatic conditions. It becomes evident that the effects of DS in cotton are well documented, however considerable research and knowledge gaps exist pertaining to fiber quality under DS of varying intensity and durations.

CONCLUSION

Natural factors are documented to impact the crop production significantly *via* influencing the growth, yield and quality of cotton. However, cotton growth and yield can be accelerated by the projected increase in CO_2 concentration as a result of climate change. In addition, the projected increase of extreme temperature and insignificant precipitation as a consequence of climate change negatively influenced the growth and productivity of cotton. Water deficit also found to limit the growth, yield and quality of cotton. Therefore, the effect of altering climate conditions should be addressed to increase cotton output and quality.

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CHAPTER 2

COTTON PRODUCTION AND EFFECT OF HIGH TEMPERATURE STRESS

ON PHYSIOLOGY

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INTRODUCTION

Cotton is a natural fiber which is produced worldwide under a wide range of environmental conditions and is therefore exposed to numerous abiotic and biotic stresses. Temperature is a primary determiner of the rate of plant growth, development, reproduction, and maturation period. High temperatures can have both direct inhibitory effects on growth and yield, and indirect effects due to high evaporative demand causing more intense water stress (van der Westhuizen, 2017).

Global warming affects all plants negatively around the world. It is known that greenhouse gas emissions in the atmosphere trigger global warming, it is estimated that the effect of increases in this greenhouse gas emissions in the atmosphere will be slow but permanent in the future. According to The UN International Panel on Climate Change, it is estimated that the carbon dioxide rate in the atmosphere will reach 450-550 ppm by 2050, and it will reach 760 ppm in the second half of the current century. Climate change, high CO_2 emissions and increasing temperatures will adversely affect cotton production. To adapt the cotton plant to climate change, many simulation studies are carried out and the response of the cotton plant to climate changes is investigated.

With the Cropgro plant simulation model, it is estimated that the yield of the cotton plant will decrease by 5% between the years 2070-2079, depending on the increasing temperatures and CO_2 amounts, and will be 3578 kg ha^{-1} (Baydar, 2010). Reddy et al. (2002), revealed that cotton yield increased from 1563 kg ha^{-1} to 1713 kg ha^{-1} in conditions where CO_2 concentration increased from 350 ppm to 540 ppm and other climatic factors remained constant. When the same CO_2 concentration and other climatic conditions were included in the study, it was reported that the yield decreased by 9% from 1563 kg ha^{-1} to 1429 kg ha^{-1}. This shows that high temperatures directly affect cotton yield negatively.

In another study, in which the amount of CO_2 in the atmosphere and high temperatures and the interactions between them were evaluated together, as the temperature increased, the boll size and maturation period decreased, the boll growth increased up to 25°C, decreased at higher temperatures. Boll maturation period, boll size, and boll growth rates were not affected by atmospheric CO_2 The period when cotton is most sensitive to temperature is the boll retention period. The obtained results indicated that the upper limit for cotton boll survival was 32 °C (Reddy et al., 1999).

In the future, that is, in the second half of the 21^{st} century, it is estimated that climate change, the increase in carbon dioxide concentration in the atmosphere and the average global temperature will be 1.5-5.9 °C higher than today, and it is expected that the extreme weather conditions that occur in a production period will increase (Hodges and McKinion, 1996). In the projections made for Turkey, the annual average temperature will increase by 2-3 °C for the years 2071-2100, and there will be an increase of more than 6 °C, especially in the Aegean region (Ton, 2011). The region with the highest temperatures in Turkey is the Southeastern Anatolia Region, and the hottest provinces are Şanlıurfa and Diyarbakır.

Global warming brings along irrigation problems in cotton production. For this reason, it is necessary to develop genotypes that use water effectively and to reduce external dependency in this regard. When high temperature stress is combined with drought stress, yield and fiber quality losses reach serious levels. Oosterhuis (2002) revealed a strong correlation between high temperature and reduced yield, where high temperatures during the flowering period of cotton resulted in lower yields. With every 1°C increase in the daily maximum temperature, the fiber yield decreases by 110 kg ha^{-1} (Singh et al., 2007).

The yield reduction is mainly from decreased photosynthesis and higher respiration at night consume the available food assimilates (Tariq et al., 2017). Decline in fiber yield is principally caused by a smaller boll biomass and low number of seeds produced in a boll by heat-induced pollen damage and low fertility and fertilization efficiency (Zafar et al., 2018). The number of seeds per boll is an important basic component of cotton yield (Oosterhuis and Snider, 2011). Groves (2009) underlined the importance of seed number in the boll determining yield by reporting that the number of seeds per area accounted for more than 84% of total yield variability in cotton. Powell (1969) revealed that boll losses observed approximately 15 days after the occurrence of high temperature stress.

EFFECT OF TEMPERATURE ON COTTON DEVELOPMENT

The cotton plant develops ideally at temperatures of 27 to 32 °C, and it has been determined that the ideal temperature for maximum number of square and bolls is 30/22 °C day/night temperatures (Reddy et al., 1992a, b). The optimum temperature for photosynthesis is 35 °C, assimilate production stops at temperatures below 17 °C and above 47.5 °C (Babaeva and Asrorov, 1987). It has been reported that pollen dust loses their vitality at temperatures of 38 °C and above, and empty burr form in the bolls (Almeida, 1985). Pollen is more sensitive to high temperature than other reproductive organs, which could account for a lack of fertilization under high-temperature stress (Weaver and Tim, 1998; Singh et al., 2007). Pollen grains are sensitive to extreme temperatures than ovule and can account for reduce fertilization under stress because of elevated temperature. Pollen tubes and pollen grains require high amount of energy relative to other vegetative tissues (Zahid et al., 2016).

The special effects of high temperature on different developmental stages like germination, growth of seedling, vegetative production, morphological development, and maturity attributes are very important (Zahid et al., 2016). The period when the cotton plant is most sensitive to high temperature is the flowering and boll formation period (Snowden et al., 2014). There is substantial data reporting severe yield reduction under heat stress during late reproductive stages of flowering and boll formation, thus signifying flowering stage as most critical to heat stress along with stand establishment, boll formation and fiber development stages (Zafar et al., 2018).

Cotton has the potential for setting about 90% of the crop in the first three weeks of blooming. Stress conditions during this period causes the shedding of square and flowers, 64% (21% first week + 43% second week) of the crop is formed in the first two weeks of the flowering period with the plant being exposed to stress during this period, there may be significant yield reductions (Wright et al., 2008), As the duration of heat stress increases, the cotton plant sheds its larger bolls, and when high temperature stress is combined with water stress causes more bolls to shed (Hake et al., 1989, Hake and Silvertooth, 1990; Demirbilek and Ozel, 1998; Demirbilek and Ozel, 1999).

The number of days of squaring, flowering and maturation in cotton decreased as the temperature increased. It has been reported that a temperature increase of 5 °C can shorten the ripening days by 35 days (Halevy and Bazelet, 1989). It has been determined that the total green parts of cotton grown at 40/30°C day/night temperatures are reduced by 50% compared to those grown at 30/20°C day/night temperatures (Reddy et al., 1991). It is stated that high temperatures also affect leaf development, and leaf growth decreases significantly at temperatures above 35 °C (Bibi et al., 2010). Additionally leaf size will be limited and existing leaves will prematurely age or senesence (Hake and Silvertooth, 1990).

High temperature stress effect of agronomical traits of cotton as known yield components such as plant height, number of nodes, length of internodes, number of boll, number of sympodial and monopodial branches and number of seeds per boll on cotton depending on stress duration and intensity. High temperature due to accelerating of the plant growth period negatively affects agronomical properties especially in early maturing cotton genotypes (Lu and Zeiger, 1994). Some researchers predict that this will bring benefits in the future, such as the possibility of growing two crops a year or the cultivation of cotton in some areas where cotton was not planted before.

The optimum temperature for main stem length, biomass accumulation rate, leaf area size is 30/22 °C, the length of sympodial branches is also affected by temperature, the length of sympodial branches increases rapidly with an increase in temperature from 20/12 to 25/17 °C. Temperature affects the number of monopodial and sympodial branches in the plant, high temperature stress causes an increase in the number of monopodial branches and a decrease in the number of sympodial branches. Temperature also affects the horizontal and vertical flowering intervals of the plant which indicator of earliness (Hodges et al., 1993).

It is known that night temperature is also important for plant growth, vegetative dry matter production, plant height and fruit set decrease at increasing night temperatures (Zeiher et al., 1994), increasing night temperatures have more negative effects on yield, above 25 °C respiration increases and increased respiration causes a decrease in carbohydrates (Arevalo et al., 2004).

Pettigrew (2008) carried out a study to determine differences in agronomic and physiological performance of two cotton genotypes

(SureGrow 125 and SureGrow 125BR) when grown under an ambient temperature control and a warm temperature regime (about 1°C warmer). With this objective field studies were conducted from 2003 through 2005. In the study white bloom counts, nodes above white bloom (NAWB) data, dry matter partitioning data, lint yield, yield components, and fiber quality data were collected. Genotypes responded similarly to the temperature regimes. Warmer temperatures resulted in lower NAWB data, indicating a slightly advanced crop maturity. In two out of three years, the lint yield from the warm regime was 10% lower than that of the control. This reduction was primarily caused by a 6% smaller boll mass, with 7% fewer seed produced per boll in the warm regime. Fiber produced in the warm temperature regime was consistently 3% stronger than fiber in the control treatment. When temperatures become too hot, ovule fertilization may be compromised, leading to fewer seeds produced per boll, smaller boll masses, and ultimately, lint yield reductions.

EFFECT OF HIGH TEMPERATURE ON COTTON FIBER QUALITY

Fibre quality is a key factor determining fibre price and quality of cotton textile products (Wang et al., 2014). Fiber properties which are dependent on deposition of the products of photosynthate in fiber cell walls are sensitive to changes in the growth environment (Lokhande and Reddy., 1994). Fibre quality is characterized by fibre length, strength and micronaire, and the textile industry has a preference for long and strong fibres of moderate micronaire for producing high-quality yarns (Long et al., 2010).

It is known that cotton fibers are also affected by temperature changes and fiber quality is adversely affected at temperatures except of between 15-33 °C (Xie et al., 1993). It is stated that fiber fineness and fiber maturity increase up to 26°C, decrease at 32°C, short fiber content increases at high temperature, and the CO_2 ratio in the atmosphere does not affect any fiber quality properties (Reddy et al., 1999). Similarly, high temperature was also reported to affect the fiber quality in terms of high micronaire values which are undesirable traits (Abbas and Ahmad, 2018). In general, cotton growing in a hot climate will have a higher micronaire due to the thicker rings of cellulose that are deposited daily in the fiber (Hâke and Silvertooth, 1990).

According to the study of Pettigrew, 2008, when the temperature is increased by 1 °C compared to normal conditions, the fiber strength is 3%, the fiber maturity is 2% higher, the fiber fineness and fiber length values do not change, and the fiber reflectance value is 1% lower. However, Reddy et al., 1999 and Meredith, 2005, stated that the temperature decreases the fiber length value. Lokhande and Reddy (1994) observed fiber length increased linearly from 18 to 22 degrees C, and declined at higher temperatures. Fiber micronaire and uniformity increased with temperature up to 26°C and declined at higher temperature, while fiber strength increased linearly with temperature. Farooq et al., 2020, revealed that fiber quality traits including fiber fineness, staple length, fiber maturity, fiber strength and ginning out turn influenced by heat stress due to variation of temperature at peak flowering/boll maturation period.

EFFECT OF HIGH TEMPERATURE ON COTTON PHYSIOLOGY

The physiological response of cotton to high temperature stress has been studied through the use of controlled environmental testing in the greenhouse and growth chamber. The duration and intensities of high temperature stress also affect plants differently. High temperatures affect all vital functions of the cell, including photosynthesis. High temperature damage is observed in the period from the germination of the plants to the harvest time. The greatest damage done by heat to plants occurs in the membrane.

While photosynthesis is reversibly suppressed at moderately high temperatures, the photosynthetic apparatus is irreversibly damaged at severe high temperatures (Berry and Bjorkman, 1980). Extremely high temperatures can cause severe cell damage and even cell death within a few minutes, while at moderately high temperatures, cell damage or death occurs only when long-term temperature is effective (Wahid et al., 2007). In addition, the parts damaged by high temperature stress, not only the membranes of the cells, but also the tonoplast surrounding the vacuole can be affected by high temperature. Compared with photosynthetic membranes, it has been reported that the tonoplast is somewhat more stable at high temperature, but high temperature shock negatively affects the tonoplast integrity and increases its permeability (Graham, 2004).

Acceleration of water loss due to high temperature in the first developmental periods increases energy consumption during respiration. This situation creates some disruptions in protein synthesis and it has been reported in studies that some protein bands do not form during protein synthesis.

Response of cultivars under stress conditions is very important, genotypes with high stomatal conductivity, photosynthetic efficiency, cell membrane thermostability and boll count should be selected under stress conditions. Adaptation abilities of plants are closely related to transpiration and photosynthesis that take place in their leaves. Stomata direct transpiration and photosynthesis by providing the exchange of CO_2, O_2 and water vapor between the leaf and the atmosphere, and stress factors limit gas exchange by causing a decrease or complete closure of stomatal openings (Xu et al., 2016).

In addition, the number of stomata per unit leaf area and stoma size are effective in gas exchange (Brownlee, 2001; Lawson, 2009). Stomas can be found on both surfaces of the leaf, only on the lower surface or on the upper surface, and the number of stomata (stoma density) per mm^2 leaf area can vary according to species and cultivars (Yoo et al., 2009; Avada et al., 2002). Stomatal conductance is governed by multiple genes (Percy et al., 1996). For photosynthesis to occur, ambient CO_2 around a leaf must diffuse into the leaf chloroplasts, where carbohydrates bind and transform. Most leaves have a waxy layer on their surface that limits gas penetration. Instead, CO_2 passes through extremely small microscopic openings in leaves known as stomata. There may be 100 to 500 stomata per square millimeter of leaf area, with stomata 10-20 μm long and maximum 5 μm wide. The total pore area of stomata in a leaf is less than 1% of the leaf area.

Stomas open and close depending on a number of environmental factors, it is known that stomata open and close in the dark, and the light strongly affects the stoma. For this reason, it is reported that stoma measurements are taken at the same time of the day, and measurements taken at different times can give different values. Stomata also close in high temperature and cold conditions to prevent leaf water loss (Bonan, 2002). Lu et al. (1998) stated that in order to determine the genotypic differences in stomatal conductivity measurements at the highest level, it is appropriate to make measurements during the peak period of flowering and between 1:00 and 3:00 p.m. of the day. They reported that varieties with photosynthesis rate and high stomatal conductivity were productive by showing their ability to cool their leaves, and could be used as an important selection criterion for irrigated crops.

The physiological benefit of high stomatal conductivity has not yet been fully elucidated (Radin et al., 1994). Ulloa et al., 2000, stated that the use of this feature by breeders as a selection criterion is limited because stomatal conductivity is strongly dependent on environmental conditions and requires a large number of measurements. Ackerson et al. (1977) stated that measuring physiological parameters is a better indicator than stomatal conductivity. According to Lu et al. (1994)

higher stomatal conductivity is associated with lower leaf area and lower leaf temperature value.

Another method for determining tolerance to high temperature is pollen germination method (Burke et al., 2004, Kakani et al., 2005, Liu et al., 2006). Pollen development, pollen tube growth, and fertilization are postulated to be the most heat-sensitive stages of the reproductive growth phase in cotton (Zafar et al., 2018). The length of the filament was significantly reduced when cotton flowers were exposed to high temperature stress, and this resulted in the appearance of an elongated stigma. The actual length of stigma remained the same, but the length of filaments were reduced to the extent that the stigma appeared to be very long, and the process of self-pollination was badly affected (Brown, 2008; Majeed et al., 2021).

Studies conducted in Arkansas for the development of an observation technique against high temperature have shown that high temperature has a strong negative effect on photosynthesis, chlorophyll reflection, cell membran thermostability and leaf growth, and at temperatures above 35 °C, leaf growth is significantly reduced, leading to a decrease in protein and yield in the seed. It is reported that chlorophyll reflection and cell membrane thermostability can be used both in controlled and field conditions as the most sensitive and practical techniques among all observation techniques, and it would be appropriate to use of these methods to increase heat tolerance in cotton breeding programs (Oosterhuis et al., 2009).

In another study conducted jointly in Australia and America to develop an observation technique to determine heat tolerance, Sicot 53 cultivar was used as tolerant and Sicala 45 cultivar low tolerance genotypes were used and artificial temperature conditions were created under field conditions and morphologically, physiologically, biochemically and molecularly investigated. It was determined that there were significant differences between cultivars for cell integrity and enzyme viability, and it was stated that these criteria could be the initial evaluation criteria to observe large populations and should be integrated with criteria such as photosynthesis, electron transport, stomatal conductivity (Cottee et al., 2012a).

The same researchers explained in their study that the GhRCAa2 gene could explain the differences in the physiological performance of varieties in terms of heat tolerance, especially in terms of photosynthesis (Cottee et al., 2012b). It is stated that some proteins accumulate and synthesize in the plant during the rapid development of high temperature, these proteins are called heat shock proteins (HSPs), and this stress protein is important in field conditions (Burke et al., 1985; Abrol and Ingram, 1998). They play a very important role in protecting plants against stress, as they form the normal protein structure in the face of heat stress and restore the disturbed cellular internal balance (Wang et al., 2004).

Heat-shock proteins (HSP) are responsible for many cellular activities, such as folding, aggregation, translocation and degradation of proteins, stabilization of proteins and membranes, and can induce protein rearrangement under stress conditions. However during the production of heat shock proteins, the production of many other proteins is also inhibited. Heat-stress transcription factors (HSFs), located in the cytoplasm in an inactive state, control HSP gene transcription and play a vital role in plant thermotolerance (Chaudhary et al., 2020).

Cell membrane thermo-stability (CMT) was proposed by Sullivan, 1972 as distinct criteria for heat stress assessment. In a study conducted in Pakistan, it was found that excessively high temperature during fruit formation period in cotton causes significant yield reduction, high cell membrane thermostability (CMT) is associated with high yield and temperature tolerance in many crops, under optimum conditions and high temperature conditions in greenhouse and field. In the study carried out, the response of Upland cottons to CMT was determined, the differences between varieties were significant, the tolerant (thermostable) cultivars/lines of FH-900, MNH-552, CRIS-19 and Karishma; it has been reported that cultivars FH-634, CIM-448, HR109-RT and CIM-443 were determined as sensitive (Rahman et al., 2004).

van der Westhuizen (2017) observed some cotton genotypes and there was in an indication that DP393 showed some heat tolerance by a smaller change in membrane leakage under heat stress when compared to the other genotypes, but Arkot 9704, VH260 and DP 210 B2RF did not show any appreciable and consistent protection of membranes, i.e. smaller increase in membrane leakage under heat stress.

Cell membrane thermostability has also been used by other researchers as a selection criterion and a suitable observation method in the detection of sensitive and tolerant genotypes (Ashraf et al., 1994; Malik et al., 1999; Azhar et al., 2009). Ashraf et al. (1994) screened five cultivars of cotton (*Gossypium hirsutum* L.) B-557, CIM-70, MNH-93, NIAB-78 and S-12 to high temperature stress were assessed at germination and a later growth stage under controlled environmental conditions and determined that B-557 and MNH-93 variety had lower injury level (higher membrane thermostability) and were higher in fresh and dry mass production than the other three cultivars. Saleem et al. (2014) observed significant differences between varieties and FH113 showed more cell thermo stability both en early and late planting time than other varieties. On the other hand, Abro et al. (2015) evaluated 58 different cotton genotypes including in a check variety (Sadori genotype) and revealed that cell membrane thermostability as a usefull techniques in idendifiying heat tolerant cotton genotypes.

It has been reported that the lines showing the lowest value in the cell damage level have the highest values in stomatal conductivity, there is a negative correlation between the cell damage level and stomatal conductivity, and these two characteristics can be used as a method in breeding studies to distinguish between heat tolerant and heat sensitive cotton lines (Khan et al., 2008). Increase in cell membrane damage may prevent the transfer of water, ions and soluble organic matter within plant cell membranes, thus carbon production, transport and accumulation may be effected from these unfavourable conditions (Christiansen, 1978).

Cell membrane thermostability is also used as an important selection criterion to distinguish genotypes under drought stress conditions (Rahman et al., 2008; Brito et al., 2011). Saleem et al. (2015) reported that cell membrane thermostability and proportional leaf water content were correlated, and that the genes involved in these characteristics were in genetic linkage with the genes controlling the number of bolls, fiber length and fiber strength in the plant. Karademir et al., 2012 stated that photosynthesis efficiency, chlorophyll content (SPAD value), cell membrane thermostability, plant height and number of bolls can be used as selection criteria in breeding studies for tolerance to high temperature.

Bibi et al. (2006) used plant growth chamber and field studies to evaluate techniques and genotypes for high temperature tolerance in cotton. Techniques tested were chlorophyll fluorescence, membrane leakage, photosynthesis, antioxidant enzyme activity, total soluble proteins, leaf carbohydrates, myo-inositol, leaf extension growth, crop growth rate and net assimilation rate. Chlorophyll fluorescence, membrane leakage, and leaf extension growth were the most practical, reliable, and sensitive techniques for quantifying cottons response to high temperature stress. Cotton plant gives a stress signal at 35 °C and 38 °C. They stated that Acala Maxxa, SG215BR and DP444BG/RR cultivars were the most tolerant genotypes, wild type cottons were more tolerant than commercial cultivars, and wild germplasms should be recognized and observed under controlled environmental conditions to increase tolerance to high temperatures.

Weaver and Locy (2005) stated that the chlorophyll reflection feature can be used effectively and quickly in genotype differentiation, the effect of high temperature on the cell level can be determined by this method, and DPL 90 cotton variety was found the best variety in terms of tolerance to both of high temperature and drougth. Bibi et al. (2004) stated that chlorophyll reflection is an important criterion for tolerance to high temperature. Chlorophyll fluorescence is a quick, easy, highly sensitive and non-invasive screening technique and therefore it has been used to determine tolerance to high temperature (Bibi et al., 2003; Karademir et al., 2012, Wu et al., 2014).

Brown and Oosterhuis (2010) reported that the physiological performances of modern varieties (Stoneville 474 and Suregrow 474) were good at the ideal temperature (30 °C), however, older cultivars (Stoneville 213 and Deltapine 16) were less sensitive to leaf photosynthesis, chlorophyll reflection and cell membrane integrity at 38 °C. It has been reported that a wild cotton species (*G. hirsutum* L. strain Palmeri, PI681044) in Mexico tolerates significantly more heat than the commercial 4 Upland cotton varieties (Tamcot Sphinx, FiberMax 960BR, Stoneville 474, Deltapine 444 BR) (Bibi et al., 2010). The same researchers reported that chlorophyll reflection and cell membrane thermostability are the most practical and reliable methods, photosynthesis is also a sensitive method, but it is not a practical method to test a large number of materials (Bibi et al., 2008).

Another important physiological indicator is the measurement of canopy temperature and canopy temperature depression. The results of earlier researchers suggested that canopy temperature and chlorophyll content can successfully be used as a selection criterion in cotton breeding program (Karimizadeh et al., 2011). Canopy temperature depression shows high genetic correlation with yield and high values of proportion of direct response to selection, indicating heritability and therefore amenability of this trait to early generation selection (Abdipur et al., 2013). Canopy temperature and infrared thermometer can be a powerful tool to monitor heat stress conditions (Dejonge et al., 2015).

Khan et al. (2014) concluded that canopy temperature proved to be reliable indicator for assessment of heat tolerance in *G. hirsutum* L., and since the variation appears to be heritable, therefore the chances for improvement of heat tolerance. Karademir et al. (2018) studied a large material which consisted of 140 lines and 5 control varieties and they measured canopy temperature in three different cotton growing stage and they observed a significant and positive correlation between seed cotton yield and canopy temperature in all cotton growing stage (pre flowering, peak flowering and post-flowering/boll formation period). However, correlations coefficient was strongest when canopy temperature was measured in peak flowering stage of cotton development period.

Canopy temperature (CT) and canopy temperature depression (CTD) has attracted the attention of breeders in recently years, because it is easy to calculate and can be used to screen large amounts of material in a single day (Kebede et al., 2012; Karimizadeh and Mohammadi, 2011). The significant positive genetic correlation between yield and CTD, cell membrane thermostability, leaf chlorophyll content, leaf stomatal conductance, and photosystem components have been reported under heat stress conditions (Singh et al., 2007).

In a study conducted in Mexico, two wheat populations were grown under three environments: drought, heat and heat combined with drought. On average, in both populations under heat and heat combined with drought environments canopy temperature (CT) measured at the mid grain filling stage (CTfg) and stay green variables were responsible for about 30% of the yield variability in multiple regression analysis. It is stated that the ability to stay green in drought conditions has the total effect of other characteristics and can be used to improve stress adaptation (Lopes and Reynolds., 2012).

Each plant species has an optimum temperature range in which it functions optimally and outside this range, cellular metabolism and thus plant growth are adversely affected. This specific temperature range is defined as the thermal kinetic window "TKW". TKW is known as 23.5-32 ºC for proper plant growth in cotton where optimum activity takes place between these temperatures (Burke et al., 1988). Temperatures above the optimum temperature range cause changes in many physiological functions including photosynthesis, membrane integrity and enzyme stability. Plant temperature should be within range of the TKW (Azhar et al., 2020). Jarvis et al. (2010) concluded that for cotton the temperature threshold extends to 33.0 °C. High temperature stress is especially effective on photosynthetic reactions of plants. The most sensitive part of the photosynthetic system to high temperature stress is the thylakoid membranes on which the photosystem II compounds are located. Therefore, high temperature has a negative effect on photochemical reactions, especially on the enzymes of carbon metabolism. As a result, energy is wasted by photorespiration and is wasted more than is produced by carbon dioxide assimilation.

EFFECT OF HIGH TEMPERATURE ON UNDERGROUND ACTIVITIES

High temperature stress affects root and stem development, uptake of water and nutrients, transport of organic compounds, transpiration, photosynthesis and respiration in plants (Singh et al., 2007). As a result, the high temperature stress that the plant encounters during the growth and development period negatively affects the genetic potential of the plant.

Previous studies showed that the green parts of the plant are more directly affected than the roots, the effect of high temperature stress on germination, seedling development period, vegetative growth and development period in cotton is well defined (Oosterhuis and Snider., 2011); however, knowing the root reaction, root-green component signal and its relationship with temperature are important and need to be investigated (Wahid et al., 2007). According to Zahid et al., 2016, genetic differences in rooting system are directly related to plant productivity and primarily increases root branching and distribution.

Strong rooting system can boost cotton yield under drying soil profile conditions. Meanwhile, the enhancement of vascular system can increase lateral root production, which provides strength against abiotic stresses. The genotypes that have deep roots with enlarged lateral root system are more resilient to abiotic stress (Cook and El-Zik, 1992). The damaging of roots minimizes their uptake of nutrients and water from soil that can disturb the entire physiological mechanism of the plant and limit its productivity. Studies showed that cotton roots develop poorly under high soil temperature and result in a poor crop stand (Majeed et al., 2021).

PLANT RESPONSES TO HIGH TEMPERATURE

The accumulated data on how plants respond to biotic and abiotic stress and how stress affects the developmental processes of the plant life cycle have led to the development of new approaches on the subject. The ability of plants to respond to stress conditions has also been effective on their geographic distribution. Plants were tried to be adapted to stress events before they were cultivated. Natural selection left those that were resistant. These adapted plant sources were then used as genetic material during their cultivation. The long-term goal of breeding for heat tolerance is the development of germplasm with improved field level tolerance under variable temperature conditions (Porch, 2006).

The responses of plants to high temperature stress are defined in different ways, they are called stress escape, avoidance and tolerance, and it is a desired feature for plants to be stress-tolerant and resist stress

(Yıldız and Terzi, 2007). Tolerance to stress conditions is generally defined as the ability of plants to grow, thrive and produce economic yields under high temperature or drought stress conditions (Wahid et al., 2007). Tolerance to heat, in other words, is defined by the fact that one genotype is more productive than other genotypes in places where high temperature occurs (Hall, 2004). Tolerance to high temperature is a complex property and is cotrolled many genes managed by both additive and non-additive genes, and additive gene effects are reported to be more dominant (Rahman, 2006).

It is known that there are also differences between cotton species in terms of tolerance to high temperatures, and *G. hirsutum* type cottons are more tolerant than *G. barbadense* type cottons (Reddy et al., 1992a). For this reason, it is reported that genetic differences can be controlled by crossing studies to be carried out between these two species in terms of genetic control of high temperature.

Cotton plant, it tries to cool down by sweating, which is the mechanism of escaping/cooling from the heat in high air temperature conditions. Under high relative humidity conditions, the transpiration of the cotton plant decreases and the canopy temperature begins to rise (Brown and Zeiher, 1998). The canopy temperature is lower than the air temperature and can reach the maximum air temperature level. The difference between the canopy temperature and the air temperature is inversely proportional to the relative humidity of the air. Air temperature affects the temperature of the canopy relative to the relative humidity of the air and may have harmful effects on the plant. Therefore, canopy temperature measurements are important in determining plant tolerance to high temperature.

It has been determined by some researchers that the cell damage level of heat tolerant cultivars is less than the sensitive cultivars when exposed to stress (Sairam, 1994 and Nagarajan et al., 2005).

Xu et al. (2020) examined the mechanism of thermotolerance of two cotton cultivars with different heat tolerance; PHY370WR (heat tolerant) and Sumian 15 (heat susceptible) and they explained differences between the two cultivars were as follows: the heat tolerant cultivar could maintain higher photosynthesis rate under high temperature and it could recover more quickly and highly in photosynthesis than the heat susceptible cultivar.

Previos studies indicated that certain wild species possess unique traits including resistance to heat. Valuable traits can be introduced in cultivated cotton varieties using hybridization of various species like, G. arboreum, G. herbaceum, G. gossypioides, and G. laxum with G. hirsutum and/or G. barbadense, afterwards using culture media to raise embryos which may ease in breaking cytogenetic hurdles. This method can be utilized to broaden the genetic base and also for transferring genes involved in traits that are absent in the cultivated species (Zafar et al. 2018).

Zhang et al. (2016) compared of expression of certain heat-stress responsive genes between heat-sensitive (ST213 and ST4288) and heat-tolerant (VH260 and MNH456) genotypes of cotton in *G. hirsutum.*

Resilient tolerance to heat stress in VH260 can be attributed to prompt sensing of heat stress and timely induction of several mechanisms functioning in coordination to secure the plants against oxidative stress, protein denaturation and membrane damage leading towards decreasing yield losses and improved boll maintenance during heat stress. They proposed to use of cotton cultivars such as VH260, which has an antioxidant protection an additive role in enhancing heat-tolerance capacity of which is an excellent source of heat-tolerance genes for breeding and genetic engineering.

The first line developed in terms of tolerance to high temperature from Upland germplasm in studies conducted in the USA was the SJ-U86 cotton line, then three varieties (AGC 85, AGC 208 and AGC 375) were developed and registered in 2006 (Ulloa et al., 2006; Percy et al., 2006). On the other hand, the high temperature tolerance of cotton varieties has been tested by many researchers. Ashraf et al. (1994) observed 5 cotton cultivars and reported that B-557 and MNH-93 had lower relative injury (higher membrane thermostability) and were higher in fresh and dry mass production than the other three cultivars.

One of the most widely used methods for monitoring the effects of high temperature on plants in field conditions is early and late sowing. Sowing time adjustment is most crucial strategy to addressing temperature stress. Recent findings suggested that changes in planting time significantly affect the cotton growth, lint yield, efficacy of nitrogen utilization and assimilate supply to reproductive organs (Zafar et al., 2018). With this method, the differences between varieties and genotypes are tried to be determined by making the flowering period of the plant coincide with different temperatures. To minimize the negative effects of heat, it will be beneficial to carry out the cultivation techniques in a timely and appropriate manner and to choose varieties that are resistant to adverse conditions in terms of temperature (Demirbilek and Özel, 1998). It was reported by adjustment sowing time it will be possible for the plant to escape from the high temperature stress (Zhu et al., 2013; Zafar et al., 2018; Khan et al., 2019)

Karademir et al. (2020) screened 200 cotton genotypes and 5 check varieties for heat tolerance under normal and late planting time according to heat susceptibility index and revealed that five cotton genotypes as highly heat tolerant (TAM 139-17 ELS, CIM-240, Haridost, MNH-990 and AzGR-11835). Farooq et al. (2020) revealed that existence of genetic diversity among cotton cultivars and they suggested to use Sitara-14, IR-NIBGE-8, CIM-602, VH-363, IR-NIBGE-9, Weal-AG-Shahkar and IUB-65 cultivars for improving fiber traits of cotton through recombinant breeding against heat stress.

The negative impacts of heat stress can be minimized by modifying certain management practices that would aid in plant stress tolerance (EL-Sabagh et al., 2020). By altering row-spacing under rain-fed systems can increase availability of soil water for plants, impact the lint yield, increase fiber quality, and reduce the level of unpredictability associated with production under stress (Rahman and Zafar, 2018). Application of irrigation during heat stress is better management operation to reduce the risk associated with high temperature (Tariq et al., 2017). Irrigation program based on plant-needs and irrigation intervals can also play a crucial role in ameliorating the negative impact of temperature, thus infrared termometer can be used for determine high temperature stress. Sarwar et al. (2019) suggested to exogenous application of macro and micro nutrients ameliorated the high temperature impact on cotton crop. These nutrients especially K, Zn and followed by B up-regulated the antioxidant enzymes (SOD, POX, CAT, AsA, phenolics and MDA), improved chlorophyll contents, net photosynthetic rate, water relations and seed cotton yield.

Exogenous application of natural and synthetic plant growth regulators is an important and quick agronomic approach to reduce the negative impact of high temperature stress. PGRs (Hydrogen peroxide, ascorbic acid, salicylic acid, Moringa leaf extract) significantly enhanced the cotton yield under heat stress by potentiating the cell membranes and enhancing the antioxidant defense (Zafar et al., 2018).

TEMPERATURE INDUCTION RESPONSE (TIR TECHNIQUE) FOR HEAT TOLERANCE

In a recently published study, it was reported that it is necessary to develop an observation technique to screen a large number of genotypes for tolerance to high temperature, and for this purpose, the Temperature Induction Response (TIR) technique was developed, in this technique, a screening protocol was developed based on the principle of “acquired tolerance” in which exposure of seedlings to a sublethal level of specific stress is used to induce tolerance to a subsequent lethal level of stress. After adapting this technique to cotton, several species and varieties were screened for thermotolerance. As a result of this technique it was observed that old world cotton species showed higher thermotolerance than new world cotton varieties, there were significant variations in 36 genotypes of *G. hirsutum* species, and the H-28 genotype with the TIR technique increased protein synthesizing capacity during the post-temperature recovery period and increased cell turnover. It has been stated that this technique was a robust and powerful technique and can be used to screen breeding lines or germplasms to identify thermotolerant lines (Kheir et al., 2012).

Sapnaharihar et al. (2014) stated that the seedlings exhibited higher recovery growth at the temperature 36-44 ^{o}C. By adopting the TIR technique, it is feasible to identify thermotolerant Rice lines from a large population at the seedling level. Hence, this method is a reliable method to screen for thermotolerance. This has a specific advantage of high-throughput and non-destructive technique. By adapting this technique, several basic issues in terms of relevance of stress adaptive mechanisms in addition to genetic variability can be efficiently studied. Besides, the tolerant seedlings identified technique can be established in the field and their progenies can be subsequently screened through recurrent selection to obtain highly tolerant cultivars.

Adapting temperature induction response (TIR) technique 100 rice genotypes were screened for thermotolerance. Significant variation for acquired thermotolerance was observed in 100 rice lines. From the 100 genotypes 30 were exhibits themotolerance to induced high temperature. In conclusion they suggested that the TIR technique was a powerful and constructive technique to identify genetic variability in high temperature tolerance in rice within a short period of time and it was suitable for screening a large number of genotypes. The identified 30 genotypes of rice can be used as donor source for developing high temperature tolerant rice genotypes to resist global rise temperature (Devi et al., 2013).

Ravindra et al. (2014) in their study used ten wheat cultivars to assess the cell viability, time laps study, percent reduction in recovery growth, survival rate and membrane stability index to evaluate their acquired thermotolerance. Forty one hour old germinated seedlings were exposed to gradual temperature induction (TIR) from 30ºC for 1h→35ºC for 1h→40ºC for 2h and finally subjected to lethal temperature 46ºC for 3h. The seedlings were allowed to recover for 68h and growth during recovery was taken as a measure to quantify the relative thermotolerance of these cultivars. The results suggested that the TIR technique was a useful technique to identify genetic variability in high temperature tolerance in wheat within a short time period and suitable for screening a large number of genotypes. This study demonstrates that the TIR technique was a simple and realistic method for screening wheat seedlings for heat tolerance. Using this technique it was demonstrated that there is sufficient genetic variability present among wheat cultivars for high temperature tolerance.

HIGH TEMPERATURE AND BIOTECHNOLOGY

Molecular marker technology, which has developed rapidly in the last 20 years, has been widely used in determining genetic differences between varieties, chromosome mapping, characterizing gene sources and especially in agricultural breeding studies. At the same time, molecular markers have revolutionized plant breeding as they play an important role in linkage analyses, physical mapping, quantitative trait locus (QTL) analyses, marker-based selection, and map-based cloning (Bernatsky and Tanksley, 1989; Lande and Thompson, 1990; Knapp, 1998).

Genetic linkage maps developed with a wide variety of molecular markers have become an important tool in the analysis of plant genomes, in different plant breeding programs and in genome analysis processes (Jeuken et al., 2001).

In cotton; various DNA markers are used in stress-related molecular selection studies. RFLP (Restricted Fragment Lenght Polymorphism) markers were found in both *G. hirsutum* x *G. harbadense* L. interspecific populations (Reinisch et al., 1994; Jiang et al., 1998; Kohel et al., 2001; Lacape et al., 2003; Rong et al., 2004) as well as in intraspecific populations of *G. hirsutum* (Shappley et al., 1998). PCR-based DNA markers; AFLP (Amplified Fragment Lenght Polymorphism), RAPD (Randomly Amplified Polymorphic DNA), SSR (Simple Sequence Repeat), STS (Sequenced-Tagged Sites), and ESTSSR (Exppressed Sequence Tags-SSR) are widely used for making genetic maps in cotton (Lacape and et al., 2003; Mei et al., 2004; Zhang et al., 2003; Rong et al., 2004; Nguyen et al., 2004). C02, C03, C05, C08, C14 and C15 RAPD primers were found to be effective in determining genotype characterization under high temperature stress as a result of bulk segregant analysis. In addition, ISSR (HB08, HB10, HB13) primers were also observed to be determinative in heat stress (Kamel et al., 2010).

In classical breeding programs, breeding studies are carried out by crossing in order to obtain seeds that are resistant to abiotic stress, high yield and quality. But such work takes a lot of time.

CONCLUSIONS

Heat stress is an important constraint and will play an increasing role in cotton yields and fiber quality due to climate change. Adaptation of cotton to future conditions requires improving well understanding and of crop responses to elevated temperatures and adapting strategies to improve their tolerance to mitigate their effect. The effect of temperature is expected to increase in the future. As the duration and intensity of high temperature and drought stress increase, yield and fiber quality loss in the plant may be higher. For this reason, protecting the plant from stress conditions during the flowering period ensures maximum yield and quality. On the other hand, some agronomic factors such as the appropriate early sowing date, the characteristics of the genotype to be cultivated and preferred to tolerant cotton genotypes to high temperature stress, the planting site and appropriate water management strategies and application of mineral nutrition are important to minimize the negative effects of high temperature stress.

It is well known that plants can only reach 60% of their genetic potential due to abiotic stress losses, diseases and pests. The most effective way to prevent yield and fiber quality losses caused by abiotic stress factors is to develop new cotton genotypes/varieties that are tolerant to stress conditions. There are differences between species in terms of the response of plants to high temperature. It was determined that *Gossypium hirsutum* L. type cottons were more tolerant than *Gossypium barbadense* L. cottons, thus the use of *Gossypium hirsutum* L. cultivars in hybridization studies will contribute to the development of this feature.

For this purpose, plant breeding studies should be carried out with the combination of traditional and molecular breeding methods. Moreover the utilization of crop wild relatives is also gaining popularity in plant breeding due to their novel features that are lacking in domesticated cultivars. It is recommented to transfer the stress resistance traits found in wild varieties to cultivated varieties. It is beneficial to carry out breeding studies by using cotton genotypes, which were determined to be tolerant to high temperature in previous studies, as parents in breeding studies. Developing high temperature tolerant cotton varieties together with yield and fiber quality simultaneously and in a short time seems to be the only solution to mitigate the effects of global warming caused by climate change.

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CHAPTER 3

EFFECT OF DROUGHT STRESS ON COTTON MORPHOLOGY, PHYSIOLOGY AND MITIGATION STRATEGY

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INTRODUCTION

The most important factors limiting yield in crop production are abiotic stress factors, especially drought and high temperature stress causes significant yield reductions and fiber quality losses in cotton farming. Drought is an important factor limiting crop production in most of the world's agricultural lands. There is a lack of water in 1/3 of the cultivated lands in the world (Loka et al., 2011).

Among the stress factors seen in arable lands around the world, drought stress takes the biggest slice with a share of 26%. A significant part of the world's agricultural lands is experiencing problems due to the insufficiency of agricultural water resources, and as a result, crop yields periodically decrease due to drought.

Under field conditions in arid regions, water and heat stress occur almost constantly together. The need to strike a balance between temperature and drought tolerance further complicates strategies to improve vegetative productivity under arid conditions. It is stated that the global average temperature will increase by 0.3 °C every 10 years, and accordingly, it is estimated that the average temperature of the world will increase by 1 °C from 1999 to 2025 and by 3 °C until 2100 (Wahid et al., 2007). According to the report prepared by the Intergovernmental Climate Change Panel (IPCC) in 2014, changes in the weather (temperature, precipitation) cause irregularities and fluctuations in the production of products. It is predicted that water shortages and droughts will increase with the effect of climate change, agricultural productivity will decrease, and food prices may increase up to 85% worldwide.

Increasing temperatures and insufficient precipitation cause drought stress in plants, and high temperatures, when combined with drought stress, adversely affect the vegetative growth and boll holding of the cotton plant. In addition, drought negatively affects cotton yield as well as product quality. For example, there are significant decreases in quality parameters such as fiber length, fiber fineness and fiber strength, which are directly related to the textile industry. Therefore, unfortunately, the production of fiber in the amount and quality desired by the textile industry cannot be realized. Yield and fiber quality losses caused by both stress factors prevent economic production and cause manufacturers to prefer other products.

Considering that with global warming, water shortages will be experienced, irregular precipitation periods will occur, and water resources will be decreased in the coming years, the importance of developing or determining genotypes that reach higher yield potential with effective use of water and less irrigation becomes clear.

Plants are living things that are most exposed to changes in environmental conditions and adverse conditions because they cannot move. They can flex their mechanisms and even adapt in a way that is least affected by environmental factors when grown in the same climatic conditions for long periods of time. Thus plants grow and develop in such a way that they are least damaged by these changes that may occur in environmental conditions.

Plants usually show numerous xeromorphic traits and structures that induce drought resistance, i.e. a thick cuticle epidermis, thicker and tiny leaves, smaller and denser stomata, palisade tissues more epidermal trichomes, and a well-structured vascular bundle sheath (Iqbal et al., 2013). Some plants form a thick cuticle or water-storing succulent leaves to reduce evaporation in the absence of water. In addition to these, they escape from stress conditions by forming seeds and tubers as much as possible in order to guarantee their generation under stress conditions.

The drought tolerance is a complex mechanism that is influenced by a wide range of physiological traits which have some relationship with productivity under water deficit conditions (Pawar et al., 2021). Therefore, research is needed to better understand the responses of upland cotton to drought stress on reproductive growth, yield and fiber quality, and how they can be improved. Ayele et al. (2020) determined differences in response to drought stress among upland cotton genotypes and they reported that led to the identification of novel sources of germplasm that could be used for introgression of enhanced stress tolerance alleles by conventional breeding.

Even though plant varieties belong to the same species, they may differ in their tolerance to drought. While some plant varieties of the same species are drought tolerant, that is, they can continue to grow and develop in arid environments and can be productive, other plant varieties belonging to the same species but sensitive to drought can be damaged enough to cause serious yield losses even in a small amount of water loss. Therefore, it is always more advantageous to use varieties with higher drought tolerance in field production.

One of the abiotic stress conditions that most affect the growth and development of plants is drought (Farooq et al., 2009). The plant in the period of water shortage developmental stage depends on the effect of drought stress on plant growth and development. Many physiological characteristics that determine the yield of the plant are also affected by drought conditions. The sensitivity of plants to water shortage is most effective in the generative period. Cotton has the ability to maintained hydraulic integrity during long-term drought stress through early stomatal closure and leaf shedding, thus exhibiting a drought avoidance strategy (Li et al., 2019).

Knowing the morphological, physiological and biochemical changes that occur in plants during water stress, briefly the drought stress response of plants, and using the obtained information to increase the drought tolerance of plants used in agricultural production is one of the issues that still maintains its importance in biotechnological studies. However, a significant part of the plant varieties used in agricultural production have been bred for many years and they are grown under the most suitable conditions in order to be productive. Therefore, most of the plant varieties used in agricultural production are not very resistant to arid conditions. When plants encounter arid conditions, depending on the severity and duration of the water stress that occurs, they can restructure their metabolism so dramatically that they change their life cycle. Their distribution in regions with varying climatic characteristics is the best indicator of their ability to adapt to very different environmental conditions (Dolfeus, 2014). In this context, it is not difficult to predict that many changes may occur in a plant that encounters drought stress, not only physiologically but also metabolically.

EFFECT OF DROUGHT STRESS ON PHYSIOLOGICAL PARAMETERS

It is widely accepted that plant growth is directly related to the water balance in plant tissues. In the case of water deficiency, the physiological processes in the plants are disrupted, and in this case, first the plant growth and then the yield are adversely affected. Since water plays an important and dominant role in plant nutrient uptake, transport, chemical and enzymatic reactions, cell growth and expansion, physiological events such as transpiration, water deficiency affects plant development, morphology and biochemical processes (Loka and Oosterhuis, 2012).

Drought stress causes many physiological, biochemical and molecular events in plants, and accordingly, plants can develop tolerance mechanisms that will enable them to adapt to limited environmental conditions.

Effective irrigation technologies applied today help to reduce the gap between actual yield and potential yield. However, in many regions there is a problem of depletion of water resources. In addition, excessive use of existing water resources also brings problems such as salinity in the soil. In order to solve this problem in a sustainable and economically viable way, researchers are turning to genetically improving plant productivity in arid conditions.

Abiotic stress due to climatic changes such as drought, salinity, excessive precipitation, temperature or cold that occur throughout their life cycle conditions directly affect plant growth and development (Taiz and Zeiger, 2010). Drought effects the plant growth by causing alteration in meristematic region that plant growth mainly occurs in this region (Borah et al., 2021).

It is stated that yield losses varying between 20 and 74% under stress conditions, there are differences between genotypes in terms of physiological parameters such as osmotic regulation and cell membrane stability, and osmotic regulation can be used as a selection criterion in breeding programs (Rahman et al., 2008). It was reported that the trends in membrane leakage and carbon isotope composition were different between the tolerant and sensitive genotypes under a water deficit, which makes these physiological traits suitable for screening for tolerance to water deficits in cotton (Brito et al., 2011).

The soluble sugar content, proline content, superoxide dismutase (SOD) activity, and peroxidase (POD) activity of the roots increased under drought stress and then decreased after re-watering, although the values remained higher than those of the controls for a short period (Niu et al., 2018).

Several physiological traits have been reported showing importance in relation to water stress tolerance in cotton. Drought stress causes a decrease in leaf water potential, leaf area and photosynthesis in the plant (Turner et al., 1986, Nepomuceno et al., 1998, Genty et al., 1987), when stress is severe, plants remain small, internodes shorten, lower leaves and bottom leaves shedding. If the drought occurs in the generative development period of the plant, square and boll shedding increases and leads to a decrease in yield (Grimes and Yamada., 1982).

Pettigrew (2004) stated that drought stress causes a decrease in leaf area index, causes square and boll shedding in the plant, and by accelerating vegetative and generative development leads to early cut-out. Specific leaf area, specific leaf weight, and boll weight have been reported to have high heritability, which means additive gene effects, while the chlorophyll stability index has low heritability, which means non-additive gene effects (Reddy and Kumari., 2004). Relative water content (RWC) is a measure of the amount of water present in the leaf tissue. High RWC under drought stress conditions would be preferable to maintain water balance. Higher RWC in leaf has been reported as selection criteria to breed plants tolerate to drought stress (Abdel-Kader et al., 2015).

Anwar et al. (2021) observed differences between genotypes in terms of RWC, ranged between 56.12 and 74.15%. Under water limited conditions, highest relative water content has been observed in the varieties MNH-886, Cyto-178 and MNH-1035, whereas lowest relative water content has been observed in CRIS-342.

Basal et al. (2004) reported that root parameters, initial leaf water content and leaf water loss are reliable selection criteria for drought tolerance. It has been determined that plant selection in the early generation is not an accurate method under drought stress conditions, and segregation in advanced generations give better results (Ahmad et al., 2009, Shakoor et al., 2010).

The effect of water deficiency on different physiological processes in the plant is complex and interrelated. Cellular water content greatly controls stomatal patency, and stomatal conductivity directly affects metabolic functions such as CO_2 diffusion and photosynthetic carbon fixation, and respiration, respectively (Loka et al., 2011).

It is stated that photosynthesis is an important physiological parameter used to distinguish between drought sensitive and resistant genotypes (Saranga et al., 2004; Levi et al., 2009). The rate of photosynthesis decreases when leaf water potential and leaf relative water content decrease (Lawlor and Cornic, 2002). Photosynthesis is the main driver for crop productivity, which is negatively influenced by water deficit conditions. Stoma closing in response to moisture stress results in a reduction in leaf photosynthetic capacity resulting in chloroplast dehydration and decreased CO_2 diffusion into the leaf (Chaves et al., 2009; Khan et al., 2018).

Conaty et al. (2015) stated that the canopy temperature is used in determining the water stress in the plant because it is related to transpiration, that they follow the canopy temperature in the process between flowering and cotton maturation period, and that a decrease in yield occurs when the canopy temperature is above 28 ˚C. However, canopy temperature can be influenced by the soil thermal environment when the plants are small and measurements may not be valid when the crop height is less than 0.5 m (Roth and Goyne, 2004). A recent research result confirms these findings (Wu et al., 2014).

Li et al. (2012) stated that chlorophyll a/b content and net photosynthesis rate decrease, transpiration rate increases in water stress during the beginning of flowering period, and the plant's defense against drought can be provided by regulating the photosynthetic system in critical periods.

There are significant differences between cultivars in terms of drought tolerance. These differences are important for the development of drought tolerant varieties. Shewale et al. (2009) stated that hairy leaves are an important indicator of drought tolerance, such as plant height, number of fruit branches, leaf area, total dry weight of the plant and relative water content. Zhang et al. (2012) conducted a study to determine the drought tolerance of 83 commercial cotton cultivars, stated that the drought tolerance index of some cultivars was high and the drought tolerance index showed a significant correlation with the chlorophyll content (SPAD value).

Stomatal regulation plays an imperative role in leaf gas exchange between the intracellular cavity of the leaf and external environment (Khan et al., 2018). It has been reported that the limitation in stomatal conductivity in case of water deficiency in the plant plays an important role in the decrease in the photosynthesis rate, when stress progresses, non-stoma-related factors also play an important role, and seed yield, seed weight, boll number and total biomass decrease significantly in severe water deficiency (Lokhande and Reddy., 2014). Tanwir et al. (2006) reported that stomata with smaller diameters reduced transpiration, which in turn increased resistance to drought.

Deeba et al. (2012) investigated physiological and proteomic response of cotton to drought tolerance and they revealed that the gas-exchange parameters of net photosynthesis (A), stomatal conductance (gs) and transpiration (E) showed a decreasing trend as the drought intensity increased. The fluorescence parameters of, effective quantum yield of PSII (FPSII), and electron transport rates (ETR), also has been showed a declining trend. Borah et al. (2021) also reported that drought stress reduces photosynthesis by reducing leaf area and photosynthetic rate per leaf area. Pilon et al. (2015) observed that lower stomatal conductance in plants under water- deficit stress and actual quantum yield of photosystem II varied among the cultivars, photosynthesis and electron transport rate also decreased over time.

Veesar et al. (2020) revealed that stomatal conductance of cotton genotypes was significantly altered under the influence of drought stress. Likewise, the cotton genotypes responded differentially to drought stress conditions. Under drought stress, cotton genotypes decreased the stomatal conductance varying from -55.50 to -101.50 mmol m^{-2} s^{-1}. In drought stress, the maximum drop in stomatal conductance has been recorded in Sadori (-101.50 mmol m^{-2} s^{-1}) distantly followed by CIM-506 (-90.50 mmol m^{-2} s^{-1}), hence indicated their less vulnerability in water stress conditions. Nonetheless, Chandi, NIAB-78 and CIM-499 genotypes has been recorded less declines in stomatal conductance under drought stress showed their higher susceptibility to water stress. On the other hand, Ackerson et al. (1997) revealed that measurement of stomatal activity may not be a good criterion for assessing plant water status of cotton. The measurement of one or more physiological processes may prove a better index of plant water status as well as providing sensitive selection criteria for breeding more drought tolerant varieties.

A newly published study revealed that highly significant differences between genotypes for morphological and physiological traits except transpiration rate and strong positive correlation between transpiration rate and relative water content, stomatal conductance and relative water content with photosynthesis (Zahid et al., 2021).

Drought stress significantly affects stomatal conductivity. Aboughadareh et al., 2017 investigated 182 wheat accessions and they reported that drought stress caused a 42% decrease in stomatal conductivity declined by 41.52% across the 182 genotypes from 39.53 mmol m^{-2} s^{-1} in the control to 23.12 mmol m^{-2} s^{-1} under drought stress. Drought stress also decreased the chlorophyll content, relative water content and maximum quantum efficiency by 14.90, 12.13 and 11.42%, respectively. Whilst maintaining higher stomatal conductance, can produce higher yields (Veesar et al., 2020).

Drought stress can be created artificially in the laboratory with the application of PEG (polyethylene glycol) (Plant Stress.com). PEG causes osmotic stress and is therefore used as a simulator in drought stress studies (Blum, 2008). PEG application is a simple, fast and easily applicable method and can be used to evaluate the drought tolerance of varieties (Zhang et al., 2007, Chutia and Borah, 2012, Zhang et al., 2014). PEG is an important approach to evaluate genotypes for drought tolerance in the greenhouse, because it is easy to maintain humidity and temperature at the vegetative growth phase in the greenhouse (Abdelrahem et al., 2012).

Mohammadkhani and Heidari (2008) reported that 24 hours after PEG application, they determined the root length, green part length and dry weight of the plant, root length, green part length and dry weight decreased in both cultivars under water stress, and germination decreased drastically with PEG application.

Zhang et al. (2007) stated that they applied PEG 6000 stress for 12 hours during germination, budding, cotyledon period and true leaf period in cotton, and 3-6 leaf period was a key period for drought tolerance. Geetha et al. (2012) evaluated fifty sunflower genotypes against drought and compared two levels of osmotic stress (PEG, -0.3 MPa and -0.9 MPa) with the control. They reported that height ratio and seedling dry weight decreased with increasing osmotic stress, and that they suggested PEG 6000 for the differentiation of sunflower varieties in drought tolerance studies.

Iqbal and Ashraf (2006) in their PEG 8000 study with sunflower, compared control, -0.6, -1.2 MPa osmotic stress, and found that PEG application severely reduced the germination rate, green and dry biomass and mean germination time. Xanthopoulos et al., 2012, examined 11 cotton cultivars using different concentrations of PEG (0, 40, 80, 120, 160 g/100ml H_2O) and their germination ability decreased under stress conditions, there are differences in germination rate among varieties, they reported that variety x PEG application interaction was important, Hermes variety was the least affected variety and Sandra variety was the most affected variety.

Fernandez-Conde (1998) in a study investigating the effect of PEG application on physiological parameters in cotton, stated that net photosynthesis rate, stomatal conductivity and transpiration were lower in stressed plants compared to control, but the rate of photosynthesis was more affected by transpiration and water use efficiency decreased in plants treated with PEG.

Nepomuceno et al. (1998) screened four cotton genotypes with varying levels of suspected drought tolerance were subjected to a water deficit of -0.3 MPa induced by PEG. Water potentials and osmotic potentials of leaves and roots of stressed and non-stressed were measured and 10 tolerant cotton genotypes maintained higher water potentials during stress period, allowing them to maintain photosynthesis, stomatal conductance, and relative water content at near unstressed levels.

Pace et al. (1999) stated that it is important to know the response of plants to limited water, in breeding drought-resistant varieties and in knowing the water need of the plant; for this purpose, in the study conducted with late cotton variety Stoneville-506 and early Tamcot HQ 95 varieties, root and above-ground parts were examined after a short drought period and the next improvement period; in plants exposed to drought, lower plant height, leaf area, number of nodes, leaf and root dry weight were determined compared to the control; however, they reported no reduction in root growth until the end of the healing period.

Chattha et al. (2019) observed positive correlation of proline contents and chlorophyll fluorescence with seed cotton yield and they suggested that these two traits can be used as a marker for drought tolerance to select cotton genotypes that can be cultivated in water shortage areas.

When plants are exposed to adverse stress conditions such as drought, the metabolism of the plant slows down and begins to deteriorate. Plants produce some organic substances such as proline, glycine betaine to prevent the slowdown and regression of their metabolism. These substances, which are harmless and low molecular weight inside the cell, are called osmolytes (Kılınçoğlu et al., 2020).

Pigment concentrations, including Chlorophyll a and b, is reduced by water-deficit stress over time. Enzyme activity has been significantly increased by water-deficit stress, with stressed plants having a 4-fold increase in superoxide dismutase activity, a 10-fold increase in catalase activity, and a 57% increase in ascorbate peroxidase concentration compared with the control (Pilon et al., 2015).

Pandey et al. (2003) compared the effects of plant hormones indole-3-yl-acetic acid (IAA), gibberellic acid (GA), benzylaminopurine (BAP), abscisic acid (ABA) and ethrel (ETH) in 5 M concentration on gas exchange, ribulose-1,5-bisphosphate carboxylase/oxygenase

(RuBPCO, EC 4.1.1.39) activity, pigment content and yield in cotton under drought stress they revealed that net photosynthetic rate, stomatal conductance, transpiration rate, carboxylation efficiency, water use efficiency, RuBPCO activity, boll number per plant, seed number per plant and lint mass per plant significantly decreased at drought while chlorophyll (Chl) b content and flower number per plant increased. Detrimental drought effect was significantly alleviated by BAP and ABA treatment.

The mechanism of avoiding stress is to reduce the effect of stress. Plants achieve this by changing their morphological structure (the surface and thickness of the leaf lamina, the size and chemical composition of their roots and stems). Proline contents and the bolls per plant showed high heritability and genetic advance through additive gene action. Therefore, these two traits can be used as a means of selection in future breeding programmes of drought tolerance (Chattha et al., 2021).

Water is a vital to plant life and thus essential for numerous plant functions, including nutrient transport, chemical and enzymatic reactions, cell expansion, and transpiration (Pilon, 2015). Under water stress conditions, plant anatomy and morphology are altered as well as biochemical and physiological processes consequently affecting plant growth and yield (Pilon, 2015).

The crop water stress index (CWSI) has been proposed as a more quantitative and repeatable method for determining crop water status than the stress degree day method. On the other hand, satellites, airborne imaging systems and hand-held instruments are frequently proposed as indicators of crop stress caused by water, soil compaction, lack of nutrients, diseases and mites (Roth and Goyne, 2004). Another indicator is the measurement of the relative water content of the leaves. Relative water content (RWC) of the leaves estimates the water content of sampled leaf tissue relative to the maximum water content that it can hold at full turgidity. Saleem et al. (2015b) reported that cell membrane thermostability and proportional leaf water content were correlated, and that the genes involved in these characteristics were in genetic linkage with the genes controlling the number of bolls, fiber length and fiber strength in the plant.

Wilkerson (2016) indicated that NDVI (Normalized difference vegetative index), leaf surface temperature and chlorophyll content showed a positive association with lint yield and lint percent during flowering while stomatal conductance showed association with lint yield and lint percent during boll development. It has been reported that fiber length and strength may be affected by drought effects during flowering, while changes in fiber micronaire are closely related to differences in drought-related effects during boll development.

Borah et al. (2021) revealed that analysing all the physiological parameters under water stress to select the drought resistant germplasm and then studying the mechanism of drought resistance using whole gene expression study helps to identify the drought responsive genes in that particular species.

Leaf water content, rate of excised leaf water loss, modifying root systems, stomatal conductance, water use efficiency, photosynthetic rate, carbon isotope discrimination, initial water content, canopy temperature and compatible solutes has been used as selection criteria against drought stress in cotton. However, appropriate plant morphology could be combined with the physiological characters for drought tolerance by using conventional breeding and molecular breeding techniques to develop drought tolerant cultivars (Basal and Unay, 2006). Ball et al. (1994) used leaf area and photosynthesis to monitor growth rates and detected a significant decrease during drought stress.

Many physiological characteristics that determine the yield of the plant are also affected by drought conditions. The sensitivity of plants to water shortage is most effective in the generative period. As a result of the researches, it is revealed that severe drought conditions in the developmental stage when seed formation begins lead to yield loss of up to 95%. It is known that the water shortage, especially during the flowering phase, causes infertility in the plant (Farooq et al., 2009).

There are significant differences between cotton varieties in terms of drought tolerance (Quisenberry et al., 1982). It has been confirmed that there is a strong and negative relationship between drought stress and fiber yield in cotton (Singh et al., 2007). In a studies conducted in Turkey, it has been reported that drought stress causes 48% yield loss in cotton yield, and water stress negatively affects fiber technological properties (Karademir et al., 2011). Similar results reported by Zare et al., 2014 who reported that drought stress caused a 47.03% decrease in seed yield, this event was due to the fact that water stress reduced the number of bolls in the plant, which may have had a negative impact on yield.

EFFECT OF DROUGHT STRESS ON MORPHOLOGICAL PARAMETERS

Cotton has an indeterminate growth habit. With the onset of drought, the balance of vegetative and reproductive development got depressed. Drought stress disrupts the boll development and distribution as the higher fruiting branches have smaller and fewer bolls. Drought stress at the time of early reproductive growth results in shorter plants with a smaller number of nodes, but plants compensate yield if sufficient water is available at latter stages. It was reported that drought stress reduces leaf surface area and thus, photosynthetic productivity leading to partial shedding of crop organs like bolls, leaves and flowers. Thus, to develop genotypes tolerant to drought stress it is necessary to understand the underlying mechanism like gas exchange, carbohydrate metabolism, osmatic adjustment, and etc. (Ul-Allah et al., 2021).

The decrease in yield was caused by the decrease in the number of bolls (Alishah and Ahmadikhah, 2009), in a study in which 32 cotton varieties were exposed to water stress, there was a decrease in productivity parameters such as seed cotton yield, number of bolls per plant and boll weight, and the factor determining yield under water stress conditions was the boll retention.

Drought stress causes a decrease in plant yield, number of bolls and fiber yield, the rate of photosynthesis changes slightly during the squaring and flowering period, and more rapidly during the boll formation period (Zhang et al., 2010). Baksh et al. (2019) revealed that water stress caused a reduction in days to first square formation, days to first flower formation, plant height, number of monopodial branches, number of sympodial branches, number of bolls per plant, boll weight, ginning out turn and seed cotton yield.

Peynircioğlu (2014) revealed that the limited irrigation decreased the average seed cotton yield, 1^{st} and 2^{nd} position boll retention rate, number of bolls per plant, fiber length, uniformity value and fiber strength values and increased ginning percentage and fiber fineness values in cotton genotypes, on the other hand seed cotton weight per boll, fiber elongation and 100 seed weight values were not affected.

Galeshi et al. (2005) exposed 40 cotton cultivars to 3 different drought stresses, examined the emergence percentage, emergence rate, number of leaves, leaf area, total dry weight (root and green parts) and root/shoot ratio. They revealed that the other properties examined except for the root/shoot ratio decreased with the increase of drought stress, and the leaf area was the most sensitive traits among all the examined properties and it has suffered a significant loss.

Drought stress causes significant yield and quality losses in cotton production and prevents an economical cotton production. In drought stress conditions, yield losses are experienced depending on the duration of drought stress, it leads to boll and boll shedding and fiber quality decreases significantly. It has been reported that severe water stress at the peak flowering stage causes loss of square and young bolls, which causes yield reduction, and fiber fineness and fiber length are negatively affected by water stress (Grimes and El-Zik., 1990; Basal et al., 2009; Hussein et al., 2011).

It is known that the period when the cotton plant is most sensitive to drought stress is the flowering and boll formation period (Snowden et al., 2014). On the other hand, some researchers revealed that the peak flowering period was the most sensitive to drought and at this time water stress led to the greatest decrease in yield.

According to the data on the varieties evaluated in the study, they reported that the flowering potential plays the most important role in drought tolerance. They stated that by determining the drought tolerant germplasms, breeders can obtain high yield cotton under water deficiency conditions.

A newly published study it was proposed that five traits which included plant height (PH), effective fruit branch number (EFBN), single boll weight (SBW), transpiration rate (Tr) and chlorophyll (Chl) content could be used in combination to screen cotton varieties or lines for drought tolerance in cotton breeding programs, and at the study Zhong R2016 and Xin lu zao 45 genotypes has been exhibited high drought tolerance. Therefore, it has been reported that they can be selected as superior parents for good yield performance under drought stress (Sun et al., 2021).

Drought stress affects both the vegetative part and root development of the plant. McMichael and Quisenberry (1991) reported that under severe water stress conditions, the ratio of shoot/root decreased, lower dry matter weight and less node formed in leaves and stems, and leaf area decreased, while Malik et al. (1979) stated that root growth was less affected than green parts development under drought stress conditions. The root is an integral plant organ that is involved in the acquisition of nutrients and water; the synthesis of plant hormones, organic acids, and amino acids; and the anchorage of plants (Niu et al., 2018). Therefore, previous drought tolerant studies have focused on root growth and root characteristics, either modifying root systems to increase water use efficiency or determining morpho-physiology of plants, and the effects of plant growth regulators on cotton roots for increasing drought resistance (Basal and Unay, 2006).

In a recent study, 50 cotton varieties were tested against drought, drought indices were determined in terms of shoot and root length of the plant, and it was determined that taller plants reached better yields under drought stress conditions (Javaid et al., 2015). Longenberger, 2005, studied three drought cycles in the greenhouse in order to develop an observation method to test a large number of materials against drought in a short time, the results indicated that one drought cycle was sufficient to determine the drought tolerance of the varieties during the seedling period, and DP 491 cotton variety was the most drought resistant variety.

Cook and El-Zik (1992) stated that features such as increasing seedling strength, rapid root system formation, low root/shoot ratio will gain importance in the future to increase drought tolerance. In previous studies, strong root system, water use efficiency, stomatal conductance, photosynthesis rate, carbon isotope discrimination, canopy temperature, initial water content, leaf water content, the rate of excised leaf water loss and osmotic regulators were suggested as selection criteria in drought resistant cotton breeding studies (Basal and Unay, 2006). Longenberger et al., 2009, reported that chlorophyll reflection can be used as an observation tool to determine plant water status under drought stress conditions, plant physiologists state that chlorophyll reflection can be used to understand the mechanism of photosynthesis, to determine the tolerance of genotypes to water deficiency.

In a recent study, NAU2954, NAU2715 markers were reported to be associated with drought stress in cotton plants. At the same time, NAU, DPL, JESPR and CIR EST-SSR primers were found to be highly polymorphic in the determination of cotton plants against drought stress (Saleem et al., 2015a).

DROUGHT TOLERANCE MECHANISMS AND PLANTS RESPONSE TO DROUGHT

Drought tolerance mechanisms in plants and response of plants when encounter drought stress it can be divided into four strategies: drought tolerance, drought avoidance, drought escape, and drought recovery (Fang and Xiong, 2015; Ullah et al., 2017). The response of plants to drought has been well described in the literature. Drought avoidance and drought tolerance are the two major strategies of plants against drought stress. Drought avoidance is the maintenance of key physiological processes, such as stomata regulation, root system development and others, during moderate drought conditions. Drought tolerance is the capability of plants to withstand severe dehydration through specific physiological activities, such as osmotic adjustment via osmoprotectants. Drought escape is the ability of plants to adjust their growth period or lifecycle, such as the cotton variety with a short life cycle, to avoid the seasonal drought stress. Drought recovery of plants is the capability to resume growth and yield after exposure to severe drought stress (Ullah et al., 2017). Under drought stress the tolerant genotypes has been showed higher metabolic activity than the susceptible one and a better recovery on rewatering for most of the parameters. It is suggested that drought tolerance is associated with it is ability to maintain relativel higher RWC, metabolic activity and membrane and chlorophyll stability under conditions of water deficit stress (Sairam, 1994). Drought tolerance is associated with higher proline contents and is improved relative to water content (RWC) maintenance under drought stress (Mahmood et al., 2021).

The duration of drought stress has a significant effect on the yield and quality performance of plants. As the duration of stress increases, productivity decreases significantly. Early maturity and a short growth period provide a chance to escape the drought spell and minimize the yield losses (Mahmood et al., 2021). However, the most effective way to reduce the effect of drought stress is to develop drought stress tolerant/resistant cotton varieties.

In the study carried out under water stress conditions, it is stated that there is genetic variation among the varieties in terms of flowering, boll formation, fiber yield, earliness and water use efficiency (Cook and El-Zik., 1993).

Guiterrez et al. (1994) selected upland (*Gossypium hirsutum* L.) cotton genotypes from the world collection for field trials in dry conditions; they reported that they investigated different mechanisms of drought resistance by examining properties such as yield, root and shoot characters, photosynthesis activity, plant form, stomal movements, water use efficiency, leaf temperature and leaf weight in the varieties included in the experiment. As a result of the research, it was determined that there were significant differences between the varieties in terms of drought resistance and the Australian variety Sicala 33 was the most suitable variety in terms of drought resistance.

CONCLUSION

So far many studies have been conducted on performance of cotton genotypes under water-stress conditions under the greenhouse, growth chamber (controlled conditions) and field (real conditions) to better understand the effects of drought on production. Under controlled conditions such as greenhouse or growth chamber, physiologists, breeders or molecular biologists studied and been interested in the performance of plants under sudden and severe drought stress with durations of a few hours or days. According to the results they evaluate plant drought resistance by using some physiological characteristics or survival rates. However, in agricultural production, this type of sudden and severe drought stress is not common event. The field condition is more complex and diverse, and there is other stresses except the drought stress in the field. Therefore, the key to improve upon drought resistance strategies is to facilitate dialogue among producers, agronomists, breeders, plant physiologists, molecular biologists and other neccesary expert areas. There is not chemical control for drougth stress. The most important solution is developing resistant varieties against drought stress for high yielding production in cotton under drought stress conditions. Therefore, breeders must have too much information about morphological and physiological characteristics of cotton for developing resistant varieties.

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CHAPTER 4

THE IMPORTANCE OF IRRIGATION IN COTTON PRODUCTION

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Although three quarters of the earth's surface is covered with water, the amount of fresh water suitable for human use is quite limited. The total amount of fresh water on Earth is approximately 35 million km^3 (2.5 % of the total water on Earth), of which only 0.3 % (about 105,000 km^3) consists of fresh water resources suitable for ecosystem and human use. The remaining freshwater is mostly trapped in arctic and high mountain glaciers and under ground reserves.

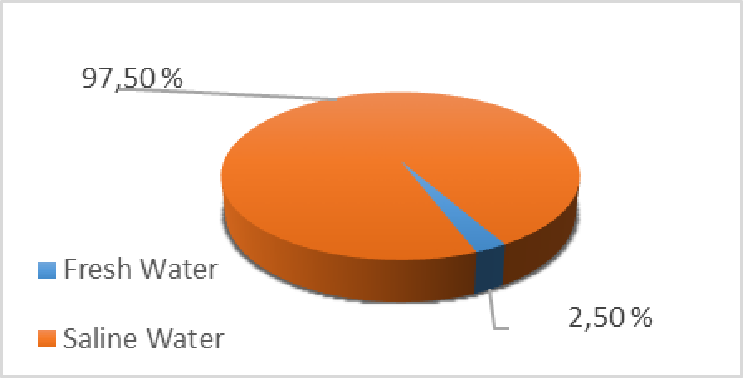

Figure 1: The world's fresh and salt water availability

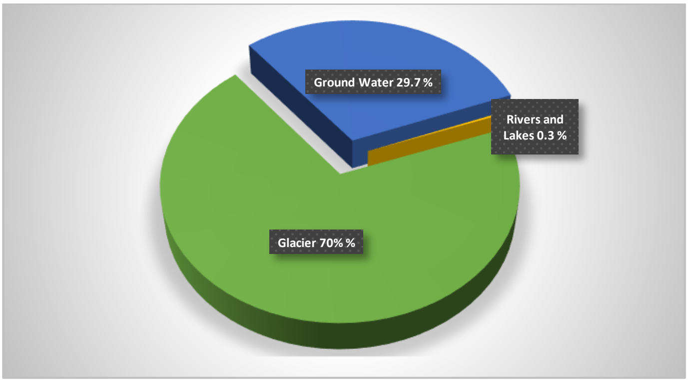

Figure 2: Distribution of the world's total water availability

About 70% of the world's water resources are used for agriculture. This is followed by industrial and domestic use with 19% and 11%.
The water scarcity that the world facing today; issues such as food needs and climate change are interconnected in a very complex way. Global warming due to the greenhouse effect creates an unpredictable situation in the mass distribution of water. This situation means that some regions will receive excessive precipitation, whereas other regions will experience serious decreases in precipitation; that shows that countries with already limited water will enter a period of indefinite water scarcity.

With the deterioration of the natural balance in recent years, the effects of global warming in the world and in our country have begun to manifest themselves as drought. Drought caused by the decrease in water resources and precipitation in our country creates problems in agricultural production. These negativities necessitate the conscious and economical use of our water resources.

Another problem that will arise in terms of crop production due to global climate change and the increase in air temperatures and CO_2 is the changes to be seen in the precipitation regime. As stated in previous studies, Aegean and Southeastern Anatolia regions are among the regions that will be most affected by drought with the starting the dry period (Türkeş, 2008).

Reducing the negative effects of the mentioned wetness and drought possibilities on agricultural production is only possible with the development of new solutions. For this reason, comprehensive information on plant water requirement, effective use of water, and correct establishment of irrigation program has become an important goal (Maya and Kanber, 2008).

In most regions with arid and semi-arid climate, including our country, irregular and insufficient rainfall causes a significant decrease in the volume of storable water. However, the increase in the population of the country has caused an increase in the demand for drinking and utility water at the same time, the rapid increase in industrialization has created a significant increase in the use of water for industrial purposes.

In order to adequately feed the rapidly increasing world population, the production of agricultural products must increase at that rate. Due to the limited agricultural areas, feeding the increasing population will only be possible with an increase in the yield to be obtained from the unit area. In order to obtain more and high quality products from the unit area, first of all, the growing media conditions plant growing conditions should be prepared on time and using the appropriate methods. High yielding and disease resistant seeds or cultivars should be selected. In addition to agricultural processes such as hoeing and spraying, fertilization and irrigation have a great role on growing the plant magnificiently and in obtaining high yield (Biber and Kara, 2006).

Irrigation is the process of applying the part of the water that plants need for their growth, which cannot be met by natural precipitation, to the soil, to the root zone of the plant in a systematic (efficient) manner within the framework of a certain plan. Although irrigation is an agricultural input, when other agricultural inputs are not sufficiently technical, plant growth cannot be perform at the desired level with irrigation alone. However, meeting the plant water requirement at the desired level has a great importance in terms of increasing the efficiency of some other agricultural inputs.

As long as irrigation is implemented in properly, it is an effective factor in achieving the desired yield and quality product as well as preserving the soil structure. Otherwise, it may cause the formation of a structure that will negatively affect agriculture in the future, such as drainage, salinity problems, and reproduction of diseases and pests.

In order for plants to fulfill their vital functions and meet the desired yield, they must take the nutrients from the soil in dissolved form with the help of their roots. Water is vital for plants in terms of both the dissolution of nutrients in the soil and the transport of these nutrients to plant roots, stems, branches and leaves. Irrigation has two main purposes:

- To provide the necessary moisture and nutrients in the soil for the growth of the plant.
- Leaching the salt in the soil or turning it into a solution.

Soil-plant-water relationship is very important in terms of cultivation. The plant takes the water from the soil with the help of its roots and transmits it to its cells, tissues and leaves. The water coming from the leaves is given to the atmosphere by transpiration. The plant, which plays an important role in the water cycle between the soil and the atmosphere, has a vital importance for the plant, the water circulating between its roots and leaves.

Despite the increasing importance of irrigation in many parts of the world, water resources used for agricultural purposes are gradually decreasing due to rapid urbanization, industrial requirements and source pollution. In order to ensure efficient use of water in agriculture, the first precaution to be taken should be irrigation performed both consciously and in accordance with the technique.

The inadequacy of water resources necessitates the expansion of irrigation systems with high irrigation efficiency. Thus, larger areas can be irrigated with the available water resources. In addition, the importance of using irrigation systems and methods, which require less labor, less energy and increase efficiency and quality, is increasing day by day.

As it is known, compared to surface irrigation, pressurized irrigation systems are systems that not only save water and energy, but also cause minimal water loss, do not create environmental pollution, and increase both the amount and quality of the product.

By applying drip irrigation systems and the appropriate planning of irrigation time, water resources can be used effectively and thus a significant amount of water can be saved. One of the most basic conditions for sustainable agriculture is drip irrigation systems, which have a water application efficiency up to 90-95% and increase the water use efficiency of plants.

Cotton irrigation

In almost no part of our country, the water required for the optimum growth of the cotton plant cannot be provided by precipitation. Therefore, irrigation is compulsory in cotton farming in our country.

Cotton is a very sensitive plant to soil moisture conditions. Soil moisture is essential for strong growth, shoot and fruit formation, as well as for proper fruit growth. It is stated that if the cotton plant, that seasonal evaporatranspiration varies between 700-1300 mm, is irrigated when 40-50% of the usable water holding capacity of the soil is consumed, high yield and quality product can be obtained at the same time, and if sufficient water is not given to the plant during the flowering periods, there may be significant reductions in yield. The lack of water in the plant and the resulting plant water tension have a significant effect on water consumption and yield (Dağdelen et al., 2009).

Excessive soil moisture during the growth period of cotton causes excessive vegetative growth and adversely affects fruit set. The fact that the soil moisture is below the desired level negatively affects the vegetative growth of the plant, especially the excessive moisture deficiencies that occur during the flowering period stop the growth completely and cause fruit drop. In order to obtain the desired number of bolls from a plant in cotton farming, soil moisture must be kept at the intended level. The maximum depth that the plant roots can reach during the growing season is called the plant root depth. This depth varies according to the plant, soil characteristics, climate, irrigation method and irrigation schedules. Effective root depth in cotton plant is considered to be about 90 cm (Tekinel and Kanber,1989). Generally, the water requirement of the cotton plant is calculated over this depth.

Water applications more than necessary may cause the soil to become airless, the plant to suffocate from stuffiness or the soil to settle after irrigation, thus causing insufficient development of the roots. In addition, the roots cannot go deep because they can find moisture in the area near to the soil surface. For this reason, other irrigations should be done at more frequent intervals. No matter how timely the subsequent irrigations are made, the negative effect of the first irrigation on cotton yield cannot be eliminated (Aydemir, 1982).

Irrigation time in cotton farming can be determined with the help of detecting the soil moisture content, measuring the moisture in the plant tissues and the indications of the plant. Soil moisture can be determined manually or by using some tools. These tools are the measurement of electrical conductivity between a tensiometer or a permeable block.

Some water demand indications such as increased flowering density, color change in the main stem or darkening of the cotton leaves appear in the cotton plant due to the water stress. In this method, irrigation calendar is created by using these indications. When there is enough moisture in the soil for germination and seedling growth, it is not necessary to irrigate the cotton plant until the flowering period, the plant water consumption is very low during this period. During the flowering period, the plants are now in a growth state, during this period the air temperature, evaporation and the amount of water lost by the plant through transpiration have increased considerably. In this period when the water requirement of the plant increases, even delaying the irrigation for a few days may increase the flower and square shedding. In case of early irrigation, sufficient flowers and bolls are not formed, the fruits formed are poured. (Aydemir, 1982).

It has been determined by studies that the yield of cotton increases three to four times with irrigation (Tekinel and Kanber, 1989). The importance of efficient irrigation systems is gradually increasing when the issues such as the decrease in the water allocated for irrigation, environmental pollution due to irrigation and the production of more products per unit water are taken into account. Drip irrigation is widely used in irrigation of row crops grown in the field today. Drip irrigation methods have important advantages such as high water and nutrient use efficiency, increase in yield and quality, low infiltration losses by controlled application of irrigation water, and reduction in total irrigation water need. Si nce only a certain area of the land is wetted with drip systems, naturally, significant water savings are achieved (Goldberg et al., 1976).

The cotton planted in the soil at appropriate humidity is not irrigated for the first 40 days on average. The last water should be given at the 5-10 % boll opening period. The water to be given later causes the harvest to be delayed too late and the cotton to be caught in the autumn rains. Stopping irrigation too late can have negative effects on yield and fiber quality by increasing pest and disease pressure.

In Çukurova conditions; comparing furrow, sprinkler and drip irrigation systems in cotton, the most applying irrigation water was found in the furrow (894-1398 mm); the least irrigation water was applied in drip irrigation (168-182 mm), although much less water was used in drip irrigation, approximately the same yield was obtained (Yavuz, 1993). As seen in this study, drip irrigation system has a great importance in terms of water saving.

In addition, it has been stated that the period from squaring to the period when the first flower is seen is the most important development period affecting the yield elements and the water stresses that will occur in this period will cause great reductions in cotton yield (Krieg,1997).

The approximate 21 days from first square to first bloom is a critical time for avoiding severe water deficit stress. During this period, cotton vegetative growth is very rapid and the number of potential fruiting sites for the crop is determined, especially in short season environments (Oosterhuis and Loka., 2012).

Acala, Maxxa and Acala phytojel-72 (Gossypium hirsutum L.) cotton varieties were planted in sandy soil by (Detar, 2007) in California, USA. To achieve maximum yield, a highly efficient underground drip irrigation system and six different water applications ranging from 33 to 144 % were tried. In the research, it has been determined that the critical water application level in the middle of the season is above 95% on average compared to the Class A evaporation pan. It has been stated that an application lower than this critical level reduces the yield and keeping the water application below 5% of the critical level causes a 4.6% decrease in yield.

Dağdelen et al. 2008, conducted a study with Nazilli 84 cotton variety in 2004 and 2005 years; by applying 4 different irrigation amounts (T100, T75, T50, T25) with the drip irrigation method they stated that 100% irrigation can be used in semi-arid climatic conditions, 75% irrigation can be applied to save water, but 25% water saving also leds to a net income decrease of 34%.

It has been determined that drought stress causes a decrease of approximately 40%-50% in the seed cotton yield and this event may have adversely affected the yield due to the fact that water stress reduced the number of bolls in the plant (Zare et al., 2014).

In the study, that carried out in Diyarbakır conditions, between 2016-2017 years applying different drip irrigation systems and different irrigation treatments, to determine the fiber yield and yield components of cotton, the main plots were different drip irrigation methods (I1: Surface drip, I2: Subsurface drip 30 cm, I3: Subsurface drip 40 cm) sub-plots consisted of different irrigation treatments, (K1: 1.25 × ETc (plant water consumption), K2: 1.00 × ETc, K3: 0.75 × ETc). Irrigation interval was applied as 5 days. Fiber yields varied between 1108–1734 kg ha^{-1} in 2016, and between 1117-2457 kg ha^{-1} in 2017, depending on the treatments. The highest fiber yields were obtained from the I3K1 treatment in both trial years, and it was reported that as the irrigation water increased in all drip irrigation systems, the fiber yield increased as well (Üzen et al. 2018).

Effect of irrigation on cotton physiology

It has been accepted by many researchers that plant growth is directly related to the water balance in plant tissues. If the plant cannot reach the water it needs, the physiological processes in the plants are disrupted and this situation affects the growth and then the yield negatively. Since water plays an important and dominant role in plant nutrient uptake, transport, chemical and enzymatic reactions, cell growth and expansion, physiological events such as transpiration, water deficiency significantly affects plant development, morphology and biochemical processes (Loka and Oosterhuis, 2012).

Water stress in the plant can be effective depending on the duration and severity of the stress, the plant growth period at the time of the stress, and the plant variety. After the germination of the seed, the generative growth period of the plant is known as the most sensitive period to water stress. Cotton is a very sensitive plant to water stress during both flowering and boll formation periods.

Drought affects both the vegetative part and root development of the plant. (McMichael and Quisenberry, 1991) reported that under severe water stress conditions, the ratio of root length of green parts decreased, the dry matter weight and less nodes formed in the leaf and stem, and the leaf area decreased.

Leaf relative moisture content is known as an important physiological indicator in drought stress studies. In terms of the physiological consequences of cellular water deficiency, one of the most appropriate measurement methods to show the plant water status is to determine the relative moisture content of the leaf. The relative moisture content of the leaf, the water potential used as a predictor of the energy state of the plant water, is useful for issues related to water transport in the soil-plant-atmosphere process. Determination of the relative moisture content of the leaf is widely used in physiology and breeding studies. It is preferred because the proportional moisture content of the leaf and the water loss observations in the cut leaf give easy and fast results. The decrease in relative humidity causes a decrease in turgidity in the leaf, stoma are closed due to this decrease, and as a result, a decrease in photosynthesis rate and a decrease in yield are experienced.

Leaf area index plays a primary role in capturing light energy and converting it into biochemical energy by plants. Determining the leaf area where production and transpiration is made is very important in terms of yield (Saeed and El-Nadi, 1998).

Plant photosynthesis and, accordingly, biomass production are closely related to the light-shedding ability of green parts (Muchow et al. 1990).

The fact that the vegetation temperature (canopy temperature), which occurs as a result of many physiological processes in the plant such as photosynthesis, stomatal conductivity, and water transport, is highly related to yield in hot and dry conditions has a great importance for the selections (Rashid et al., 1999).

It has been stated that the relationship between chlorophyll content and vegetation temperature will increase the genetic progress in obtaining plants with high cooling ability and high chlorophyll content and also in many studies that the amount of chlorophyll in the leaves of plants changes depending on the amount of irrigation water given, that is, the rate of chlorophyll in plants decreases against water stress (Babar et al., 2006).

In the study conducted by Avşar, 2019, was reported that water stress applications in cotton caused a decrease in physiological parameters such as chlorophyll content, leaf proportional water content, NDVI value, photosynthesis rate, stomatal conductivity and transpiration rate and an increase in canopy temperature.

The effect of irrigation on cotton fiber quality

It has been reported by many researchers that the drought that occurs during the period when cotton fibers begin to elongate adversely affects fiber length, fiber strength and fiber maturity (McWilliams, 2004; Mert, 2005; Başal et al., 2009).

In the study that carried out in Diyarbakır conditions, it was concluded that the technological properties of the fiber were affected by water stress conditions. It was determined that water stress caused a decrease in fiber fineness, fiber length, fiber strength, fiber elongation, fiber uniformity index and, spinning consisteny index, increased fiber yellowness and short fiber index and fiber reflectance value was not affected by water stress (Avşar, 2019).

Since irrigation changes the environmental conditions, it also indirectly affects the boll and fiber properties. Rather than the amount of irrigation water, the time and interval of irrigation have an effect on the fiber properties. The decrease in soil moisture during the boll formation stage leads to long and thin fibers with low strength (Kodal et al., 1995; Legal Ul, 2003). For a similar purpose, in a study conducted in the Aegean Region, it was stated that the fibers were longer with full water application, whereas the fiber strength was no different in irrigated and non-irrigated treatments (Özkara and Yalçuk, 1984). In another study conducted in the Aegean Region, it was revealed that 100 seed weight, fiber fineness and fiber length increased depending on the number and amount of irrigation, whereas fiber strength did not change (Özkara and Şahin, 1993).

In a study conducted by Darawsheh, 2010 cotton fiber quality parameters under stress and normal irrigation conditions; has been reported that the yellowness value of the fiber (+b) is higher at $P \leq 0.01$ significance level in water stress treatments compared to full irrigated treatments.

As a result of the study conducted in 2016 to determine the effects of different irrigation levels (100%, 75%, 50% and zero) with Stoneville 468 cotton variety on the growth parameters, yield, quality and leaf nutrient content of cotton plant, It was determined that fiber length, fiber strength and fiber elongation values were the highest in full irrigation and decreased in parallel with the water stress (Ektiren (2017).

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CHAPTER 5

COTTON AT A GLANCE IN TURKIYE

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SUMMARY

Cotton has an increasing value day by day thanks to the important products it offers to the service of humanity, such as primarily its fiber, oil and linter, cotton plant; it provides the raw materials of the agricultural producer who is grown in the field, the gin industrialist where it is processed, the textile industrialist with its fiber, the oil and feed industrialists with its seeds, and the paper industrialist with its linter. For all these reasons, cotton; due to the employment it creates, it maintains its feature as one of the most important cultural plants in the world in terms of both socio-economic aspects and the added value it provides to the national economies.

The ten-year average data in the 2011/12 and 2020/21 cotton production seasons show that the total cotton cultivation area in the world is 32.953.000 hectares, the production is 25.595.000 tons and the consumption is 24.452.000 tons. Average cotton cultivation area, cotton production and consumption in Türkiye during the same production seasons are 465,000 hectares, 780,000 tons and 1,495,000 tons respectively. More than 80% of world cotton production is covered by 7 countries (India, China, USA, Brazil, Pakistan, Türkiye, Uzbekistan) including Türkiye.

Türkiye is the seventh largest producer in the world. However, in order to meet the needs of the Textile Industry, which has been developing rapidly in the country in recent years, it imports almost as much or more cotton as it produces every year. In 2020 and 2021 years, 60 % of the cotton produced in Türkiye was obtained from the Southeast Anatolia,

25% from the Aegean and 15% from the Çukurova Regions. With the GAP Project initiated in 1989, irrigation areas in the region have increased. With the increasing irrigation areas, cotton cultivation and production rates have increased with a great acceleration. More than half of the cotton production in the country has started to take place in this region. When Türkiye's cotton agriculture in the last twenty years is examined; It can be said that the private sector plays an important role in the supply of cotton seeds and the development of new cotton varieties. Between 2001-2021, cotton seed production rate of private sector increased from 19% to 95%. In addition to these developments, in the last 10 years, the Turkish Government support for projects that encourage them to work together, by gathering universities, public research institutes and private companies under one roof, through supporting channels such as TUBITAK and TAGEM, has made great breakthroughs for breeding domestic cotton seed production.

The Turkish textile industry is one of the most important and dynamic sectors of the Turkish economy, which accounts for 8% of the gross domestic product. In 2019, Türkiye's exports of textiles and raw materials amounted to US$ 7.841 billion, while exports of ready-made clothing and apparel totaled US$ 26,027 billion, with US$ 18.186 billion. Türkiye's textile industry and related sub-sectors employ close to 2 million people. Only in the agricultural sector, more than 3.5 million people earn their living from cotton farming. For these reasons, cotton is a very important cultural plant for Türkiye both in terms of socio-economic structure and strategically.

INTRODUCTION

Cotton is a cultivated plant that requires high sunlight and long time. Cotton, a warm climate plant, is grown between 37^{O} North and 32^{O} South parallels. About 90% of the world's cotton farming takes place in the Northern Hemisphere. Cotton is produced in nearly eighty countries around the world. More than 80% of cotton production is carried out in seven countries, including Türkiye. Cotton is grown on 2.5% of the arable land in the world. Cotton is one of the most important cultivated plants in terms of its usage areas and the added value it creates, and it is increasing day by day. In addition, it provides employment for millions of people during cotton production, transportation, ginning, baling and storage and in sub-industries such as agricultural inputs, machinery and equipment, cotton seed crushing and textile manufacturing. Although cotton is primarily the raw material of the textile and ready-made clothing industry with its fiber, it is also an important cultural plant used in the fields of oil, feed and energy. Cottonseed oil is in the fifth place among the cooking oils consumed in the world. In recent years, in order to reduce environmental pollution caused by petroleum-derived fuels, oil obtained from cotton seeds has started to be used as a raw material in biodiesel production in increasing amounts. Thus, cotton started to play an important role in energy agriculture.

Cotton cultivation areas, fiber yields, production and trade values for cotton of the 16 countries that have a say in cotton production and trade in the world in 2019/20 and 2020/21 are given in Table 1. Cotton was produced in 80 countries of the world in the 2019/20 and 2020/21 periods. From these countries; India (24.2%), China (24.2%), USA (14.9%), Brazil (10.6%), Pakistan (4.4%), Uzbekistan (3.1%), Türkiye (2.9%) Australia (1.4%), Argentina (1.4%), Greece (1.3%), Benin (1.2%) and Turkmenistan (1.1%) Brukine Faso (0%, 8) and Mali (0.7%) share 91.4% of production, 87.3% of cultivation area and 85.5% of consumption (excluding Vietnam and Indonesia). ICAC Secretariat; 2021/22 reported world cotton area and production estimated at 33,188 million hectares and 25.73 million tons (ICAC – Country Online / 2021-12). When the world cotton yield values in the last twenty years are examined; It is seen that the world average yield value in the production season of 2001/02 is 646 kg ha^{-1}, and the yield value in the production season of 2020/21 is 760 kg ha^{-1}. The cotton yield in the world has increased by about 100 Kg ha^{-1} in the last two decades. In the 2020/21 production season, the cotton yield between countries in the world has changed between 100 Kg ha^{-1} (Kenya) and 2047 Kg ha^{-1} (Australia). According to the latest ICAC forecasts, the world average yield is expected to rise to 775 kilograms per hectare in the 2021/22 production season. The five countries with the highest efficiency in the 2020/21 season, in descending order; Australia (2047 Kg ha^{-1}), China (1864 Kg ha^{-1}), Türkiye (1827 Kg ha^{-1}), Brazil (1719 Kg ha^{-1}), Greece (1121 Kg ha^{-1}) and Uzbekistan (994 Kg ha^{-1}).

Türkiye has become the world's sixth largest cotton producer country after China, USA, India, Pakistan and Uzbekistan with approximately 900 thousand tons of fiber cotton production. Severe drought, low cotton prices, and farmers' switch to alternative crops have caused a dramatic decline in cotton production in recent years. In addition to a significant decrease in cultivation area and production in recent years, Türkiye's production has outstripped the world due to new production regions of Brazil and increasing annual production levels (ICAC, 2021).

When the long-term data of the cotton volume subject to international trade is reviewed; It can be said that cotton imports in the world were at a capacity of 2.5 million tons in the 1950s and increased by about one million tons every decade as a result of the developments in communication and transportation. Cotton import amount in the world in 2020/21 is 10,052,000 tons. The top 5 countries with the highest percentage in this figure are China (27.9%), Vietnam (15.4%), Türkiye (11.5%), Pakistan (8.7%) and Indonesia (5.0%), respectively. Although countries such as Indonesia, Vietnam and Bangladesh produce almost no cotton, they are among the important countries in import and consumption due to the development of textile industries by foreign investors due to cheap labor. When the world cotton trade is analyzed in terms of export values; In the 1950s, 2.6 million tons of cotton was exported in the world, 3.7 and 3.8 million tons in the 1960s and 1970s, 4.4 million tons in the 1980s, 5.1 and 5.8 million tons in the 1990s and 2000s. World cotton export values, which reached a capacity of 7.6 million tons in 2010, reached 10.6 million tons in the 2020/21 season. In the 2020/21 production season, the country with the largest export rate in the world is the USA with a large rate of 34.2%, followed by Brazil with 22.6% and India with 12.5%, from Table 1. The longstanding rise in the global cotton trade does not reflect the demand for cotton.

The cotton market is extremely global, with more than one-third of the world's cotton production traded annually. Cotton prices in the Global Market are determined by the markets given below (Cottonic, 2021).

- New York Futures: Refers to the US cotton futures exchange. The New York futures exchange has five contract months (March, May, July, October and December).
- A Index: The A Index has been published by the commercial group Cotlook since 1960 and is thought to represent the 'world cotton price'. Pricing is based on daily surveys of cotton traders and is defined as the average of export prices quoted by international traders and shipped to spinners in the Far East, where most of the world's fiber is spun into yarn.
- China Cotton Index (CC): The China Cotton (CC) Index expresses the prices of cotton in China. It is the simple average of offers made by Chinese traders for Chinese cotton to be delivered to businesses in China. The most frequently quoted CC Index is for quality code 328.
- India and Pakistan Spot Markets: Some of the most active spot markets in the world are in India and Pakistan. The average daily prices in these markets are reported by the cotton organizations in these countries.

Table 1: Cotton Production Area, Yield, Production and Trade in Some Selected Countries in 2019/20 and 2020/21

Countries	**Production Area (1000 ha)**		**Yield (Kg ha^{-1})**		**Production (1000 MT)**		**Consumption (1000 MT)**		**Imports (1000 MT)**		**Export (1000 mt)**	
	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21
India	13.373	13.477	464	446	6.205	6.004	4.453	5.698	496	184	696	1327
USA	4.654	3.347	931	950	4.335	3.181	468	523	1	0	3.466	3.626
Chinese	3.300	3.170	1.758	1.864	5.800	5.910	7.230	8.400	1.600	2.800	30	30
Pakistan	2.520	2.000	522	445	1320	890	1984	2.152	890	873	9	9
Brazil	1.666	1.377	1.802	1.719	3.002	2.356	570	690	1	3	1.946	2.398
Uzbekistan	1.034	1.034	513	994	531	1.028	724	796	0	0	100	12
Mali	738	165	385	380	284	63	2	2	0	0	208	149
Burkine Faso	579	556	342	386	198	215	6	5	0	0	192	210
Benin	666	614	465	515	309	317	0	2	0	0	306	317
Turkmenistan	545	566	519	519	283	289	141	143	0	0	149	121
Argentina	450	410	807	845	363	347	134	110	0	0	85	123
Türkiye	**478**	**359**	**1.704**	**1.827**	**814**	**666**	**1.474**	**1.577**	**1.017**	**1.160**	**98**	**127**
Australia	69	297	1.657	2047	115	608	2	2	0	0	296	340
Greece	291	286	1.219	1.121	355	321	16	16	7	5	319	355
Indonesia	5	5	621	621	3	3	549	504	547	502	1	1
Vietnam	1	1	3000	1500	3	2	1466	1518	1409	1552	0	0
Subtotal	**30.363**	**27.658**			**23.914**	**22.195**	**17.204**	**20.116**	**4.012**	**5.025**	**7.900**	**9.144**
Other	**4.132**	**4.323**			**2.220**	**2.108**	**5.485**	**5.546**	**4.667**	**5.027**	**1.297**	**1.460**
World Total	**34.495**	**31.981**			**26.134**	**24.303**	**22.689**	**25.662**	**8.679**	**10.052**	**9.197**	**10.604**

Source: ICAC, Cotton This Month, December 1st, 2021

COTTON PRODUCTION AREAS, YIELD AND PRODUCTION VALUES IN TURKIYE

Türkiye is one of the important countries in terms of total cotton production, consumption and total import size in the world. Türkiye has produced over 500,000 tons of cotton fiber every year since 1980. 2019/20 and 2020/21 seasons data of Türkiye; It ranks 12th in terms of the size of its production areas, 4th in terms of fiber yield and consumption, 7th in terms of production, 3rd in terms of imports and 10th in terms of export. Cotton production and area in season in 2020/21 are 666,000 tons and 359,000 hectares, respectively. In the 2020/21 production season, Türkiye represents 2.7% of the world's total cotton production, 6.1% of total cotton consumption and 11.5% of total cotton imports (Table 1).

The production area (hectares), production amount (1000 Million Tons) and Fiber Yield (Kg h^{-1}) values of cotton farming in Türkiye between 1945-2020 are given in Table 2. All values are presented in Graph 1, 2 and 3 for better monitoring of cotton planted areas, production quantities and yield trends right after Table 2.

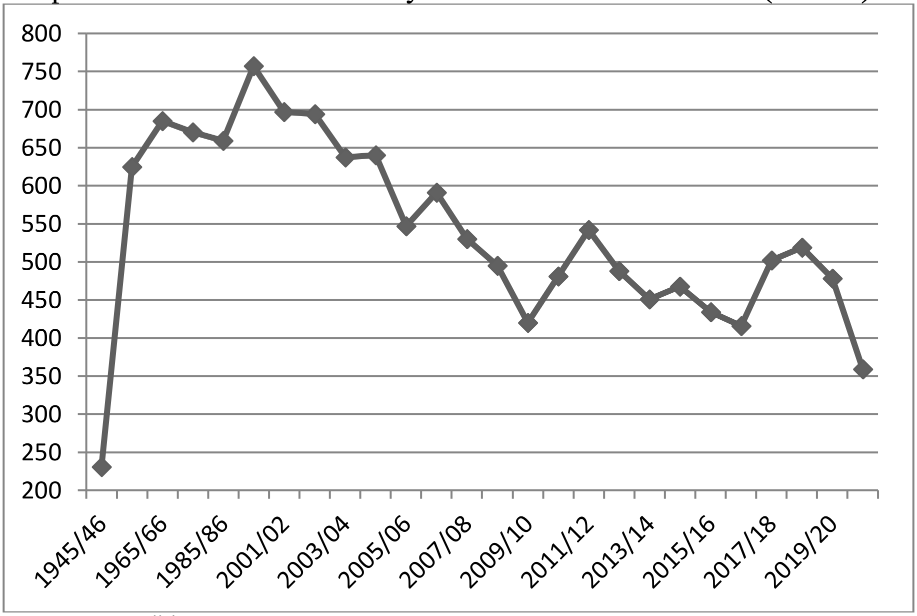
Table 2. Cotton Production Area, Production and Yield Values Between 1945 and 2020 in Türkiye

Years	**Production Areas**	**Production**	**Fiber Yield**
	(1000 h)	(1000 MT)	(Kg h^{-1})
1945/46	231	54	235
1955/56	625	157	251
1965/66	685	325	474
1975/76	670	480	716
1985/86	659	518	832
1995/96	757	851	1127
2001/02	697	920	1214
2002/03	694	983	1035
2003/04	637	918	1396
2004/05	640	936	1462
2005/06	547	864	1582
2006/07	591	977	1653
2007/08	530	868	1636
2008/09	495	673	1360
2009/10	420	638	1520
2010/11	481	817	1700
2011/12	542	955	1760
2012/13	488	858	1760
2013/14	451	878	1950
2014/15	468	846	1810
2015/16	434	738	1700
2016/17	416	756	1820
2017/18	502	882	1760
2018/19	519	977	1880
2019/20	476	814	1700
2020/21	359	656	1830

Source: TÜİK

Between 1945 and 1955, cotton plantted areas increased significantly and cotton production continued to increase in these years. From 1955 to 2020, cotton cultivation area changed between 359 000 and 757 000 hectares. The lowest (359 000 h) and highest (757 000 h) cultivation areas were between 2020/21 and 1995/96, respectively. Cotton cultivation areas in Türkiye started to decrease after the production season of 1995/96 (757,000 ha) until 2009/10 (420,000 ha) production season.

Graph 1. Cotton Areas in Türkiye Between 1945 and 2020 (1000 h)

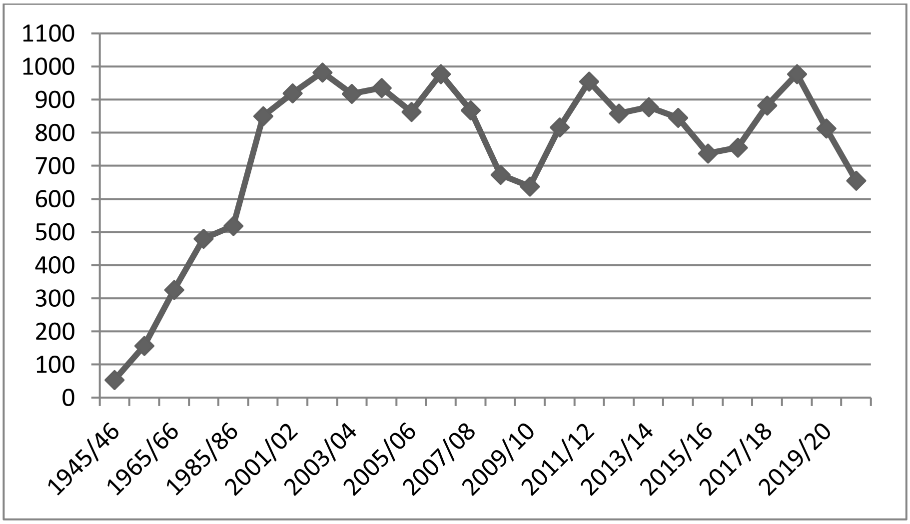


Source: TÜİK

After increasing to 542,000 ha in the 2011/12 production season, it decreased to 359,000 ha in the 2020/21 production season (Graph 1).

With the cotton production areas continuing with decreasing values in Türkiye, it is expected that the production amounts will decrease. However, the high yield potential certified cotton seeds used in the country, the optimization of fertilization, irrigation and plant protection activities and the innovations in agricultural mechanization have caused the production to not decrease appreciably. While the highest production amount in the country was 983,000 million tons in 2002/03 production season, the lowest production values were obtained between 1945 and 1985. Türkiye's cotton production amount, which did not fall below 700,000 million tons between the 2010/11 and 2020/21 production seasons, first decreased to 656,000 million tons in the 2020/21 production season (Graph 2).

Graph 2. Cotton Production in Türkiye Between 1945 and 2020 (1000 MT)

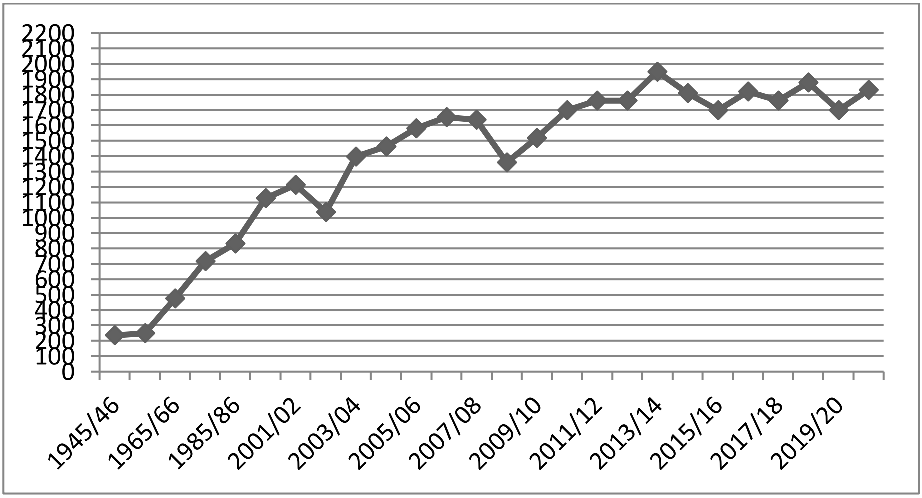


Source: TÜİK

Yield values in cotton farming areas in Türkiye have increased from 700 Kg ha^{-1} to 1800 Kg ha^{-1} in the last thirty years. In addition to the high yield potential of cotton varieties in Türkiye, the use of certified seeds, optimum fertilizers and pesticides were the determining factors for high yield (Graph 3).

All cotton planted areas in Türkiye are irrigated. The available water during the growing season of cotton increased the yield in most areas, especially in the Southeast Anatolia (GAP) region. Experienced and innovative cotton producers in Türkiye are obvious. Besides these; Cotton yields have increased in recent years, thanks to investments in modern equipment, planting in larger fields, and the use of certified seeds. It has shown a great increase in a short time thanks to the support given by the state especially for certified cotton seed users.

Graph 3. Cotton Fiber Yields Between 1945 and 2020 in Türkiye (Kg h^{-1})



Source: TÜİK

COTTON PRODUCTION IN TURKIYE BY REGIONS

Cotton is grown in four main areas in Türkiye. These regions are Southeast Anatolia (GAP), Aegean, Çukurova and Antalya (Table 3).

Table 3. Cotton Planting Areas and % Values by Regions between 1995 and 2020 in Türkiye.

Years	**Southeast Anatolia (GAP)**	**%**	**Aegean**	**%**	**Çukurova**	**%**	**Antalya**	**%**	**TOTAL**	
1995	204,2	27	249,9	33	272,5	36	30,0	4	756,6	100
2000	316,8	48	201,7	31	123,0	19	12,6	2	654,1	100
2005	295,0	54	137,8	25	108,6	20	5,4	1	546,8	100
2010	287,8	60	82,6	17	106,1	22	4,1	1	480,6	100
2015	264,5	61	91,7	21	71,6	16	6,2	1	434,0	100
2019	288,9	61	88,4	19	95,2	20	4,0	1	476,5	100
2020	215,4	60	89,8	25	50,3	14	3,6	1	359,0	100

Source: TÜİK

When the cotton cultivation areas in Türkiye are examined in terms of average values for the years 2010-2000, it is seen that the Southeastern Anatolia (GAP) Region is in the first place with 60%, the Aegean Region is in the second place with 20%, the Çukurova Region is in the third place with 18% and Antalya is in the last place with 1%. (Table 3). Şanlıurfa, Aydın, Diyarbakır, Hatay, Adana and Izmir are the provinces with the highest cotton cultivation area and production. These provinces met 85% of the production in Türkiye in the 2019/20 cotton production season.

The cotton cultivation area in the Southeast Anatolia (GAP) region continues to increase gradually (from 8% in 1980 to 60% in 2020) due to the increase in the irrigation system created by the GAP. The Southeastern Anatolia Project (GAP) is a massive $32 billion government project to harness the power and potential of the upper reaches of the Tigris and Euphrates rivers and to irrigate the fertile plains between them. When the GAP is completed, it is planned to irrigate 1.7 million hectares of land in total, which will double Türkiye's irrigable agricultural lands. The average annual expansion of the irrigation network in the last fifteen years is about 10 000 hectares. As a result of irrigation from the Atatürk Dam in the Harran Plain, the crop yield of cotton, wheat, barley, lentils and other grains was doubled. The cotton cultivation area in the GAP has increased from 50,000 hectares to 300,000 hectares in the last thirty years. With this; cotton yields increased from 500 Kg ha^{-1} to 1500 Kg ha^{-1}, making the GAP Region the most cotton producing region of Türkiye. Turkish State; In parallel with the increase in irrigation opportunities in the region, it provides technical and financial assistance to farmers to set up modern irrigation systems in order to prevent ecological problems and wastage of water resources (USDA b, GAIN Report, 2020).

In the Aegean Region, cotton could not compete with other products in terms of profitability. For this reason, cotton production areas in the Aegean Region have changed between 80 000 and 250,000 hectares in the last thirty years. Cotton production in all regions except the GAP region is an expected result that will vary according to the yield of alternative products and the cost of production. However, the expansion in the GAP region will be able to compensate for the reduction in traditional cultivation areas in Türkiye.

The cotton production area in the Çukurova region has gradually decreased from 350 000 hectares to 50,000 hectares in the last thirty years. Rising production costs, high insecticide use against pests (Example: Bemisia tabaci) and competition with other crops have forced cotton growers to switch to binary planting alternations such as citrus, soy, wheat/corn. In the Çukurova region, farmers have difficulty in deciding between corn and cotton production. In addition to the high yield and low production costs of the corn plant, the fact that it has a ready buyer and its profitability in terms of relatively high prices causes the cotton producer to turn to this product. Cotton fields in Antalya are under pressure from housing and tourism development, horticulture and citrus orchards.

Average fiber quality parameters of the three regions are given in Table 4. Aegean cotton is generally regarded as the best quality and is more preferred by the local textile industry.

Table 4. Average Fiber Quality Parameters of Cotton Growing Regions in Türkiye

Regions	**Fiber Length (mm)**	**Fiber Strength (g/tex)**	**Fiber Fineness Mic.**	**Fiber Uniformity (%)**	**Short Fiber Index**	**Reflectance (% Rd)**	**Yellowness (b)**	**Trash Count (g/number)**
Aegean	29,8	31,5	4,59	84,7	8,9	70,8	7,9	35,3
Cukurova	28,8	29,8	4,79	83,1	9,5	68,5	8,2	49,4
Southeast Anatolia (GAP)	29,2	30,4	4,44	84,4	8,8	69,3	7,8	72,8

COTTON SUPPLY AND USE IN TURKIYE

In Türkiye, as a result of the developments in the textile and ready-made clothing industry, the cotton produced in the country remained at an insufficient level. For this reason, Türkiye, which started to import a significant amount of cotton especially after the 1990s, has become a cotton importing country. With the increase in exports of textile products cotton import has increased in the last 20 years. Cotton import in Türkiye in the 2019/20 season is 996 thousand tons. Covering the consumption of production in Türkiye has been around 45-50% for the last ten years, and for this reason, it has been imported from abroad as much as cotton grown in the country. The share of the USA in Türkiye's cotton import in the 2019/20 season is approximately 39%, Brazil's is 19%, and Greece's is 16%. The high state support for cotton production, especially in the USA and Greece, causes these countries to supply cheaper raw materials to the whole world. Türkiye imports cotton mainly from Azerbaijan, Turkmenistan and Mexico after these three countries.

Table 5. Türkiye Cotton Supply and Use (1000 tons)

	2015/16	**2016/17**	**2017/18**	**2017/18**	**2019/20**	**Change (%)**
Area (000 h)	434	416	502	519	478	-7,9
Yield (kg-ha^{-1})	1.700	1.820	1.760	1.880	1.700	-9,6
Production	738	756	882	977	814	-16,7
Consumption	1.598	1.508	1.571	1.679	1.474	-12,2
Pro.-Con.: Difference	**-860**	**-752**	**-689**	**-702**	**-660**	
End Stocks	826	802	918	873	1.131[1]	29,6
İmport	918	801	876	762	996[5]	30,7
Export	50	73	71	105	78[5]	-25,7

Source: TÜİK, [1]ICAC- 2020.

The amount of raw cotton export of a country varies according to the amount of stocks produced and consumed domestically, as well as the amount of stock carried over from the previous season. Considering the raw cotton need of the textile and ready-made clothing industry in Türkiye, it is expected that fiber cotton exports will remain at a low level. In 2019/20, 78 thousand tons of fiber cotton was exported in Türkiye. Most cotton exports were made to EU countries, especially Italy, Poland, the Netherlands, and Greece.

In Türkiye; depending on production, consumption, import and export, varying amounts of fiber stock are carried over to the next year. While Türkiye's fiber cotton stock was 826 thousand tons in 2015/16 season, this amount increased to 1.5 million tons in 5 years. With the effect of the Covid-19 epidemic, consumption in Türkiye as well as in the world decreased by about 7% in the 2019/20 season, reaching 1.5 million tons, and ending stocks increased by 23% to 1.4 million tons. The stock/use ratio increased from 70.4% to 93.1%.

As in every country in the world, cotton prices in Türkiye vary depending on the domestic supply and usage situation, the world cotton production and consumption amounts and the developments in the world cotton trade. Especially the trade wars and stock policies between China and the USA, which have a say in world trade, have a very strong effect on cotton prices. In the 2019/20 season, world cotton prices decreased due to the pressure from low consumption levels under the influence of Covid-19. Stock levels generally followed a lower course compared to previous years. Fiber cotton prices in the 2019/20 season decreased by 10% in USD terms compared to the previous season, and averaged 1.60 $/kg (9.88 TL/Kg - Aegean Cotton 41 Colors). It started to rise in the 2020/21 and 2021/2022 seasons and was sold at 13.79 TL/Kg and 29.50 TL/Kg, respectively.

Table 6: World Cotton Prices (2015-2021).

Yıllar	COTLOOK A INDEX / COTLOOK A ENDEKS			ABD MEMPHIS / USA MEMPHIS			ICE COLOR GRADE 41/ İTB 41 RENK		
	Cent/Libre	US $/Kg.	TL/Kg.	Cent/Libre	US$ /Kg.	TL/Kg.	Cent/Libre	US$ /Kg.	TL/Kg.
2015	70,39	1,55	**4,53**	76,40	1,68	**4,91**	70,77	1,56	4,55
2016	79,52	1,75	**6,11**	82,21	1,81	**6,32**	76,34	1,68	5,87
2017	85,51	1,89	**7,25**	87,23	1,92	**7,40**	82,90	1,82	7,03
2018	85,90	1,89	**10,05**	88,18	1,94	**10,31**	77,72	1,71	9,09
2019	75,84	1,67	**9,76**	76,84	1,69	**9,89**	75,78	1,67	9,75
2020	81,01	1,79	**13,79**	83,98	1,85	**14,29**	77,45	1,70	13,18
2021	126,71	2,79	**29,52**	131,24	2,89	**30,58**	119,65	2,63	27,88

Source: İzmir Commodity Exchange

STATE SUBSIDIES GIVEN TO COTTON GROWING IN TURKIYE

Against the changes in international markets and the support policies applied by the states to cotton, support policies for the purpose of ensuring the sustainability and self-sufficiency of cotton production in Türkiye are included in the Five-Year Development Plans (Table 7).

A producer producing 1 kg of cotton in 2020 used 1.10 TL difference payment subsidy, 0.009 TL soil analysis subsidy, 0.009 TL fertilizer subsidy, 0.135 TL diesel subsidy. In total, 1.253 TL state subsidy was given for 1 kg of cotton in 2020.

Cotton producers in Türkiye complaining about insufficient subsidies due to the high input amounts. Producers, who made a profit below their expectations from cotton production, started to turn to alternative products.

Table 7. State Support for Cotton in Türkiye in 2016 and 2020

<table>
<tr><th>Years</th><th>Difference Payment</th><th>Soil Analysis</th><th>Fertilizer</th><th>Deisel</th><th>Total</th></tr>
<tr><td>2016</td><td>0,75</td><td>-</td><td colspan="2">0,022</td><td>0,772</td></tr>
<tr><td>2017</td><td>0,80</td><td>0,002</td><td>0,008</td><td>0,074</td><td>0,884</td></tr>
<tr><td>2018</td><td>0,80</td><td>0,002</td><td>0,008</td><td>0,081</td><td>0,891</td></tr>
<tr><td>2019</td><td>0,80</td><td>0,008</td><td>0,008</td><td>0,125</td><td>0,941</td></tr>
<tr><td>2020</td><td>1,10</td><td>0,009</td><td>0,009</td><td>0,135</td><td>1.253</td></tr>
</table>

Source: TEPGE calculations from TOB data, 2020 calculations were made on the basis of 2019 yield.

ORGANIC COTTON PRODUCTION IN TURKIYE

The first serious attempt for organic cotton production started in 1980 in Türkiye to include cotton as a rotation crop and also to prove that organic farming should not be limited to only food production. Organic cotton production in Türkiye was several hundred tons during early 1990’s and reached several thousand tons by early 2000’s. Türkiye was the world leader for organic cotton production but domestic production has declined 18.000 ton in 2010. Organic cotton is still in a stage at growth, being cultivated in 24 countries worldwide with the top three producers India, China and Türkiye (Sarsu and Yucer, 2011; Özüdoğru, 2011)

In Türkiye, 600 producers grew 24,288 tons of organic cotton on 11,551 hectares of land in the 2019/20 production season. Compared to 2018/19, this represents a 56% increase in the number of farmers, a 6% growth in fiber volume and an 8% increase in fiber volume. Due to the shortage of cotton supply in the global economy, more companies are turning their attention to alternative sourcing zones. This situation causes investors to turn to Türkiye. The positive difference in organic cotton prices feeds the increase in organic cotton production in Türkiye. Eleven new producer groups received certificates for organic cotton farming in 2020. As a result, Türkiye's organic cotton production is expected to grow by approximately 177% in the 2020/21 season.

NEW COTTON VARIETIES STUDIES IN TURKIYE

The Seed Registration and Certification Center (TTSM) was established in 1959 under the Ministry of Agriculture, and since then it has been operating under the name of the Republic of Türkiye. It officially operates under the Ministry of Food, Agriculture and Livestock. Cotton improvement studies in Türkiye started with the establishment of Nazilli Cotton Research Institute in 1934. In the first breeding studies, adaptation and selection practices of genetic stocks brought from other countries were made as material. Later, new cotton varieties were started to be developed by using hybridization and selection methods. Acala 1086 is the first cotton variety developed at

Nazilli Cotton Research Institute in 1959. Turkish breeders used the selection method made from Acala 8 as a breeding method for the development of this variety. In 1964, Deltapine 15/21 variety was developed by the selection method from Deltapine 15 variety by the Eastern Mediterranean Agricultural Research Institute. The third variety developed at the beginning of the Turkish National Breeding Project was Coker 100.

After the first cotton varieties were obtained in 1959, breeding studies were accelerated after the 1990s. In chronological order; 4 cultivars were developed in the 1970s, 5 cultivars in the 1980s, 23 cultivars in the 1990s, and 66 cultivars in the 2000s. The increase in developed varieties continues in the 2020s. The public sector started cotton seed production in 1959, and the private sector started cotton seed production in 1995 (Sarsu and Yücer, 2011).

After 2012 Public Research Institutes working under the General Directorate of Agricultural Research and Policies (TAGEM), affiliated to the Ministry of Agriculture and Forestry, focused on breeding and developing new varieties and increased the number of cotton varieties developed by the state. As a result of the improvement studies carried out in Türkiye, a total of 113 cotton varieties were registered between 2001 and 2020. 55 cotton varieties were registered by TAGEM Research Institutes and 58 cotton varieties were registered by private sector seed companies (TTSM Registers 2021).

Most of the proprietary cotton varieties in Türkiye were brought from other countries as breeding lines or new cotton varieties. Because few private sectors have their own training or research and development program. All cotton varieties developed by the state were obtained as a result of hybridization and selection studies. Until 2000, most of the cotton seed (75%) was provided by the state. However, the share of the private sector in cotton seed production has gradually increased and reached 90% in 2020. The main reason for this rate is that the private sector is stronger than public research institutes in seed marketing.

When Türkiye's cotton agriculture in the last ten years is examined; It can be said that the private sector plays an important role in the supply of cotton seeds and the development of new cotton varieties. However, state support for the private sector to take this role has been too great to be underestimated. In the last 10 years; It has gathered universities, public research institutes and private companies under one roof with the support channels of the Turkish State such as TÜBİTAK and TAGEM. Türkiye cotton varieties have been developed thanks to the state's support for new projects by gathering these three institutions together.

Almost all of the seeds of cotton produced in Türkiye are renewed every year. The use of certified seeds in cotton producing areas is supported by the state. The rate of certified seed usage increased rapidly in all cotton production areas and reached 100% (Sarsu and Yücer, 2011).

TRANSGENIC COTTON IN TURKIYE

The production of a transgenic cultivar is strictly prohibited in Türkiye. With this aspect, the country is the world leader and an exemplary country in the production of non-GMO cotton.

Developments in the field of biotechnology, especially gene technology, have started to gain momentum since the 1980s. (Qaim, M. 2009). Field trials of Tobacco GM plants were started for the first time in 1986, primarily concentrated in the USA, Canada, France and England, and then spread by covering developing countries such as Argentina and Mexico. The first commercially known transgenic product was the tomato with a long shelf life, called "Flavr Savr", which was put on the market in 1995. In the following periods, with the rapid development of technology in the developing countries of the world, the tomato was genetically transferred; corn, cotton, soybean, rapeseed and potato" products followed.

The cultivation areas of genetically modified seeds have reached up to 200 million hectares today (Arvas and Kocaçalışkan, 2020, p. 202). The lands cultivated with transgenic products in the world; 50% of GM soybeans, 31% of GM corn, 13% of GM cotton and 5% of GM canola are produced. The first 4 countries where transgenic agriculture is most common are 40% USA, 26% Brazil, 12% Argentina, and 7% Canada (Paull and Hennig, 2019, p. 1-2; Wu, Zhang, Wu, Qian, Zhang, Wang and Wu, 2020, p. 1). In recent years, there has also been a great increase in GM cotton cultivation areas in order to obtain high quantities of quality products per unit area worldwide. However, there is great debate as to whether it can fully achieve these promised goals.

Transgenic cotton was first approved for field trials in the USA in 1993 and commercial use began in 1995. It was recognized by China in 1997. In 2002 and the following years, it was approved by other countries, including India and Mexico, Argentina, Australia and South Africa, Brazil, Burkina Faso and Colombia, and its cultivation was started (Baffes, 2004; Gruere, 2012; Kranthi and Stone, 2020; Qiu, 2010). According to the Acquisition of Agri-biotech Applications (ISAAA), 15 countries around the world cultivated Bt-cotton in 2018 (ISAAA, 2019). While Bt-cotton cultivated areas were 24.1 million hectares in 2017, this area increased to 24.9 million hectares in 2018 (Shera et al., 2018). This land was planted on; Insect-resistant cotton 18.14 million hectares, Herbicide-resistant cotton on 757,000 hectares, and Both Insect and Herbicide resistant cotton on 5.97 million hectares. In 2018, India was the country where the most Bt cotton was planted, while the USA, China, Pakistan and Brazil planted Bt cotton, respectively. These four countries were followed by Argentina, Myanmar, Australia, Sudan, Mexico, South Africa, Paraguay and Colombia (ISAAA, 2019, p. 1).

Türkiye has been developing national cotton seeds that are suitable for mechanical harvesting, productive, high yielding and resistant to diseases, with the classical breeding method without transferring genes, with the classical cotton breeding research. Turkish breeders did not include transgenic cottons in crossing studies. Cotton varieties developed with classical breeding methods and fiber obtained from unit area increased cotton yield by 10 percent in 10 years. Türkiye is the world leader and exemplary in the production of GMO-free cotton.

In accordance with the Biosafety Law published in the Official Gazette No. 27533 on 26. March 2010 in Türkiye;

a) It is forbidden to put GMOs and their products on the market without approval.

b) It is forbidden to use or make use of GMOs and their products in violation of the Board's decisions.

c) Production of genetically modified plants and animals is prohibited.

ç) The use of GMOs and their products other than the purpose and area determined by the Board within the scope of placing on the market is prohibited.

d) It is forbidden to use GMOs and their products in baby foods and infant formulas, follow-on foods and follow-on formulas, and supplementary foods for infants and young children.

Türkiye has not entered into the production of genetically modified cotton despite the pressures in the world and the preference of the major producing countries. It is one of the first countries in the world in terms of yield and quality with the cotton obtained by classical breeding methods. Finally, with a development in 2017, the efforts of the Izmir Commodity Exchange and the National Cotton Council, the production of non-genetically modified cotton in Türkiye was registered with the "GMO FREE" label. This situation is reflected as an added value for “Turkish Cotton” in the world cotton stock markets.

CONCLUSION AND RECOMMENDATIONS

Cotton, which is cultivated by humans in ancient times, is the first plant processed for its fiber. In India, the cradle of cotton in the ancient world, cotton cultivation was carried out at least 5000 years ago, and its use in weaving cloth dates back to BC. It was determined in archaeological excavations dating back to 3000 BC. The history of cotton in Anatolia goes back to 330 BC. However, its real development was in the time of the Selçuk Turks in the 11^{th} century and the Ottoman Turks in the 14^{th} century. After the proclamation of the Republic of Türkiye, cotton agriculture was given great importance.

The rapid increase in the world population, on the other hand, the increase in the standard of living in industrialized and developing societies has increased the consumption and need for cotton. Cotton; It has an important position in Turkish agriculture, industry and trade. Cotton plant is the second important vegetable oil source after sunflower in Türkiye.

In the Turkish Textile and Clothing industry, approximately 2 billion dollars' worth of fiber cotton is processed annually, producing cotton products with a total value of 15 billion dollars. Foreign revenues of up to 10 billion dollars are obtained annually from these products. In addition to the employment of 2.5 million people in the textile sector in Türkiye, more than 10 million people live on cotton production and its subsidiaries. Cotton is an agricultural product that has no alternative for Türkiye.

There are some negative situations in the cotton production, which has a great importance in the Turkish economy, and accordingly in the textile sector. For example, the negative effects of global climate change, increasing temperatures and decrease in irrigation water may cause serious problems in the coming days. None of the cotton varieties produced in Türkiye have been improved in terms of resistance to drought or high temperature. The deterioration of growing conditions such as drought and high temperature in Türkiye will cause a serious decrease in cotton yield and quality. Besides these; the high wages paid for fertilizers and pesticides used in cotton farming in Türkiye will lead to a decrease in the profit rate of the producer and to turn to alternative products. In addition, the negative effects of the Covid-19 epidemic, which has been affecting the whole world for the last two years, on the cotton economy are known.

In order to solve the above problems and to ensure that the cotton producer remains competitive, some measures need to be taken in Türkiye. Firstly; agricultural policies should be developed to spread cotton genotypes that can achieve high yield and quality with less water. Cotton policies should be re-evaluated in order to solve the high cost problem of cotton producers, increase production and create a competitive environment.

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CHAPTER 6

SOIL TILLAGE IN COTTON CULTIVATION

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The fibers obtained from the cotton plant are a very important raw material used to meet the wearing needs of people. In addition, cottonseed oil and cottonseed meal have very important usage areas. For these reasons, cotton has been grown and used by human beings in large areas for many years.

There are two most important basic conditions for success in cotton cultivation. One of them is the use of superior varieties in terms of yield and quality characteristics. The other is to carry out optimum agronomic applications. These agronomic applications are soil tillage, appropriate planting method, right planting time, fertilization technique, weeding, irrigation etc.

Soil tillage is done for many reasons such as preparing a suitable seedbed for seeds or seedlings, aerate the soil, destroying weeds, providing root development. The effect of tillage on yield is very important because soil tillage affects the physical properties of the soil. The physical properties of the soil directly affect root and plant growth. For example, as a result of the penetration resistance being too high, the roots of the plant cannot grow sufficiently. Insufficient root development causes low yield. Insufficient aerate the soil greatly limits root and plant growth. Excess soil water may adversely affect root growth and cause plant death at an advanced stage. It is possible to multiply such examples.

It is wrong to consider only the yield to be obtained from the plant in soil tillage. The purpose of soil tillage is also; to protect soil fertility, reduce erosion, prevent soil compaction, protect soil flora and fauna and preserve diversity (Önal, 1995; Aykas and Önal, 1999). Unsustainable soil tillage system will cause the soil to become barren and unproductive in the future. For this reason, the soil tillage method to be preferred should ensure both sustainable use of the soil and high yield to be obtained from the plant.

Soil tillage systems are generally classified under 2 headings:

1- Conventional tillage,
2- Conservation tillage (Aykas et al., 2005)

A brief review of these methods;

In the conventional tillage system, the plow is used to overturn the soil. Soil tillage with this method especially disrupts the biological balance in the soil. Aerobic microorganisms living in the soil are found near the surface where the soil aerate is more, while anaerobic organisms are found in the lower parts of the soil. The overturning of the soil disrupts this balance and it takes time for this balance to be restored. Another negative feature of conventional tillage is that the surface becomes very suitable for erosion since there is no plant residue on the soil surface. A large part of our country's agricultural lands consists of sloping lands. Erosion risk is very high in sloping lands. Since agricultural practices (tillage, planting, etc.) in sloping agricultural areas are not carried out with methods suitable for soil and water conservation, and the necessary protective precautions are not taken in other lands, the soils are used uninformed and rudely, and thus erosion occurs (Cebel and Akgül, 2011). In the conventional tillage system, raindrops hitting the soil surface without stubble with a higher energy break up the soil aggregates and cause more soil to be transported by surface flow (Ergül and Polat, 2009). Erosion is very significant in an area of 57.6 million hectares in our country (Doğan, 2011). In conventional tillage systems, no studies are conducted to conserve soil, water and energy (Ergül and Polat, 2009).

Plow are not used in conservation tillage systems. Conservation tillage is a general usage term, under which there are many tillage systems. conservation tillage systems include strip tillage, plant-tilllage, mulch tillage, minimum tillage and direct seeding (Aykas et al., 2005). In the conservation tillage system, it is appropriate that the field surface be covered with at least 30% plant residues (Köller, 2003). The general principle of these systems is to tillage the soil less, to have plant residues on the surface, to prevent soil compaction by reducing field traffic, to better protect soil and water resources, and to reduce erosion. With conservation tillage, th The effect of traditional and protective tillage methods on erosion in cotton cultivation:e organic matter level in the soil is increased (Yalçın et al., 2003). One of the most important advantages of this method is the reduction of erosion since plant residues will remain on the field surface. At the same time, it provides economic gain due to the decrease in farm traffic. Minimum tillage and direct sowing both save time and fuel and reduce soil erosion (Yalçın et al., 2007).

Conservation tillage systems are environmentally friendly methods. However, some problems may be encountered in the transition from the conventional method to this system. For example, new tools and equipment may be needed in this system, thus creating new costs for farmers. In direct sowing, special drills developed for this purpose are used. When these systems are switched, there may be a decrease in yield in the first years. This problem may cause some producers to have a negative view of conservation tillage systems. In this system, another problem is that the weed is excess in the first years. What should not be forgotten is good management in the conservation tillage system. By applying systems suitable for each region and crop, it is possible to successfully switch to conservation tillage systems. When a farmer wants to start direct sowing for the first time, this process can be quite difficult. Before and during this tillage system, it is necessary to have sufficient knowledge on some subjects (Çelik, 2016). Despite its obvious economic, environmental and social advantages, adopting conservation agriculture has not been easy around the world (Çelik, 2016).

Soil tillage is one of the most important agricultural processes that affect the yield of cotton plant, as it is in all plants. It is known that conventional tillage method is widely used in cotton plant. The adoption of conservation tillage in cotton planting systems lags far behind other major crops in the United States (DeLaune, 2019). Irrigated areas in Diyarbakır province, the tillage system mostly used in cotton production after wheat, cotton or corn is depth tillage with moldboard in fall+cultivator+cultivator after herbicide against weeds +scrubber at least twice in spring (Gürsoy et al., 2013).

Many scientific studies have been conducted on the applicability of conservation tillage methods, which have positive aspects such as sustainability in agriculture, reduction of input costs, erosion control and protection of soil-water resources, in cotton plants. In some of these studies, conservation tillage systems were compared with conventional tillage methods. The effects of different cover crops to be grown in winter and different soil tillage methods on cotton yield were investigated by some researchers. In some studies, the effects of different soil tillage methods on soil properties and water use efficiency in cotton cultivation were investigated.

If the effects of conventional and conservation tillage methods in cotton cultivation and some studies on this subject are examined;

1- The effect of conventional and conservation tillage methods on erosion in cotton cultivation:

40% of agricultural lands in the world are under the influence of water and wind erosion. 86% of Turkey's land is under the threat of erosion, 63% of which is severe and very severe (Çarman et al., 2014). In the conventional tillage method, the vegetation on the upper part of the soil is turned over with a plow and completely taken under the soil. Therefore, after ploughing, the soil surface becomes completely unprotected to water and wind erosion. Erosion is a very important threat to agricultural lands. Mutchler et al. (1985) reported that soil loss in conventional tillage for cotton is much higher than for soybeans and maize. However, as a result of 11 years of work, it has been reported that this loss will be reduced by 47 % by using the no-till method and the application no-till method reduces the surface flow from 48 % to 35 % (Mutchler et al., 1985). In the conservation tillage method, plant residues on the surface play an important role in erosion control. For this reason, the application of conservation tillage systems in cotton plants, where erosion control is important, will reduce soil losses.

Winter cover crop and no-till method are two promising conservation practices to reduce soil erosion and promote long-term sustainability (Fan et al., 2020).

2- The effect of conventional and conservation tillage methods on soil properties in cotton cultivation:

In reduced tillage, soil microbial biomass C increased by an average of 11 and 18%, respectively, compared to to conventional tillage continuous cotton and the cotton-corn rotation, respectively, while microbial biomass N for reduced tillage was 62% higher than in conventional tillage (Wright et al., 2008).

As a result of the study conducted by Wright et al. in South-Central Texas for 5 years, it was determined that reduced tillage and diversified crop systems changed the distribution of plant nutrients in the soil compared to conventional tillage and continuous cotton. In fact, reduced tillage contributed to higher fiber yield than conventional continuous cotton and increased plant P and NO_3 in the surface soil (Wright et al., 2007).

Compared to reduced tillage, contour ridge tillage significantly improved the nitrogen uptake and nitrogen use efficiency indexes of both cotton and maize on three of the four sites (Nafi et al., 2019).
In a study, it was found that the penetration resistance was ranged between 0.1–0.4 Mpa in cotton farming, ridge planting plots, and 1.0–1.5 Mpa in the plots where the conventional method was applied. These results revealed that the ridge planting method in cotton farming is more advantageous in terms of soil penetration resistance, which is very important for root development (Kılıçkan and Yalçın, 2017).

It has been determined that the plow, which is one of the tillage tools, decreases the bulk density of the soil and increases the porosity, while the values obtained in the tillage with chisel plow are within acceptable limits. In the ridge planting method, which was tried for the first time in this study in the Harran Plain, the bulk density was low and the hydraulic conductivity value was high. On the other hand, the hydraulic conductivity value was found to be high in the soil profile depth of 20-30 cm in the plot tilled with chisel plow. It has been determined that the penetration resistance in the upper layers of the soil in chisel plow cultivation is higher than in the plow, and the opposite is the case in the lower layers (Özpınar and Işık, 1998).

In subhumid Southeastern USA, Nouri et al. 2019 examined the long-term (34 yr) effect of two cover crop species, hairy vetch (*Vicia villosa*), and winter wheat (*Triticum aestivum* L.), and no cover crop, applied on conventional tillage and no-tillage on soil hydro-physical properties and cotton yield. Result of demonstrates that long-term incorporation of cover crops, particularly vetch with no-tillage, significantly improved the initial infiltration rate, cumulative infiltration, and field-saturated hydraulic conductivity and increased the mean weight diameter of aggregates by promoting the macro aggregation. Improvement in soil physical properties was associated with an increase in cotton lint yield under cover crop and no-tillage management (Nouri et al., 2019).

The no-tillage method with a rye cover crop can increase surface soil organic carbon levels while improving infiltration and penetration resistance in semi-arid continuous cotton crop systems compared to conventional tillage. Infiltration was found to be 34% higher in the no till-rye system than in conventional tillage (DeLaune, 2019).

If we evaluate the results of this research, which reports the effect of conservation tillage methods on soil properties; In cotton cultivation, we see that conservation tillage methods have a positive effect on the physical properties of the soil, and there is no adverse effect that restricts cotton cultivation.

3- The effect of conventional and conservation tillage methods on yield in cotton cultivation:

Mutchler et al. (1985) determined that the no-till application increased the seed cotton yield by approximately 20%.

In a study conducted in the southeastern USA, none of the conservation tillage systems produced in higher cotton yields than fall plow system. However, planting into killed rye resulted in yields equal to the fall plow system but, more fertilizer N (approximately 34 kg N ha^{-1}) was required for cotton planted into rye. When cotton was planted after the vetch, the yield was equal to the fall plow system in 2 of the 3 years and the N fertilizer requirement decreased by about 34 kg ha^{-1}. When compared with fall plow system, no tillage into clover or winter fallowed soils resulted in inferior cotton yields each year (Brown et al., 1985).

Reduced tillage contributed to higher fiber yield than conventional continuous cotton (Wright et al., 2007).

In a study of cotton tillage in Greece, plants grown under reduced tillage methods exhibited delayed emergence, reduced growth, fewer bolls, and lower yields. At harvest, conventional tillage gave the best yield with seed cotton at 4 t ha^{-1}, followed by heavy cultivator at 3.8 t ha^{-1}. Rotary cultivator and disc harrow methods yielded much less with 3.2 t ha^{-1}. There were plots of no-till yielding 2.8 t ha^{-1} of seed cotton (Cavalaris and Gemtos, 1998).

Cotton yields were found to be 10% to 15% higher on average under tillage conditions than no-tillage conditions (Askew, 2002).

In a study conducted in the USA, no-tillage systems, with and without a cover crop, had significantly greater lint yields and irrigation water use efficiency than conventional tillage. Also, inclusion of wheat in no-tillage increased yields and irrigation water use efficiency compared with strip tillage (DeLaune, 2020).

By examining the UAS (Unmanned Aerial Systems) data in cotton plant, conventional tillage and no tillage methods were compared. As a result, no tillage system found to have taller canopy, bigger biomass, higher canopy cover and higher NDVI, as compared to conventional tillage system (Ashapure, 2019).

There was no difference between conventional and reduced tillage methods in cotton in terms of seed cotton yield (Yalçın et al., 2003).

In the southeastern USA, 3 different strip tillage systems were compared with conventional tillage and no tillage systems. As a result, it was reported that all three strip tillage systems are equally effective for cotton production and that annual deep tillage is not necessary if controlled traffic is employed (Khalilian et al., 2017).

Considering these results, in which the effect of conservation tillage methods on cotton yield is examined, it is seen that conservation tillage systems reduce cotton yield in some studies, do not affect it in some studies, and increase it in some studies.

Weed and disease-pests problems can be a problem in the first years when conservation tillage systems are started. For this reason, there may be a decrease in yield in the first years. These problems decrease in the following years. In addition, effective control of weeds and disease-pests can prevent yield reduction. If conservation tillage systems are applied for many years, the soil becomes much more fertile. As a result, plant yield also increases.

4- The effect of cover crops used conventional and conservation tillage methods in cotton cultivation:

Producers requiring a cover crop system might prefer the no-tillage cover crop system, since it had the highest mean net returns of the two cover crop systems (Hanks and Martin, 2007).

The conservation tillage practice of shallow, in autumn, in-row subsoiling in conjunction with a cover crop may offer the best alternative for farmers trying to reduce the negative effects of soil compaction, maintain adequate residue cover, and improve seed cotton yield (Raper et al., 2000).

The use of black oat or rye cover crops has the potential to increase cotton productivity and reduce herbicide inputs for non-transgenic cotton grown in Alabama (Reeves et al., 2005).

In a study conducted by Kolay et al. (2016), forage peas were planted in the cotton-corn alternation system during the winter period when there was no crop in the field. The most suitable tillage system has been determined for this system. As a result of the study, it was determined that the development of forage peas was the best in the method of chopping cotton or corn stalks + sowing of forage peas after tillage with plow and cultivator + application of total herbicide to forage peas + no-till cotton sowing method.

As a result of the study carried out with two different tillage (traditional tillage and no tillage) and five different cover crop applications in cotton farming, no significant differences was found between the applications in fiber yield (Fan et al., 2020).

In cotton cultivation, the use of cover crops in winter is important in terms of erosion control. Cover crops can be mixed into the soil and used for green manure, or cotton can be planted directly on the cover crop using herbicides Cover crops can also be used for green grass purposes by harvest before cotton sowing. After harvesting for green grass, cotton can be planted by mixing the remaining waste with the soil or can be done direct sowing. Either way, it is beneficial because it will add organic matter to the soil.

5- Cost analysis of conventional and conservation tillage methods in cotton cultivation:

In a research conducted on the energy and cost analysis of the plots where different tillage methods are applied in cotton production, the energy equivalents per unit area of the inputs in the production, the energy efficiency of the obtained product, the total cost and profit values were calculated. In the study, the highest energy input was in the conventional tillage method, and the lowest energy input was in the direct sowing method (Topdemir and Coşkun, 2019).

Hanks and Martin (2007) reported, the conventional tillage system had relatively high returns but was among the riskiest (highest variance) of the treatments analyzed. Producers requiring a cover crop system might choose the no-till cover crop system, since it had the highest mean net returns of the two cover crop systems (Hanks and Martin, 2007).

Among the products included in the study (nonirrigated soybean , irrigated soybean, irrigated grain sorghum , irrigated soybean followed by irrigated grain sorghum, irrigated soybean followed by irrigated corn , and continuous irrigated cotton), other than cotton, traditional tillage, higher than protective tillage resulted in an average net return. Although the most profitable system protection is continuous tillage cotton, net returns have varied widely over the years (Parsch et al., 2001).

In a study conducted in the USA, despite high herbicide costs, long-term annual profit increased in no-tillage compared to conventional tillage due to low machinery depreciation and high yield (Harman et al., 1989).

In a study comparing conventional and conservation tillage systems conducted in Marianna and Clarkedale, Arkansas, USA, results from Marianna did not, in general, show any difference in yield or net return between conventional tillage and conservation tillage. However, Clarkedale results showed that conventional tillage yields and net returns were significantly lower than conservation tillage yields (Ramu et al., 1996).

As seen in the studies, the conservation tillage systems and the direct sowing included in it reduce the input cost. In most of the studies on the economic analysis of tillage systems in cotton, conservation tillage systems have been found to be more profitable than conventional tillage.

6- The effect of conventional and conservation tillage methods on weed growth in cotton cultivation:

In a study conducted to determine the weed density levels in the total production costs of conventional and reduced tillage in cotton, it was determined that reduced tillage increased weed density, unlike the conventional method. Therefore, reduced tillage required 22.83% more working time and 24.14% more cost than conventional tillage (Yalçın et al., 2003).

In a study conducted in Alabama, when cotton was grown after black oat, rye, and wheat cover crops, no cover crop was effective at controlling weeds without the herbicide application. Rye and black oats provided more effective weed control than wheat in conservation tillage cotton. The use of black oat or rye cover crops has the potential to increase cotton productivity and reduce herbicide inputs for non-transgenic cotton grown in the Southeast (Reeves et al., 2005).

In a study on weed control in cotton cultivation, tillage and no-tillage soil, tillage did not affect the weed control provided by herbicides (Askew, 2002).

As it can be seen when the studies are examined, the number and density of weeds can be higher in conservation tillage systems. Especially in the first years of transition from traditional tillage to conservation tillage systems, this problem is seen. This problem can be eliminated with the measures to be applied and herbicide applications by taking into account environmental factors.

RESULT

As a result, it is seen that the conventional tillage system is widely applied in cotton cultivation. Conventional tillage is a method that increases the risk of erosion in agricultural soils and has some negative effects on soil properties. Conservation tillage systems should be used in cotton cultivation, but the most appropriate measures should be taken for the problems (weeds, diseases and pests...) that will be encountered during the transition period to these systems. In the conservation tillage system, these problems will decrease in later years. Planting cover crops in the winter period when the field is free field in cotton cultivation will prevent soil loss by erosion and provide organic matter for the soil. However, it is very important which cover plant to choose.

Conservation tillage systems can be applied not only in main crop cotton cultivation, but also in second crop cotton cultivation. Yalçın et al. (2007) reported that reduced tillage and direct sowing can be easily applied in second crop cotton farming in Turkey.

In many studies, conservation tillage systems have been found to be economically more profitable than conventional tillage, as they reduce input costs.

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CHAPTER 7

DEFOLIATION AND HARVESTING

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Introduction

Cotton is primarily grown for its fiber as the raw material of the textile industry. Cotton fiber is preferred towards vegetative and synthetic fibers due to its properties such as absorbing human sweat and staying stronger compared to other fibers when heated and boiled. Besides to human health, cotton is an important industrial plant in terms of the economy of country. Cotton is a fiber plant that produces raw materials for approximately 50 branches of industry. On the one hand, the rapid increase in the world population, on the other hand, increasing the awareness of living standards and the use of cotton-based products that do not harm nature in industrialized and developing communities increase the consumption of cotton, and therefore need for cotton is gradually increasing. A quality fiber production starts with the selection of the cotton variety to be planted, continues by paying attention to all cotton production practices, and ends up with a properly planned and well performed harvest.

Approximately 40% of cotton growers harvest cotton by machine in the world. In Australia, Israel and United State of America, cotton harvesting is performed only by machine. These countries are followed by Greece (92%), Argentina (75%), Uzbekistan (30-40%). In Turkey, 80-85% of cotton is harvested by machine (100% in the Aegean Region). In hand picking, the labor cost reaches very high rates such as 15-20% of the total input costs. The transition to machine harvesting was inevitable due to the increasing the cost of harvesting and difficulties in providing and employing workers. For this reason, cotton harvester gains great importance. A self-propelled harvester with 4 rows and inter-row spacing of 76 cm can harvest approximately 1.2 ha (12 decares) in 1 hour for the first hand and 1.6 ha for the second hand, and this area is about 120 decares per diem in approximately 10 hours. This is equivalent to about 400 picking workers. Total product losses in machine harvesting vary between 1-12%, but in average around 10%. This rate varies between 4-5% for hand picking. As a result of the use of nylon sacks in cotton picking by hand, the pieces of the sacks are mixed into the fiber during the processing in the ginning factories. This situation causes major problems in the dyeing of yarns and fabrics obtained from these fibers and damage to the textile industry. Because of these reasons; development and sustainable of cotton farming reveals the need to increase machine harvesting practices in our country.

In Turkey, where the cotton picking is peformed by hand, it is generally picked twice. However, machine harvesting has become common in recent years. Harvest period for cotton vary according to the climate conditions, cotton variety and planting time. The most important issue to be considered for the cotton harvest is that the cotton is not harvested with moist and trash. It should not be rushed to enter the field after rains and seed cotton must be dried on the plant. If the dew condition is realized, collected cotton with moist should be laid and baled after drying. There are significant losses in the quality characteristics of cotton that is harvested with moist and trash. One of the most important issues to be considered in hand picking is that the sacks are made of synthetics. If sacks made of plastic and jute are used, it may mix with the fiber, causing contamination.

Harvest period for cotton farming may varies according to the regions and cultural practices, fall precipitation and planting time crops after cotton, damage situation of plants and cotton harvesting methods. Harvest period, variety type, climate and soil conditions depend on whether cotton is grown under irrigated or rainfall conditions. In early harvests, fibers do not mature well and may affect fiber quality values negatively. When harvest period is delayed, natural conditions such as sun, precipitation, wind etc. can damage the quality of the fiber. Harvest must be performed in a way that it provided the fiber characteristics does not cause operational faults for ginning, yarn making, weaving and dyeing, and the moisture content in the seed cotton must be 10% or less. Harvest is also closely related to the temperature demand of the cotton plant. Varieties with low temperature demands are harvested early. The lengths of the development periods (first true leaf-square/square-flower-boll/boll-harvest) are closely related to climate, especially temperature. For instance, time until the first flower appears in planting at the end of April is longer than planting at the end of May.

Regrowth

Since the origin of cotton is perennial, regrowth and development of the cotton plants can occur in 7-10 days (according to weather conditions) after the leaves are defoliated or dried in any period. Especially if plant to be harvested by machine, the green part formed as a result of regrowth may mix with the seed cotton and pollute it during the harvest. For machine harvesting, leaves must be defoliated at an appropriate period. For this reason, the most appropriate period for defoliation should be determined by taking into account the properties of the planted variety and the regional conditions. If leaves are defoliated in the early period, yield decreases and fiber quality may be adversely affected. On the other hand, in case of defoliation in later periods, the adverse weather conditions may be experienced, and the desired level of leaf defoliation cannot be achieved.

Effect of the defoliant increases with temperature and daylight, but decreases in low temperature and cloudy weather conditions. After the application of defoliant in a warm and sunny environment, leaves defoliation can be completed in 10-14 days. This period may be longer on low temperature and cloudy days. In adverse weather conditions, dry leaf condition may be encountered instead of defoliation. It is beneficial to have temperature at least around 15°C at the time of defoliant application. In warm conditions, 5% to 10% more defoliation can be achieved than in cool conditions (Hayes et al., 1996). If weather conditions at the application time show uncertainty in the cases of cool weather or precipitation conditions, the application dose should be divided into two and applied twice. In the same conditions, mineral oils such as spreader, adhesive and diluent should be used to increase the effect of the chemical.

Hand cotton picking can be started when 40-50% of the bolls are opened. However, for machine harvesting, feature of the harvester must be considered into account. For a good leaf defoliation, the plants in the field should be close to each other in terms of growth and development. Uniform growth and development of plants in the field depend on the uniformity of the field soil structure, surface structure and drainage. Genotypes with long branches defoliate their leaves more easily than those with short sympodial branches. In genotypes with sparse and deeply slit (lobed) leaves, the effect of the chemical may be greater than those with dense and large leaves. Leaf defoliation may be less for plants grown in the condition of fertile soils or with excessive nitrogen application (Oğlakçı, 2012). If it is desired that the seed cotton is clean and the harvesting efficiency is high, cotton leaves should be defoliated before harvesting either manually or by machine. Leaf defoliation can shorten the boll opening time about one to three days, and earliness is provided between 1% and 20% in the first hand (Oğlakçı and Gençer, 1992). Also, early cotton harvesting can create more time to soil preparation for the next crop.

In addition, when the leaves are defoliated, especially in the late stages of plant growth and development; reproduction of pest populations such as pink bollworm (*Pectinophora gossypiella Saundcrs*.) and boll weevil (*Anthonomus grandis*) can be prevented. By partially defoliate the lower leaves, aerating the lower parts of the plants and reducing the relative humidity, thus pests such as Whitefly (*Bemisia tabacii Gemi.*) and Aphid (*Aphis spp.*) and boll rotting diseases such as *Ascohyta spp*., *Glomerella spp*. and *Alternaria spp*. can also be reduced (Oğlakçı et al., 2007).

Defoliation

With the increases of machine harvesting either in our country or in the world, the importance of defoliation has begun to increase (Mert, 2007). Efficiency and easiness in the harvesting can be achieved by defoliates all the leaves of the plant towards the harvesting period. In addition, by providing earliness, harvest can be completed in a short time, once or twice. Harvested seed cotton is cleaner than those obtained from undefoliated plots. When all leaves are defoliated, machine harvesting can be easy and trash-free, and the population density of the pests that may occur in the late stage can be reduced and the living conditions of the disease agents are adversely affected.

In general, the benefits of defoliation can be summarized as follows (Oğlakçı and Gençer, 1992; Mert and Bayraktar, 1999; Edmisten, 2000; Jost and Brown, 2003);

a- Defoliating chemicals increase the efficiency and speed of the cotton harvester,

b- Allow the harvest to be completed at once,

c- By enabling the harvest to be performed earlier, allows the fiber to be picked without being affected by the rains,

d- Since the leaves are defoliated earlier, allows the harvest to be performed uncontaminated,

e- The use of defoliants in places where planting is carried out in high densities and air humidity is high, prevent the lower bolls from rotting (one lower boll rotting per plant means 25-30 kg/da of seed cotton loss),

f- By reducing the end-of-season populations of pests such as whitefly, pink bollworm and bollworn cause the density of these pests in the next farming season,

g- By preventing fumagine caused by pests such as whitefly and aphid, reduces contamination of fibers,

h- In cottons, maturation and opening are delayed due to various reasons, especially ethephon encourages opening, making it possible to harvest more products.

Factors affecting leaf defoliation

Defoliation in cotton is affected from the growing factors such as variety, temperature, soil fertility, irrigation, planting density, diseases and pests, weed control and land leveling, and growing factors such as plant maturity, structures that prevent chemical uptake in the leaves, and the activity of chemicals in the leaves (Roberts et al., 1996). Cotton varieties tendency towards natural defoliation is different due to differences in maturity, disease and pest resistance, thickness of the waxy layer on the leaf cuticle, and plant hormone density (Roberts et al., 1996).

Temperature is one of the factors affecting leaf defoliation. As in all plants, leaves of cotton are important plant organs that provide tolerance against adverse climate conditions. This occurs as a result of some chemical changes in the leaf structure. In very dry and hot conditions, the leaves form a thick waxy layer to prevent intense water losses, this delaying chemical uptake. On the other hand, in humid and hot conditions, the thickness of the waxy layer on the leaf decreases, and a flexible and spongy structure is formed to allow chemicals to penetrate more easily and quickly (Mert, 2007). Depending on the plant condition, temperature, humidity, chemical applied and its ratio, the leaves begin to defoliate 2-7 days after the application of the defoliant, but the defoliation of all leaves usually takes 10-14 days (Edmisten, 2000).

Defoliant chemicals used in cotton harvesting

Before harvesting, chemicals are applied to cotton in order to increase the defoliating and drying rate of the leaves. These chemicals are applied as boll opener, defoliant and drier at least 14 days before harvest (Edmisten, 2012). With the timely application of these chemicals, it allows timely harvesting. The main purposes of applying these chemicals are:

Eliminate large trash and mottling,
To allow the product to dry faster,
Reducing boll rotting,
To increase earliness and yield,
Promote boll opening and maturation,
Making a more efficient harvest once during good weather conditions and the availability of harvesting equipment,
Finishing the harvest before rain and foggy conditions,
Maximizing the number of harvestable bolls,

Maintaining high fiber quality to ensure maximum economic return.

Determining which harvesting aid chemicals to use is a complex decision. Factors such as nitrogen and plant water availability have a significant impact on the success of cotton defoliation and drying efforts for harvest preparation. Decisions on whether to use one or more chemicals, the most appropriate dose and timing vary according to plant conditions. Generally, the process from chemical application to harvest is a period of 14 to 21 days. It may take longer with late sowing, rainy and cool fall weather.

Chemicals for harvest can be classified into two groups as herbicide and hormone effective (Table 1). Herbicide defoliants cause damage to leaves by increasing ethylene production, hormone effects increase the ethylene density in the leaves without causing any damage to the leaves (Edmisten, 2000; Jost and Brown, 2003).

Figure 1. Cotton field after defoliant application (Photo: H. Haliloglu)

Table 1. Grouping of chemicals used in defoliation according to their active substances (Edmisten, 2000; Jost and Brown, 2003). (from Mert, 2007).

Class	Active Ingredient Description	Description
Hormone effect chemicals	*Thidiazuron*	Thidiazuron does not directly cause damage to the leaves. Instead, it increases ethylene production and inhibits auxin transport. It has no boll-opening effect.
	Dimethipin	Dimethipin inhibits protein synthesis, which plays a role in the control of stomata. This causes rapid water loss in stomata, increasing ethylene production. Dimethipin has no boll-opening or regrowth inhibitory effect.
	Ethephone	Increases ethylene production. It is primarily used as a boll opener. It has no regrowth inhibiting effect.
herbicide effect chemicals	*Tribufos*	In Tribufos application, the cell layer under the leaf cuticle are damaged. This damage causes stress in plants and triggers ethylene production. Ethylene production initiates leaf defoliation. Tribufos has no boll-opening or regrowth inhibitory effect.
	Carfentrazone	Carfentrazone inhibits chlorophyll synthesis. Causes destruction of cell membranes. This stress, on the other hand, increases ethylene production, causes defoliating. Carfentrazone has no effect on boll opener and regrowth inhibitor.
	Pyraflufen Ethyl	Its effect is the same as carfentrazone.

Some chemicals such as dimethipin, ethephone, carfentrazone, thidiazuron, chlorate, tribufos etc. are used for defoliation in cotton production. These chemicals increase the production of ethylene in the leaves and trigger a rapid growth due to abscisic acid formation at the point where the petioles attach to the branches, causing accelaration and defoliation the natural aging process of the leaf (Cathey, 1986; Roberts et al., 1996).

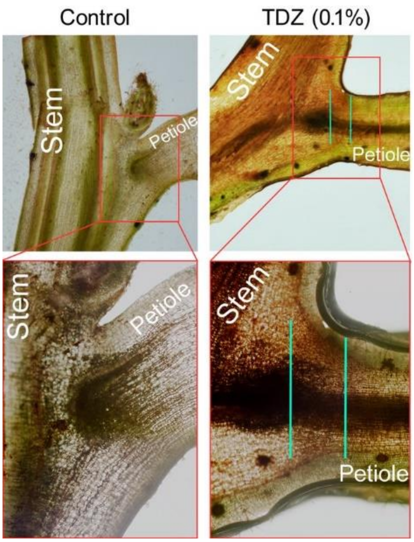

Figure 2. The effect of thidiazuron (TDZ) application on petiole (Li et al., 2021)

While young plant leaves contain a large amount of auxin, auxin density decreases with aging, and ethylene and abscisic acid (ABA) levels increase (Roberts et al., 1996). In this way, the hormonal balance in the leaves changes and defoliation occurs. Defoliants were previously aplied by planes. However, it is prohibited in our country for some reasons such as undesirable situations due to the fact that the chemical, which is aplied especially in windy weather, can not provide a full surface coating in applications made by plane, and because it goes to the places around the target field with the effect of the wind. 20-40 liters per decare should be used for spraying with ground machine, in densely planted cotton fields more water should be used. If it rains within 24 hours after the defoliant application, the application should be repeated (Jost and Brown, 2003).

Different methods are used to determine the time of defoliation.

1. Determination of maturation of top bolls or boll counts by manual ınspection or boll cutting technique

Period definitions are made in terms of growth and development of cotton bolls, such as young, immature, mature and physiologically mature bolls. Those 30 to 32 days old and older are defined as mature bolls and it is emphasized that 28-30 days old boll seeds can germinate (Berkey, 1975; Delouche, 1981).

In this method; the boll located at the top or the fourth node downwards from the tip of the plant, is pressed tightly between the thumb and forefinger and if a resistance or hardness is felt in the boll structure, it is considered mature. The other method, when cutting the boll with a sharp knife, is based on the resistance level of the boll and the color of the cotton seed coat and inner part, and it is decided whether the boll is mature or not.

Immature bolls can be sliced easily with a sharp knife, whereas mature bolls are very difficult to cut.

2. The ratio of bolls opened per plant (%)

Considering the size of the field, plants are sampled repeatedly. During this sampling, the harvestable mature bolls per plant (determined by hand or knife) and the number of opened bolls are determined. The opened boll ratio is calculated as follows.

Ratio of Opened Bolls (%) = (Number of Opened Bolls / Mature Bolls + Number of Opened Bolls) x 100

In case of opening 40-60% of the bolls, it is recommended to apply defoliant (Oğlakçı and Gençer, 1992).

3. Number of days after flowering

Taking into account the flowering, fruiting characteristics of cotton varieties and the harvesting conditions of the cotton farming area, defoliation can be applied within a certain period of time from the planting or the beginning of flowering. On this subject, it has been reported that defoliation performed between the 75th and 90th days after the first flowering exhibited no negative effect on yield and quality factors under Çukurova conditions (Oğlakçı and Gençer, 1992); in a other study conducted under Harran Plain conditions reported that the leaves has not defoliated well in the defoliation applications made 90th day after flowering due to insufficient temperature (Çopur et al., 2010).

Cotton is harvested in two ways, by hand and by machine.

1. Harvest with hand

Hand picking is generally performed in cheap and small family enterprises. In seed cotton harvest; it is necessary to take seed cotton from the opened boll manually and to collect it as cleanly as possible from leaves, square (bracte) and other plant residues. Picking or harvesting begins when 40 to 60% of the bolls are opened and is completed with two or three hand pickings at 15-20 day intervals. In dry conditions, one or two hand pickings are performed. Opened bolls should not be kept in the field for a long time. When it is kept for a long time, the tress may droop and spill, and the cotton fibers become dirty and the color of the fiber becomes dull and mottling (Şenel, 1980). Usually 10% of the advertised cotton base price is accepted as the picking fee. In recent years, cotton picking fees (hand or machine) are determined by the Chambers of Agriculture.

Hand picking requires skill. The pickers hold the boll with one hand and take the seed cotton from the boll with the other hand (Figures 2 and 3), and while doing so, takes care not to leave any cotton stumps and collect it cleanly (dry leaves, squares or other residues) (litter or foreign matter).

Figure 3. Hand picking

Figure 4. Hand picking (Photo: H. Haliloglu)

In hand picking, the seed cotton are placed in baskets or saddles or in aprons attached to the waist and then stacked in big sack. Although hand-picked cotton is cleaner than machine-picked cotton, from time to time the rate of impurities in the seed cotton may increase up to 15-16% due to the skill of the worker as well as the ambition of making money. However, the impurity rate in hand picking is around 5-6% on average (Oğlakçı et al., 1983). In hand picking, a worker can harvest 40-60 kg of seed cotton per day. A skilled worker can harvest 90-100 kg in a day, even starts to collect in the early hours of the day, can harvest 120-130 kg of seed cotton (Oğlakçı, 2012).

2. Harvest with machine

After the patent on the cotton harvester in 1850, many patents were obtained with the studies on the harvesting machines. From the years when the harvester was developed until the 1950s, it could not find a general application area. However, with the increase of labor costs, the usage possibilities of cotton harvesters have increased. In countries where cotton agriculture is developed, cotton is harvested by machinery, especially in the United States, India and China (Wanjura et al., 2015).

In Turkey, studies on cotton harvester started in Adana, Antalya and Nazilli in 1973 and were continued to the 1990s by various researchers (Gözkaya, 1978; İnan, 1978; Gencer and Yelin, 1982; Sabancı and Işık, 1987). In the studies carried out until today, it has been determined that the yield losses and impurity ratio are higher, and the fiber quality is 1-2 degrees lower in general in machine harvesting. In these studies, the fact that the harvesters are old types and varieties has a share in the high losses and low quality. Cotton varieties planted after 1996 are suitable for machine harvesting and the new cotton harvesters used have increased the performance.

Spindle Picker and Stripper type harvesters are mainly used in cotton harvesting. Spindle picker harvester are taken the seed cotton to the storage by pulling them through the spindles after the leaves are defoliated in the fields that have opened almost all of the bolls. Stripper type harvesting machines harvest seed cotton by stripping the bolls and leaves on the plant. All of the harvesting machines used in Turkey are Spindle Picker type harvesters. In recent years, some of the Spindle Picker Harvester collect the seed cotton and turn them into 2-2.5 ton bales (onboard module building). Seed cotton bales allow transport and harvesting machine to work more effectively.

Stripper type harvesters:

In this system, the harvest is carried out by breaking all the opened and unopened bolls on the plant at a time. The machines used can be 2-8 rows self-propelled as well as tractor-mounted types. These machines, which can be manufactured with rods or fingers, have "V" shaped slots on the front.

The cotton plant entering these slots passes between the fixed boll-breaking rods, which are parallel to the direction of forwards and rising backwards. Since the stems, branches and bolls are in different diameters, the retained bolls break. In the finger type, the box part has 8 or more long and parallel iron fingers. The harvesting efficiency of these machines is 70-85%. In the machines developed later, cotton bolls are broken by passing cotton plants between the brushes and rubber wings arranged on it with a rotating cylindrical roller. In these machines, the efficiency can vary between 85-90%. (Bayındır, 1996; Wanjura et al., 2015).

The collected bolls are conveyed to the storage of the harvester by pneumatic or mechanical elevators passing through the carpel separator or cleaning part. In this type of harvesters, the harvesting is performed on a delayed time. In other words, the leaves on the plant are expected to defoliate and all of the bolls to mature. Chemical defoliants and dryers are also used to accelerate the harvest. It is used for the harvest of short-fiber, slow-growing, low-sized, storm-resistant varieties. In the harvest made with harvesters, green bolls and leaves are collected together with seed cotton. For this reason, the impurity rate in the cotton collected is very high. Scraper type harvesters are mostly used to collect the remaining bolls after cotton is harvested with spindle type harvesters.

Spindle picker type harvesters:

Although this type of harvesters were put into practice later than the first type harvesters, they more accepted. Picker type machines do the harvesting with the help of a set of fingers or spindles as in hand picking. There are two types of these as linear and chain. But the work of both is based on the same principle.

In these most commonly used machines; the rotating spindles take the seed cotton held by the carpels in the opened bolls. The grooved spindles are selective and they enter amongst the plants and take the seed cotton from the opened bolls it encounters. The unopened bolls remain on the plant. When these bolls open later, a second hand can be performed. Harvesting with these machines is done after defoliant is applied to the plants and approximately 80-90% of the bolls are opened.

In linear type machines, 600 to 1700 spindles are placed on a vertical shaft in a linear that can move up and down. Since the rotational speed of the linear, which allows the conical or straight spindles to enter the plant, and the machines speeds are interconnected, the plants do not lie down, the spindles rotate without making any forward movement and wrap the seed cotton with the effect of the comb on it.

Since the movement of the spindles on the linear follows a specially shaped path, it enters vertically into the plant and leaves the plant vertically. When one of these spindles, which can rotate around itself without being connected to each other, comes into contact with the opened bolls, the cotton cling on the spindle. The spindles are threaded. However, they still cannot easily hold and pull dry cotton. For this reason, they are moistened by continuously giving water from a tank in the machine. Thus, the fibers can be clung onto the moist spindle more easily. It is scraped off by scrapers made of rubber on the spindle. Then, it is absorbed by the aspirator and transferred to the tank of the machine. Along with moistening as the spindles pass through the rubber eraser pads used for this work; The fiber fragments, plant sap, green boll and the remains of leaves, dust and garbage remaining on the spindles are cleaned by scraping. Thus, cotton spotting is prevented (Wanjura et al., 2015).

The transfer of cotton to the machine tank is carried out by air-effect transport systems such as non-clogging pneumatic, jet-air, split. Spindle collectors are the most commonly used in cotton harvesting today. 70% of the cotton collected in America and all of them in Greece are made with this type of machine. The collection efficiency of this type of machine is about 92-96%.

In chain type machines, there are two linears at the front and rear and two chains on them. The spindles are placed on the bars on these chains. As the chains rotate, the spindles rotate freely around their own axis. There are 2500-3500 spindles in this type of machines.

Figure 5. Rotary spindles (Photo: H. Haliloglu)

Efficiency of harvesters

The efficiency of harvesting machines can vary according to the yield obtained from the field and the working efficiency of the machine, the number of turns in the field, and the shape and area of the field. It is quite difficult to come up with an ideal plant type for machine harvesting. However, in terms of harvest efficiency, the plants do not be too elongate (long-branched), tall or short, and have a uniform (uniform) growth and development, and the height of the first sympodial branch from the ground, especially for spindle pickers, is 15-20 cm (Kaynak and Çopur, 1999). In addition, features such as the large boll and fully open, resistant to wind, boll attachment close to the main stem (cluster), short time between the maturation of the first and last bolls, and hairless leaves are preferred. In the field where machine harvest will be made, the plants should not be lodging or horizontal.

In the field where machine picking will be performed; sowing should be done on the ridge or the ridge should be done with root filling afterwards. The fields should be flat and free of weeds, and there should be no large stones, iron or wood that would hinder the operation of the machines.

Harvest cost in spindle pickers vary depending on the seed cotton yield of the field, shape of the field, size of the area and number of rows of the machine (4, 5, 6 or 8 rows), whether it is new or old. In this type of harvesters, the seed cotton of the opened bolls is collected by a large number of spindles that rotate on their own axis and move horizontally on the collection set. This type of harvester does not damage to unopened bolls. The seed cottons collected are separated from the spindles by pulling backwards (inwards) the spindles on the collection set, sucked by a compressor and conveyed to the box located at the top or the rear of the harvester (Figures 6 and 7).

Figure 6. Cotton harvest by machine

Figure 7. Seed cotton bale harvested by machine (Photo: H. Haliloglu)

Harvesting efficiency with spindle collectors may vary depending on the moisture condition of the cotton. High dryness of fibers makes it difficult to collect and increases losses. Therefore, if the moisture of the seed cotton is less than 10%, the seed cotton is moistened with the humidifier of the harvester. High humid makes difficult to separate the seed cotton from the spindles and the cotton wrapped around the spindles and a formation like a twine emerges. Therefore, the water to be given to the cotton should be in an amount of increase the humidity of the seed by 1-2%. In addition, seed (breakage and cracking in the seed coat) and fiber quality may be adversely affected in very moist cottons (Oğlakçı, 2012).

In four-row spindle pickers; according to the size and shape of the field, 15-16 decares can be harvested per hour; in six-row harvesters, 28-40 decares can be harvested per hour (Brashears, 1999). In addition, since the plant and the unopened bolls are not damaged with this type of machinery, harvesting can be performed with more than one time as in hand picking. Spindle type picker harvesters are successfully used in high fertile and irrigated cotton farming areas (Mert, 2007).

There are also self-propelled or tractor-towed types of harvesters. In addition to these, there are harvesters that work with suction power and are mostly used to pick up the seed cotton that has been fallen on the ground.

A large amount of seed cotton is harvested in a short time with the harvester. Even if defoliation applications are carried out under optimum conditions, sometimes the lower leaves may not fall and they may be mixed with the seed cotton during harvest. This situation gets with the storage problem of seed cotton collected by machine. In Turkey, the majority of seed cotton is ginned with rollergin type machines. Warehouses are needed because the capacities of Rollergin type gins are low. To solve the storage problem, the seed cottons should be ginned with high capacity sawgin or rotobar ginning machines.

Harvest losses

Harvest losses; In addition to the potential yield losses, mold should be considered together with the contamination and deterioration caused by diseases and pests in the bolls that can be harvested.

Harvest losses

1. Damage caused by pests and diseases in young and immature bolls: mold, cracking of the bolls or the formation of blind bolls, mottling and stickiness,
2. Precipitation polluting the seed cotton, shedding, mottling and adversely affecting the seed,

3. Especially in arid regions, the wind carries dust and soil, polluting the seed cotton and causing spillage of the tress,
4. Pollution caused by particles such as dust and soil in the air along with precipitation,
5. Color and pollution formation as a result of dew formation on the seed in conditions where the relative humidity is high and the night air temperature is low,
6. The amount remaining in the boll (carpel) during harvest,
7. Negative fiber and seed properties and stickiness in fiber of cotton bolls whose growth and development are exposed to warm or cold weather conditions,
8. Shedding of seed cotton during harvest,
10. During the rainfall, the raindrops and the water falling from the leaves to the ground pollution that occurs as a result of splashing its particles on seed cotton seed that are close to or in contact with the soil.

Measures to be taken to increase fiber quality in cotton farming are as follows:

- Variety selection should be done well,
- Sowing time should be well determined according to the variety,
- Excessive irrigation and fertilizer applications should be avoided,
- Cultural practices should be done in a timely and properly,
- Harvest should be practised at the most appropriate time,
- Blind and immature bolls should not be collected,

- Harvesting should not be started early in the morning or when the seeds are moist after precipitation,
- Varieties should not be mixed during harvest and storage,
- During harvest and storage, first and second hand seed cottons should not be mixed,
- Mixture of impurities should be prevented during harvest,
- During harvesting and baling, synthetic products such as nylon sacks and nylon rope should never be used, cotton materials should be used,
- After harvest, the seed cottons should be stored under suitable conditions.

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CHAPTER 8

QUALITY PARAMETERS OF COTTON FIBRE

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INTRODUCTION

Cotton fiber is the most important raw material of the textile industry, which is one of the cornerstone of Turkey's economy. The fact that it is natural, moisture-holding ability, resistance to heat treatments, air permeability, hygienic and lower static electricity than other fibers makes it indispensable. Cotton fiber, which is so important for the textile industry, is also used in the chemical, oil, cosmetics, pharmaceutical and livestock industries (Duygal, 2016).

Due to the increasing competition conditions in the textile sector, it has become even more important to purchase cotton bales of suitable quality. Since cotton is a natural fiber and also a commercial product, its supply, price and quality may vary according to the supply and demand market conditions. For this reason, it is very important for the yarn industry to select cotton bales at an reasonable price and quality and to classify these bales according to their quality and blend them accordingly (Sharma, 2014).

Since many different types of cotton are cultivated in our country, there are differences in quality between regions and even between basins. Due to the storage conditions of the ginning companies, storage and ginning of different quality cottons together will cause quality differences even within the same bale and lot, difficulty in machine settings difficult during the yarn production phase, reducing the yarn production efficiency, and causing abrasion during the dyeing phase (Ozbek et al., 2014).

Quality differences in cotton fiber due to genotype or environmental conditions create serious quality problems from the processing of the cotton fiber to the final product. The most efficient way to prevent these problems is to determine the fiber properties with the HVI device, which produces accurate results in a short time, and to minimize the problems that may occur due to fiber quality in the yarn production stage by arranging the bales according to these properties (Glade et al., 1981).

The fiber quality parameters and classification details of Upland cotton are given below.

Upper Half Mean Length (UHML): It expresses the longest 50% of the fibers in the fiber bundle as mm or inch (Anonymous, 1999). It is one of the most important quality criteria of cotton, it expresses the spinnability of the fibers (Anonymous, 2014a).

The weight calculation of the upper half mean length is made from a special staple diagram, the fibrogram. A randomly placed fiber beard of fibers is scanned optically across its length and fibrogram is obtained from it (Anonymous, 2014b).

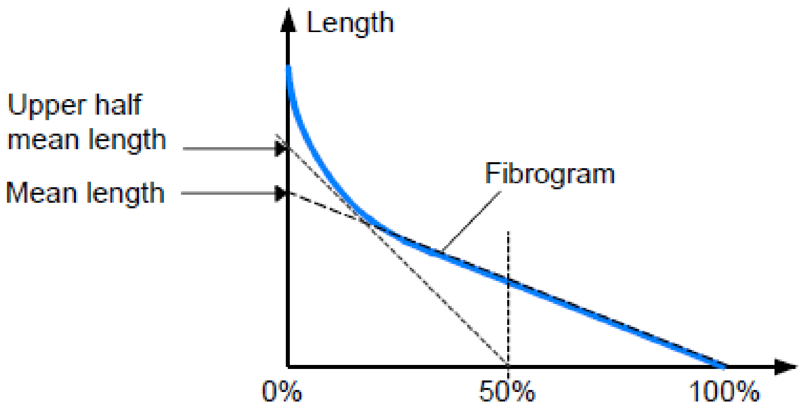

Figure 1. USDA-mode/ Fibrogram

Although the length of cotton fiber is hereditary, it is also slightly affected by environmental conditions. Intense temperatures during the development period, water stress, lack of plant nutrients reduce fiber length. Excessive pre-cleaning and high humidity in ginning process can also negatively affect fiber length (Haliloğlu, 2015).

Due to the variation within the cotton fiber, there is no definite fiber length value within the same genotype and fiber sample (Behery, 1993). Long-staple cottons are generally thinner and stronger than short-staple cottons (Beheary et al., 2021).

In the international cotton trade, the inch or 32nds unit is used. Calculation of the ranges in millimeters is not used in the international market because it does not fully correspond to the conversion (Anonymous, 2014b).

Table 1. Staple length ranges and conversions (short/medium staple)

Inches	UHML (inches)	UHML (mm)	Code (32nds)	Inch	UHML (inch)	UHML (mm)	Code (32nds)
<13/16	<0,79	<20,1	24	1 1/8	1,11-1,13	28,2-28,7	36
13/16	0,80-0,85	20,1-21,6	26	1 5/32	1,14-1,17	29,0-29,7	37
7/8	0,86-0,89	21,8-2,6	28	1 3/16	1,18-1,20	30,0-30,5	38
29/32	0,90-0,92	22,9-23,4	29	1 7/32	1,21-1,23	30,7-31,2	39
15/16	0,93-0,95	23,6-24,1	30	1 ¼	1,24-1,26	31,5-32,0	40
31/32	0,96-0,98	24,4-24,9	31	1 9/32	1,27-1,29	32,3-32,8	41
1	0,99-1,01	25,1-25,8	32	1 5/16	1,30-1,32	33,0-33,5	42
1 1/32	1,02-1,04	25,9-26,4	33	1 11/32	1,33-1,35	33,8-34,3	43
1 1/16	1,05-1,07	26,7-27,2	34	1 3/8	>1,36	>34,5	44
1 3/32	1,08-1,10	27,4-27,9	35				

Fiber length affects yarn strength, yarn evenness and efficiency of the spinning process. The fineness of the yarn is also affected by the fiber length (Anonymous, 1999).

The fiber length ranges, conversions and classification of Upland cotton are given in Table 2 (Anonymous, 2018).

Table 2. Classification of the cotton fibre according to length

Fiber Length (inch)	mm	Code (32nds)	Description
1”	<25,4	<32	Short
1 1/32”- 1 5/32”	26,2-29,4	33 – 37	Medium
1 3/16”- 1 ¼ ‘’	30,2-31,7	38 – 40	Long
>1 9/32”	32,5	> 41	Extra long

Micronaire: It is measured by the amount of air passing through a fiber sample of a certain weight (10 ± 0.5 grams) and the drop in pressure (Anonymous, 2014b). It is an hereditary trait, but it can also be affected by environmental conditions such as humidity, temperature, sunlight, plant nutrients and excesses in the number of plants or bolls during plant growth (Anonymous, 1999).

Classification of fibers according to their fineness is shown in Table 3 (Anonymous, 2014b).

Table 3. Classification of the cotton fibre according to micronaire

Micronaire	Description
Less than 3,0	Very fine
3,0-3,6	Fine
3,7-4,7	Medium
4,8-5,4	Coarse
5,5 and higher	Very coarse

Micronaire affects the spinning limit, yarn evenness, yarn breaking strength, yarn appearance, fabric drape, yarn production efficiency and yarn brightness (Anonymous, 2011a).

Micronaire affects the manufacturing process and the quality of the final product in various ways. During the opening, cleaning and carding processes, low micronaire cottons should be operated at lower speeds to prevent fiber breaks. Since there are more fibers per cross-section in yarns made from low micronaire fibers, the yarns produced from them are more strong (Anonymous, 1999).

If the fibers with low micronaire are mature, the fibers are smoother and more strong; If the maturity of the fibers with low micronaire is also low, the dye absorption power will also be low. Low micronaire increases the probability of nep formation. High fiber micronaire limits the number of yarns that can be produced (Kretzschmar, 2018).

Fiber Strength (grams/tex): It is the expression in grams of the force that must be applied to break fiber bundle per tex. While measuring the length in the HVI device, the strength measurement is also made. The force applied up to the breaking point is determined by attaching the fiber bundle between two clamps 1/8 inch apart. The breaking strength is mostly affected by the selection of the variety. Fiber strength in mid-early cultivars is generally higher than in early-early cultivars. Likewise, high-strength yarns, hence fabrics, are produced from high-strength fibers (Anonymous, 1999). Decreased strength; It causes fiber breakage, increased fiber breaks, increased fiber waste and dust formation (Anonymous, 2011a).

Fiber strength is directly proportional to spinning machine efficiency and yarn strength. However, fiber strength is also related to other cotton properties such as fiber length, micronaire and maturity. The fiber bundle strength is a decisive factor in the spinning machine speed. If the fiber strength is not sufficient, the speed of the machines and the production efficiency must be matched. Likewise, the final yarn strength will be less (Sharma, 2014).

Classification of fibers according to strength is given in Table 4 (Anonymous, 2014b).

Table 4. Classification of the cotton fibre according to strength

Strength (grams/tex)	**Description**
Less than 21	Very weak
22-24	Weak
25-27	Medium
28-30	Strong
31 and higher	Very strong

Fiber Uniformity Index (%): It is the ratio of the mean length to the upper half mean length. It is an indicator of the distribution of fiber length within the fibrogram (Anonymous, 2018). If all fibers in the same bale are the same length, the mean length and the upper half mean length will be the same, so the uniformity index is 100. However, this value is always less than 100, as there is always a natural variation between fiber lengths (Bel, 2004).

$$\text{Uniformity Index} = \frac{\text{Mean Length (ML)}}{\text{Upper Half Mean Length (UHML)}}$$

The fiber uniformity index affects yarn evenness, yarn break strength and efficiency of the spinning process. It is also proportional to the short fiber content, cotton with a low fiber uniformity index is likely to have a high short fiber content. This type of cotton is likely to be difficult to process and the yarns produced are low quality (Anonymous, 1999). The fiber uniformity index is a very important factor in obtaining optimized and correct spinning draft roller settings in yarn production. The low uniformity index causes very high variation during the spinning process and makes it difficult to set the correct setting for the particular cotton blend in yarn production (Sharma, 2014).

Classification of fibers according to the uniformity index is given in Table 5 (Anonymous, 2014b).

Table 5. Classification of the cotton fibre according to uniformity index

Uniformity Index (%)	**Description**
Below 77	Very low
77-80	Low
81-84	Medium
85-87	High
87 and higher	Very high

Elongation (Elasticity; %): It is an indicator of the elasticity of the fibers in the cotton bundle. By placing the fiber bundle at 1/8 inch clamp distance, the back clamps are pulled at a constant speed and the elongation distance before breaking is recorded. The ratio of the elongation distance to the fiber bundle length expresses the fiber elongation (Anonymous, 2014b). Cotton with high fiber elongation from two cottons with the same strength is processed more easily during the spinning process and it is turned into yarn more easily. Fiber elongation is also higher in mature fibers (Quisenberry and Kohel, 1975).

Classification of fibers according to elongation is shown in Table 6 (Anonymous, 2014b).

Table 6. Classification of the cotton fibre according to elongation

Elongation (%)	**Description**
Below 5,0	Very low
5,0-5,8	Low
5,9-6,7	Medium
6,8-7,6	High
7,7 and higher	Very high

Short Fiber Index (SFI): It is the percentage expression of the amount of fibers shorter than 0.5 inches (12.7 mm) in the bundle (Anonymous, 2014b).

Whether the cotton is harvested by hand or machine, the preparation processes before the ginning and spinning affect the amount of short fiber. While high short fiber index increase the pilling in the yarn, it decreases the yarn smoothness. High short fiber index also lowers yarn strength; thus, the number of twists required to obtain the same yarn strength should also increase (Kretzschmar, 2018). At the same time, the increase in the short fiber index reduces the efficiency of the machine during the spinning process, causes excessive yarn faults and slows down the yarn production (Sharma, 2014).

Classification of fibers according to short fiber index is given in Table 7 (Anonymous, 2014b).

Table 7. Classification of the cotton fibre according to short fiber index

Short fiber index (%)	**Description**
Below 6	Very low
6-9	Low
10-13	Medium
14-17	High
18 and higher	Very high

Spinning Consistency Index (SCI): It is a calculation method used to estimate the spinnability of fibers. It is a multiple regression equation that helps to find yarn breaking strength and spinning performance. The multiple regression equation reveals the contribution of most of the fiber properties measured by HVI to the yarn properties. SCI value is affected by micronaire, length, uniformity, strength, reflectance (Rd) and yellowness (+b) value (Anonymous, 2014b; Sharma, 2014).

Spinning Consistency Index (SCI)=-414,67+2,9 x (strength) – 9,32 x (micronaire) + 49,17 x (length) + 4,74x (uniformity)+ 0,65x (reflectance)+0,36x+(yellowness)

The spinning consistency index is also suitable to make the classification system used in cotton warehouses more useful and simpler. In fibers with a high spinning consistency index, spinnability is generally high, so yarn strength is also high in yarns made from them (Anonymous, 2014b).

Spinning consistency index, conversions and classification of Upland cotton are given in Table 8 (Sharma, 2014).

Table 8. Classification of fibers according to the spinning consistency index

Spinning Consistency Index (SCI)	**Description**
Below 120	C
120-129	B
130-140	A
140-149	A+
150 and higher	A++

Maturity Index (%): The maturity index is a relative value calculated using a complex algorithm that includes other HVI measurements such as micronaire, strength and elongation. It shows the degree of cell wall thickness in a cotton sample (Anonymous, 2014b).

As the fibers develop, the cell wall becomes filled with cellulose and the maturity of the cotton fiber increases. While the cross-section of mature fibers is similar to a bean or kidney, the cell walls of the immature fibers are thinner as they are not filled with cellulose, as shown in Figure 2 (Anonymous, 2011b).

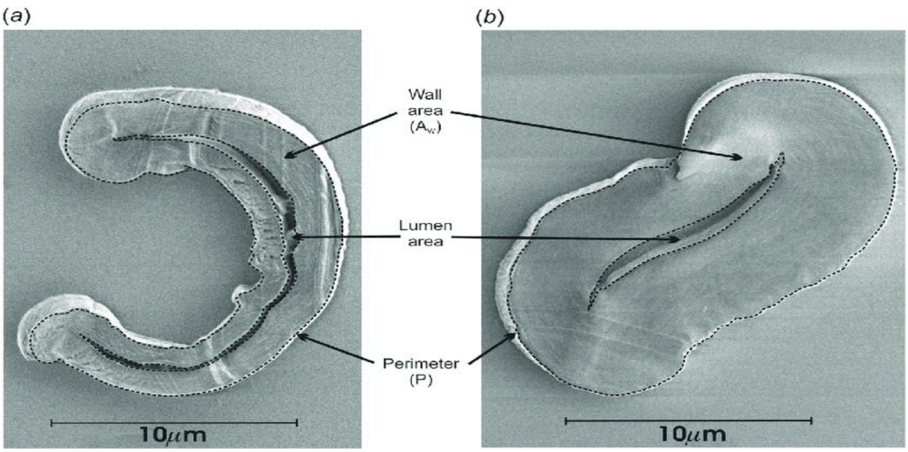

Figure 2. Cross-section images of mature (b) and immature cotton fibers (Long et al., 2009)

While the high temperature and drought, daylight, temperature differences between day and night, precipitation regime, excessive use of fertilizers and irrigation delay maturation; harvesting cotton earlier than it should, reduce the maturity index (Bradow and Davidonis, 2000; Wang et al., 2014). A fully mature fiber means that the fiber has completed its full growth process and is developing in all respects. Maturity is therefore a key parameter for cotton selection and the spinning process. The effect of low maturity value on the spinning process or yarn quality is as follows:

Fiber breakage: Immature fibers in the blowroom and carding section split into multiple fragments, causing an increase in short fibers and microdust, further reducing the effective length and strength of the fiber. This fiber breakage increases the level of ends down, yarn faults, spinning waste and yarn faults. All this leads to lower production, yarn recovery with lower yarn strength, thus reducing the operating efficiency of spinning machines.

Dead cotton neps: Immature fibers cause heavy neps during spinning process that reflect as white dots in the dyed fabric and cause fabric rejection (Sharma, 2014).

Classification of fibers according to maturity index is given in Table 9 (Anonymous, 2014b).

Table 9. Classification of fibers according to maturity index

Maturity Index (%)	**Description**
Below 75	Uncommon
75-85	Immature
86-95	Mature
Above 95	Very mature

Dye absorbency and retention vary according to the maturity of the fibers, the higher the maturity index, the better the absorbency and dye holding properties (Anonymous, 1999). Immature cotton fibers have a softer touch and a higher shine, but these fibers contain more neps and have lower strength. For these reasons, low amount of immature fiber is preferred in a cotton lot (Alhalabi, 2007).

Reflectance (Rd): It gives the whiteness amount of the light reflected by the cotton fibers. It is the Rd value given in the Nickerson/Hunter color scale. It expresses the brightness of the fiber bundle (Anonymous, 2014b). Since the brightness value means that the color appears brighter/vivid, it is desired to be high (Sobrinho et al., 2015).

Classification of fibers according to the reflectance is given in Table 10 (Alhalabi, 2007).

Table 10. Classification of fibers according to reflectance

Reflectance (Rd)	**Description**
40-55	Matt
55-65	Close to matt
65-70	Medium bright
70-80	Bright
80-85	Exstra bright

Yellowness (+b): It is the yellowness of the light reflected by the cotton fibers, indicating the degree of color pigmentation. It corresponds to the +b value in the Nickerson/Hunter color scale (Anonymous, 2014b; Anonymous, 1999). It is desired that the yellowness (+b) between 5-7, and an increase in the yellowness causes problems in dyeing processes (Gamble, 2008).

Classification of fibers according to their yellowness is given in Table 1.11 (Alhalabi, 2007).

Table 1.11. Classification of fibers according to yellowness

Yellowness (+b)	**Description**
4-8	White
8-10,5	Light yellow
11-13	Yellow
13-18	Very yellow

Color Grade (C Grade): The color grade of cotton samples is determined by a three-filter colorimeter developed by Nickerson and Hunter. Reflectance (Rd) and yellowness (+b) values are used together to determine the color grade of cotton (Anonymous, 2014b). It is determined by finding the intersection point of Rd and +b values in the Nickerson-Hunter cotton colorimeter diagram (Anonymous, 1999).

The color of cotton fibers can be affected by rain, frost, insects and fungi, and contact with soil, grass or touch of cotton plant leaf during the growing season. Color can also be affected by extreme humidity and temperature levels while cotton is stored, both before and after ginning. As the cotton discolors due to environmental conditions, the probability of a decrease in processing efficiency increases. Discoloration also affects the ability of fibers to absorb and adherence dyes and finishes (Anonymous, 1999).

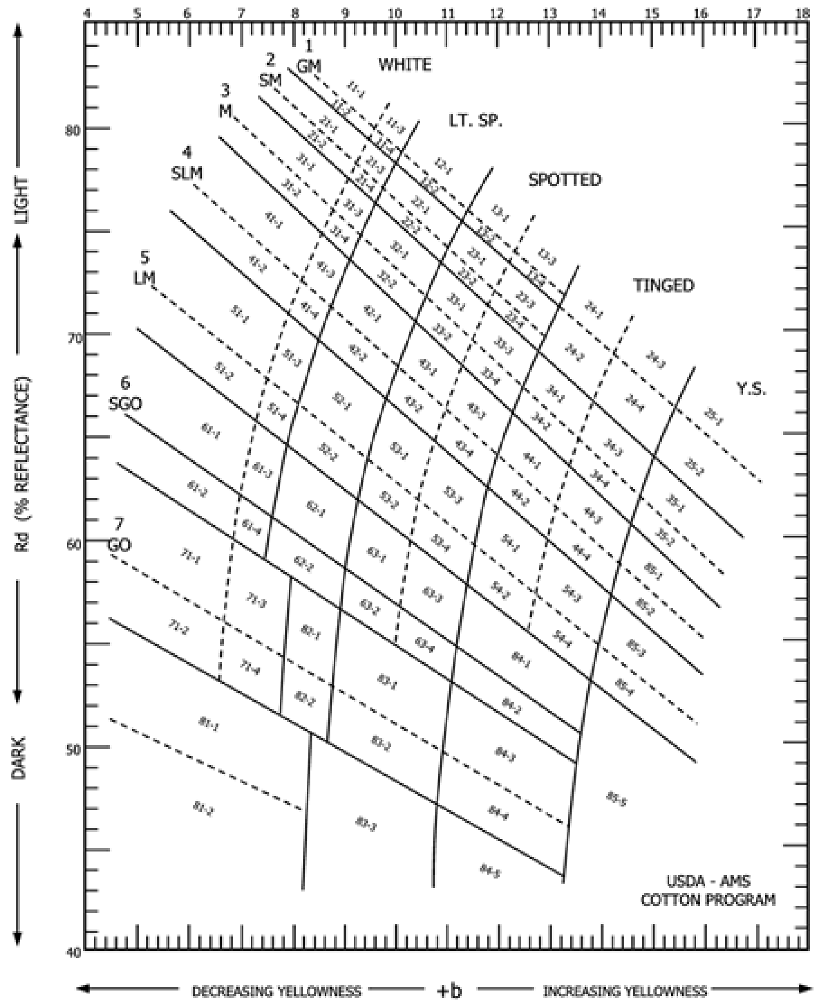

Figure 3. USDA color grading scale for Upland cotton (Anonymous, 2014b)

Trash Count: It is the amount of non-fiber material such as leaves and bark belonging to the cotton plant. The surface on which the color sample is placed is scanned with a video camera, and the trash count and the area it covers are calculated (Anonymous, 1999).

The increase in the number of trash in the cotton fiber can cause an increase in the amount of waste, breakage in the yarn, decrease in the efficiency in the spinning process, and fabric defects during the weaving and knitting processes (Anonymous, 2011b).

Classification of fibers according to the trash count is shown in Table 12 (Anonymous, 2014a).

Table 12. Classification of fibers according to trash count

Trash Count	**Description**
<25	Very low
26-75	Low
76-110	Medium
111-150	High
>151	Very high

Trash Area: It is measured together with the amount of trash count. The trash count in the measurement area represents the ratio of the area to the whole measurement area. If the trash is large as a surface, even if the trash count is low, the trash area will be high (Anonymous, 2014b).

Classification of fibers according to trash area is given in Table 13 (Anonymous, 2012).

Table 13. Classification of fibers according to trash area

Trash Count (Area %)		Trash Code	Description
Rollergin, Rotobar	Sawgin		
0 – 2	0- 0,4	1	Very clean
2,1 – 4,5	0,5- 1,2	2	Clean
4,6 – 6,5	1,3-2,4	3	Medium
6,6 – 7,5	2,5- 4,0	4	Medium dirty
7,6- 10	4,01- 5,5	5	Dirty
10,1 - 14	5,6 – 6,9	6	Very dirty
14,1 and above	7 and above	7	Very much dirty

Trash Grade: It is the degree of leaf or trash found by calibrating the HVI device with known samples. The samples are graded between 1 and 7 numbers, which increase with the increase in the number of foreign matter (Anonymous, 2014b).

Classification of fibers according to the trash grade is given in Table 14 (Anonymous, 1999).

Table 14. Classification of fibers according to trash grade

Trash Area (%)	Trash Grade
0.12	1
0.20	2
0.33	3
0.50	4
0.68	5
0.92	6
1.21	7

Neps Amount: It is the amount of fiber neps in the cotton fiber bundle. The number of neps in untreated raw cotton is related to the type of cotton and the way it was harvested. Neps does not occur before the cotton is harvested, it appears when the fibers are collected. Neps is formed due to the mechanical processes that occur during the harvesting, ginning, opening and cleaning of cotton. For many reasons, the number of neps increases in the blowroom unit and decreases in the comb and combing units (Anonymous, 2014a).

CONCLUSION

Cotton fiber quality is an important and critical factor determining worth of cotton fibre and price. Technological advances in the textile sector, the increase in consumption demand with the population increase, the prominence of fiber quality parameters, high raw material costs increase the demand for high-quality cotton. It is necessary to determine the quality criteria of cotton, which is increasingly important, with methods suitable for today's technology, and to ensure the standardization of cotton, thus creating a common language with other countries in the world. The textile industry has a preference for longer and stronger fiber and moderate micronaire for producing high quality yards, however, it should not be ignored that genotypic and environmental factors affects fiber quality properties. Among the factors affecting cotton fiber quality are the selection of variety, sowing time, moisture content in the soil, irrigation time and amount, plant nutrients, plant diseases and pests, climate and maintenance conditions, harvesting and harvest-aid applications, ginning methods, and storage.

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CHAPTER 9

COTTON DISEASES

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1. Introduction

Cotton is a plant of the order Malvales, family Malvaceae, genus Gossypium. Cultivated cottons are clasified under two groups as Herbacea and Hirsuta. Cotton is an industrial plant with ball-shaped fruit, 3-5 slices, grown in hot regions. Cotton are in Arabic is called kutum in English and French named cotton and in Turkey also "koza". It is a cultivated plant that has been grown since ancient times. Archaeological evidence shows that different types of cotton were cultivated and used for clothing in both India and South America independently between 6,000 and 7,000 years ago (Anonymous, 2021). It is a plant that generally likes a hot climate and grows in alluvial and rich soils. Cotton fibers and the seeds are the indispensable raw materials of the textile and the oil industry.

Cotton is of great importance as an industrial plant in Turkey's agricultural production potential. The share of cotton in total fiber production in Turkey is 62% and in vegetable oil production is 25%. It is also known that cotton pulp contributes greatly to our livestock as feed (Şahin, 1994).

In recent years, cotton cultivation areas have been decreasing in some areas. One of the most important reasons for this is the increase in the costs of the pesticides used and the decrease in yield as a result of the spread of diseases and pests. The most important pests in cotton are *Tetranychus urticae, Aphid, Thrips tabaci, Bemisia tabaci, Helicoverpa armigera*. The most important diseases are Cotton angular leaf spot (Xanthomonas malvacearum), Seedling root rot (*Fusarium spp.*

Phytium spp, Rhizoctonia solani), Fusarium wilt (*Fusarium oxysporum f.sp malvacearum*) and Verticillium wilt caused by *Verticillium dahliae*. Diseases in cotton are given in Table 1.

Table 1. Pathogens causing disease in cotton plant

Cotton Diseases		
Fungal Diseases	**Bacterial Diseases**	**Viral Diseases**
Cotton Leaf Spot Diseases (*Alternaria macrospora*, *A.alternata*, *Mycospherella gossypina*)	Cotton Bacterial Blight Disease (*Xanthomonas campestris* pv. *malvacearum*)	Abultion Mosaic Virus
Root Rot Diseases of Cotton Seedlings (*Fusarium* spp., *Pythium* spp., *Rhizoctonia solani*, *Thielaviopsis basicola*)		Cotton Anthocyanosis Virus
Cotton Verticillium Wilt *(Verticillium dahliae*)		Cotton Leaf Curl Virus
Black Root Rot (*Thielaviopsis basicola*)		Cotton Leaf Mottle Virus
Cotton Verticillium Wilt (*Fusarium oxysporum*)		
Cotton Anthracnose (Glomerella gossypii) (Anamorph: *Colletotrichum gossypii*)		
Powdery Mildew Disease in Cotton (*Leveillula taurica*, *Oidiopsis gossypii*)		
Sclerotiorum Rot (*Sclerotium rolfsii*)		
Cotton Cercosporella Spot Disease (*Mycospharella areola*) (Anamorph: *Ramularia gossypii*)		
Cotton Ascochyta Blight (*Ascochyta gossypii*)		

In this study, general information about the important diseases of cotton (symptoms, definition of the factor-life, struggle, etc.) are given with the support of some important studies.

a) Verticillium Wilt *(Verticillium dahliae*)

Verticillium wilt was first detected in Turkey in 1940 in Kırkağaç, Manisa (İyriboz, 1941). In some later studies, it was determined that the disease caused 11.8% of the product loss in the Aegean region and 4.0% in the Antalya region. In the Southeast Anatolia region, it is stated that the average prevalence rate of the disease in the region is 79.28% and the rate of detection is 16.27% (Karaca et al., 1971).

Apart from cotton, the pathogen also causes disease in many vegetables, legumes, ornamental plants, industrial plants, fruit trees and weeds (Aydın and Sağır, 2001). The fungus overwinters as microsclerotia in the soil and becomes vegetative under suitable conditions and enters from the root end of the host plants, through the capillary roots. The fungus that enters the root meristem tissue progresses between and intracellularly and reaches the central part. From here, the xylem settles in the vascular bundles and is carried along the vascular bundles by conidiospores and micelles. In the studies, it is stated that although the disease factor progresses to the seed, the seed does not play an important role in the transmission of the disease. There are deciduous and evergreen pathotypes of the pathogen (Göre et al., 2007).

Verticillium spores are carried by sap to the leaves of the above-ground part of the plant during transport. During this transport, the vascular bundles are blocked in some parts of the plant and the shoots dry up. In these parts, the tissues turn brown. The development of the disease usually occurs in spring and early summer (until July), stops in summer, and continues to develop again in autumn (after September). The life cycle of *Verticillium dahliae* is given in figure 1.

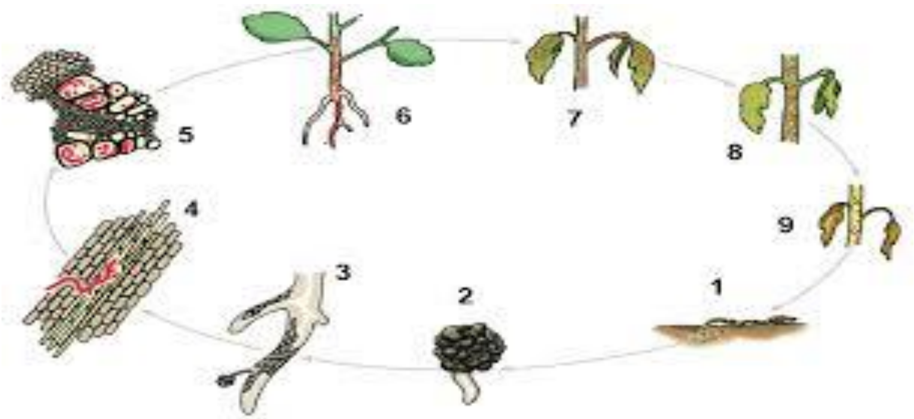

Figure 1. The life cycle of *V. dahliae* (Anonymous, 1997).

Verticillium wilt negatively affects the fiber and technological properties of cotton (Schnathorst and Mathe, 1966). As a result of the disease, the percentage of immature fibers in cotton increases, fiber length, fiber strength and fiber quality decrease. In addition, fibers obtained from wilted plants have a large amount of residues during processing (Watkins, 1981). In the view of Verticillium dahliae under the microscope, the hyphae are branched, verticillate. This image is given in figure 2.

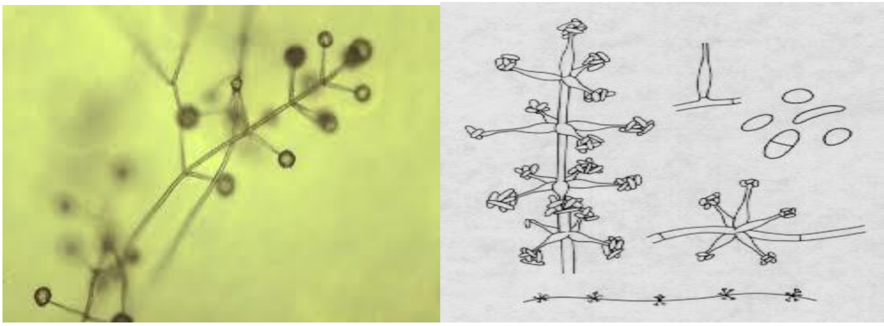

Figure 2. The view of *V. dahliae* under the microscope (Anonymous, 1997)

The disease symptoms caused by the plant usually appear in the late period, during the boll set period. The lower leaves first wilt and take on a pale green color. As symptoms progress, “V” shaped chlorotic lesions form on the leaf margins and become necrotic by collapsing over time. In addition, discoloration of the stem tissues at the root and root neck can be seen in the longitudinal section (Figure 3). Symptoms can be confused with other vascular wilt pathogens such as Fusarium. However, in Fusarium wilt, the symptoms on the lower leaves are usually light yellow.

Figure 3. Leaf and stem symptoms of *V. dahliae*

A successful and economical chemical control against the disease factor has not been found yet. However, a certain degree of success is achieved when cultural methods are applied. The most important cultural method is crop rotation. The alternation of cotton with some other plants prevents the increase and spread of inoculum in the soil. In fertilization, potassium deficiency and excessive nitrogen use increase the disease. For this, balanced fertilization should be done. A good seedbed should be prepared. Weed control should be done. When weed control is done, the control method should be chosen well. Because deep tillage increases the severity of the disease. For this, weed control should be done with more superficial tillage. Other cultural methods, attention should be paid to irrigation. Disease resistant varieties should be grown. There are resistant cultivars developed against *Verticillium dahliae* strains. Plant residues in the field should be collected and burned.

b) Cotton Seedling Root Rot

Among cotton diseases, seedling root rot is caused by more than one pathogen. These are *Fusarium spp., Phytium spp., Rhizoctonia solani, Macrophomina sp., Aspergillus niger, Aspergillus flavus, Cladosporium spp. Thielaviopsis spp.* They cause disease in plants alone or together. Pathogens spend the winter in soil and plant residues in various forms such as mycelium, sclerot, conidia or chlamidospore. When planted in contaminated soil, they infect newly germinating seeds when suitable ecological conditions are found (Anonymous, 1997a). Since it is seen from the emergence of cotton in the first period, gaps occur in the field with the emergence of the disease. After the damage, the farmer has to plant again. However, if it is late, significant yield losses occur because it cannot be planted again and it affects the root and root collar of the seedlings, causing the root to rot and die. While the average annual loss due to diseases in cotton during the 10-year period in the USA was calculated as 3.1%, it was reported that 27% of the estimated total losses in fiber production due to diseases during these years occurred due to seedling diseases (Devay, 2001). These pathogens are soil-borne and the first symptoms are seen in the newly formed roots. The bark tissue of the root changes color and softens, then rot occurs (Figure 4). Roots and root collars of infected seedlings turn brown and thin, as a result, the plant cannot stand, falls over and eventually the plant dries up. These pathogens are especially common in wet and cool years, in moist soils and in alternating fields (Kirkpatrick and Rothrock, 2001). Seedling root rot is seen in the field in two ways. The first is that the seed cannot rise to the soil surface despite germination (pre-emergence collapses), secondly, the seedling falls over and dies even though it reaches the soil surface (collapses after emergence). Disease symptoms and damage caused by damping off patogens vary according to the age and development period of the plant. Due to the lack of seedlings, it causes the formation of empty areas in the field. To prevent this risk, the producer uses more seeds than necessary (Anonim, 1997b).

Figure 4. Symptoms caused by root rot pathogens in cotton plant

The prevalence of these pathogens varies from field to field and from region to region. Considering the factors that cause damping off in cotton in the world, the most common and destructive factors are Rhizoctonia spp., Pythium spp. and Thielaviopsis spp. is known (Agrios, 1998). In a study carried out to determine the factor causing damping off in important cotton production areas in the Aegean Region between 2006 and 2007 in Turkey, it was determined that nearly 80% of the diseased seedlings collected were contaminated with *Rhizoctonia solani* (Akpınar, 2008).

There are different alternatives for the control of the disease. Cultural, chemical and biological control is carried out against the disease complex. In cultural measures, it is important to practice alternation to reduce inoculum in the soil. In the alternation, especially cereal plants should be selected. Again, excessive irrigation and frequent planting should be avoided.

Chemical control is also applied when necessary against this disease. This form of control is in the form of application to the seed. In recent years, very effective, mixed systemic drugs have been offered to the farmers. For example, double mix Prothioconazole + Metalaxyl or triple mix Azoxystrobin + Metalaxyl-M + Fludioxonil are commercially available. However, heavily contaminated soils limit the effectiveness of these drugs.

Biological control against soil pathogens is an important alternative control method. *Trichoderma spp*. and *Gliocladium virens* (Lewis and Papavizas, 1991; Howell et al., 1997), plant growth promoting rhizobacteria (PGPR) (Hagedorn et al., 1989), *Bacillus subtilis* (Asaka and Shoda, 1996), *Pseudomonas cepacia* (Zaki et al., 1998), effective results have been obtained from various biocontrol agents. Among these organisms, *Burkholderia cepacia* Deny®, *Bacillus subtilis* Subtilex®, Kodiak® is recommended as a licensed biopreparation as a seed chemical against the disease (McSpadden et al., 2002).

Similarly, Trichoderma harzianum Rifai strain KRL-AG2 strain; It is sold under the names T-22HC®, Trianum P®, RootShield Granules®, T-22 Planter Box®, as a licensed biopreparation against Rhizoctonia in cotton and many other cultivated plants in the USA, Canada, the Netherlands and Mexico (Kabaluk and Gazdik, 2005).

c) Fusarium Wilt (*Fusarium oxysporum* f. sp. *vasinfectum*)

Cotton fusarium wilt is caused by the *Fusarium oxysporum* f.sp. *vasinfectum* W.C. Snyder & H.N. Hansen (Fov) pathogen. This pathogen is of soil origin. They enter the plants by infecting from the capillary roots and settle in the vascular bundles. In this case, in the advanced stages of plant development, congestion in the vascular bundles and wilting occur in the plant, and as a result, the plants wither and die. Thus, yield and quality losses occur (Hillocks, 1992). *Verticillium dahliae* also causes wilt in cotton. But the distinguishing difference is that *Fusarium* becomes effective at higher temperatures. In addition, the symptom occurring on the lower leaves is lighter yellow in *Fusarium* and brownish yellow in *Verticillium*.

Figure 5. Color change in the transmission bundles and yellowing symptoms on the leaves in the diseased cotton plant.

In the control of Fusarium wilt in cotton, cultural measures such as rotation, using clean seeds, appropriate fertilization, appropriate irrigation, weed control and use of disease-tolerant varieties are generally used. Apart from these, physical and biological control methods also reduce the occurrence of the disease to a certain extent, but cannot completely suppress the disease. Some fungicides are used, but there is no data that they completely prevent wilt disease. Therefore, the use of disease-tolerant cultivars and the promotion of plant resistance are stated as the two most effective methods of controling the disease (Pieterse et al., 2014). In a study on tolerant cultivar identification, *F. oxysporum*. f.sp. *vasinfectum*, BA525 was the least affected with 6.9% disease severity, and Flash was the most affected with 44.8% (Şahbaz and Akgül, 2016).

d) Cotton Anthracnose (*Glomerella gossypii*, Syn. *Colletotrichum gossypii* **)**

This pathogen causes anthracnose disease in cotton plants. It reproduces mostly by asexual reproduction. Colletotrichum gossypii is asexual reproduction and Glomerella gossypii is the name given as a result of sexual reproduction. The disease is caused by the spreading conidia. These conidia can also be reproduced in artificial media (Roca et al., 2004). *G. gossypii* is transmitted by seed and can also overwinter in infected cotton plant residues. Perithecium usually develops in dead tissue and forms the primary source of inoculum. Conidial spore stage is seen in secondary infection. For the development of disease symptoms, approximately 90% relative humidity and 25°C temperature are required for 8-10 hours (Anonymous, 1982).

The disease caused by G. gossypii is most common on seedlings and bolls, but lesions also occur on the stems and leaves of plants, sometimes producing a burn-like appearance. Seedlings from infected seeds wilt and die. Infected bolls develop small, round, watery spots that rapidly expand, collapse, eventually forming reddish rims with a pink center (Fig. 6). In dry weather, the diseased areas may become grayish in color (Watkins, 1981).

Figure 6. Disease symptom in cotton leaf and boll

Disease is also dispersed to other places by rain, avalanche drops or by winds. This disease is seen in all cotton-growing countries (Anonymous, 2021). They cause significant damage to cotton according to countries and years. It is important that the seed is contaminated in the spread and development of the disease. Therefore, seed dressing is necessary.

e) Cotton Bacterial Blight Disease (*Xanthomonas campestris* pv. *malvacearum*)

The causative agent of this disease is gram-negative bacteria. The average temperature demand is 25-30°C and the rate of damage may be high in places that require and have humidity. It is a bacterium that is highly resistant to environmental conditions such as drought and heat. Especially in areas with summer rains, the pathogen passes to the boll and from there to the cotton seeds. The disease causes significant damage, especially in the rainy May-June months. It spends the winter in contaminated cotton seeds and plant residues in the soil. If the boll that are not opened due to disease are too small, casting occurs. In adults, normal development does not occur, the yield and quality of cotton decreases. It is not used as a seed.

Bacterial blight disease causes symptoms on the leaves, petioles, bolls and combs of the plant and appears as dark green and brown spots (Figure 7). The first signs of spotting appear as a light green, round oil spot on the cotyledon leaves of the plant. With the warming of the weather, the spots dry up and take the form of a whitish crust. If the climatic conditions are suitable for the disease, the spots pass on the true leaves, stems and bolls (Zachowski et al., 1989).

Figure 7. Leaf and boll sign of Cotton Bacterial Blight Disease

Cultural measures are important in its control. Using certified clean seeds, destroying plant residues in the field, cultivating in well-drained soils, avoiding excessive irrigation and rotation in contaminated fields are important cultural methods (Anonymous, 2017). Chemical control is done in the form of pre-sowing seed dressing as a preservative.

f) Cotton Leaf Curl Virus

Cotton leafroll viruses are a series of plant pathogenic virus species belonging to the Geminiviridae family. It is the main disease of cotton in some countries of the world, in Asia and Africa. Infected cotton leaves curl upwards and leaf-like formations form underneath with vein thickening (Fig. 8).

Figure 8. Symptoms caused by the virus on cotton leaf

The virus that causes the disease is carried by the whitefly (Bemisia tabaci) and infects healthy plants. It is very difficult to control because of the multiple viral strains of the virus or the multiplicity of species that carry it. In addition, the problem is further complicated by the fact that this virus complex has a higher recombination rate (Brown, 1992; Rahman et al., 2017).

The first thing to do in the fight against this virus is to control the whitefly, which is its carrier and spread. In addition, it is important to use resistant varieties (Humza et al., 2016).

2. Conclusion and Discussion

In this review study, information about 4 fungal, 1 bacterial and 1 viral diseases related to important diseases seen in cotton is given. In addition, cotton is present in diseases such as Cotton Cercosporella Spot

Disease (*Mycospharella areola*), Cotton Ascochyta Blight Disease (*Ascochyta gossypii*), Coal Rot (*Macrophomina phaseolina*). These diseases can be seen as important diseases in different countries according to years. The most important diseases in cotton in Turkey are seedling root rot caused by various pathogens in the early stages and Verticillium wilt in advanced stages. The fungi that cause these diseases are soil pathogens. Their control are difficult. Because they can survive in the soil for years. It is a good practice to use rotations to minimize the effect of cotton diseases on yield. In particular, the alternation with the cereal group and the maize plant will minimize the inoculum resources on the soil or plant. In Turkey and especially in the Southeastern Anatolia Region, cotton is irrigated intensively. Therefore, the moisture rate increases both in the soil and on the plant surfaces. Diseases are more severe at high humidity. As a result, cultural measures are important in the control against diseases in cotton.

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CHAPTER 10

COMMON WEEDS IN COTTON FIELDS

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INTRODUCTION

Cotton is an industrial crop, grown mainly for the textile in tropical, sub-tropical regions, and temperate climates (Karademir et al., 2020; Yasar and Karademir, 2021). Cotton, which can be easily converted into cash, contributes positively to the economy of the regions, and countries where it is grown with its plant, wide usage areas, added value and employment opportunities (Rehman et al., 2015; Cecen and Karademir, 2021). So this crop is an important agricultural product in countries with favorable climates such as India, China, the USA, Pakistan, Brazil, Uzbekistan, Australia, and Turkey, also it is known popular crop in Turkey (Tarhan and Karademir, 2019; Tokel, 2021). In cotton production, variety, climate, soil, water, and agricultural processes can be counted among the important factors affecting yield and quality (Kolay et al., 2016; Cevheri, 2021). For good cotton production, even if the variety, fertilization, and irrigation are done appropriately, yield losses will be inevitable unless effective management is applied against pathogens, insects, and weeds (El-Wakeil and Abdallah, 2012; Pala and Mennan, 2019a).

Weeds, which are among the unwanted plants, reduce the yield of cotton by competing with cotton for water, nutrients, light, and space, especially in the early period of cotton from germination to the first two months (Pala and Mennan, 2018). In addition, weeds cause a decrease in fiber quality by hosting other harmful organisms and mixing with the product during the harvest period (Pala and Mennan, 2020). Different types of weeds with grass and broadleaf can be a problem in cotton fields (Pala and Mennan, 2018). Some grass weeds are common in cotton fields such as bermudagrass, nutsedge, crabgrass, barnyard grass, and johnsongrass (Pala and Mennan, 2019b; Ferrells et al., 2020). The species that are more of a problem than grass and are common in cotton fields are pigweed, gooseberry, goosefoot, nightshade, and cocklebur. In cotton fields, cultural measures can be taken against weeds, physical-mechanical, chemical, or alternative methods can be applied (Tariq et al., 2020, UCIPM, 2021). Today, the chemical method is the most preferred method in weed control in cotton because it is practical and economical (Pala and Mennan, 2018; Dogan et al., 2021). In areas where chemical control is insufficient, 2 hand and tractor hoes are also made together with chemical control (Pala and Mennan, 2018). However, the unconscious use of chemicals and excessive tillage bring ecological problems such as groundwater pollution and erosion (Karayel and Sarauskis, 2019). Knowing the weed species that are a problem in cotton fields and developing an appropriate weed control strategy is inevitable for sustainable cotton production (Lakara et al., 2019). The first step in weed control is the identification of weeds (Mishra and Gautam, 2021). Identified weeds should be recorded and their records should be kept (Holm et al., 1977). The characteristics of the weeds found should be determined with the help of weed science books, web pages or expert personnel (Westwood et al., 2018). Since the local names of the detected weeds may differ, it is important to learn their Latin. If necessary, digital, or classical herbariums should be made (Wu et al., 2021). It is important to determine the biology, such as the life cycle and reproduction of the weeds, and the ecology, such as their spread and adaptation, in order to develop suitable control methods for the weeds that are a problem.

Weeds that are a problem in cotton fields are divided into two classes as grass (monocotyledonous) and dicotyledonous (dicotyledonous) (Torres-Sánchez et al., 2021). Among the grass weeds, the families Poaceae and Cyperaceae come to the fore Pala and Mennan, 2018). It is seen that broadleaf weed families are Asteraceae, Chenopodiaceae, Convolvulaceae, Euphorbiaceae, Fabaceae, Malvaceae, Portulacaceae, Solanaceae, Xantomonaceae, Zygophllaceae (Pala and Mennan, 2018). The types of weeds that are a problem in cotton fields are as follows. The main differences between grass and broadleaf weeds are the first point of focus for the development of a control strategy. Afterward, weed control methods should be applied according to the families. However, the most important and detailed approach is to control weeds on a species-based basis.

GRASS AND BROADLEAF “WEEDS”

Cotton fields have both grass and broadleaf (more trouble) weeds (Pala and Mennan, 2017). Weeds in cotton fields complicate the maintenance of cotton, reduce irrigation efficiency, secrete allelopathic chemicals and prevent the cotton plant from coming in, prevent the cotton plant from getting water, mineral matter, and light by growing fast, reduce its yield by competing with the product, and impair the fiber quality by mixing with the harvested crop (Lakara et al., 2019).

Weeds are generally competitive, sometimes releasing allelopathic chemicals that inhibit the development of cotton (Sathishkumar et al., 2020). The negative effects of cotton are related to the type of weeds, the coverage area, their density, and the duration of competition between cotton and weed. Some weed species can be more competitive than cotton in terms of reaching the light by grading more, some developing more root systems and reaching water and mineral substances more easily, while others can be more competitive than cotton with their secretions of allelopathic substances.

Figure 1. Common weeds in cotton (Pala and Mennan, 2019b).

These species, which have settled in cotton fields, can germinate together with cotton and suppress the development of cotton seedlings, especially in the first development period of cotton especially after emergence from 1-2 weeks to 11-12 weeks (Bukun, 2004). The halt in the development of cotton during this period may adversely affect its future potential (Raimondi et al., 2017). It is important that weeds can be identified and controlled with appropriate methods during this critical period, which is the early growth period in cotton during and after the germination period. Although weed control in cotton is concentrated in this period, pre-planting or pre-emergence herbicide use is the most preferred method in Turkey. Control of weeds such as pigweed and johnsongrass, which are denser and more competitive in cotton fields, should be given more importance than the less common and problematic prickly root weeds. Weeds also cause various direct and indirect effects by being host to diseases and insects. Common weeds in cotton fields are listed below.

Table 1. Common weeds in cotton fields

	Common Name	**Scientific Name**
1	Bermuda grass	*Cynodon dactylon* (L.) Pers.
2	Nutsedge	*Cyperus rotundus* L.
3	Crabgrass	*Digitaria sanguinalis* (L.) Scop.
4	Barnyard grass	*Echinochloa crus-galli* (L.) P.Beauv.
5	Johnson grass	*Sorghum halepense* (L.) Pers.
6	Pigweed	*Amaranthus palmeri* S.Wats.
7	Gooseberry	*Physalis angulata* L.
8	Goosefoot	*Chenopodium album* L.
9	Nightshade	*Solanum nigrum* L.
10	Cocklebur	*Xanthium strumarium* L.

(Smith et al., 2000; Pala and Mennan, 2019b).

Of course, different weeds than the above 10 weeds can be a problem in different regions. However, it should not be forgotten that since the cotton plant is broadleaf, the management of broadleaf weeds is also difficult.

1. Bermuda grass [*Cynodon dactylon* (L.) Pers.]

Figure 2. Bermudagrass (UM-Extension, 2021)

Cynodon is a genus of plants in the grass (Poaceae) family, it is a large and nearly ubiquitous family of monocotyledonous flowering plants known as grasses (Wu et al., 2011). It includes the cereal grasses, bamboos, and the grasses of natural grassland and species cultivated in lawns and pastures.

The latter are commonly referred to collectively as grass (Dunster, 2017). The genus as a whole as well as its species is known commonly as Bermuda grass and scientific *Cynodon dactylon* (Farsani et al, 2012).

This species, which is a problem in agricultural production areas and non-agricultural areas, is used in chemical methods because it cannot be controlled only by mechanical methods because it has rhizomes. In fact, methods in which mechanical and chemical control are integrated give more successful results. With the ineffectiveness of herbicides used against this weed, complaints are increasing every year. Therefore, solarization, mulching, thermal and robotic control methods should be developed for bermudagrass.

2. Nutsedge (*Cyperus rotundus* L.)

Figure 3. Nutsedge (RoundUp, 2021)

Cyperus is a genus of plants in the sedges (Cyperaceae) family (Carter, 2005). The Cyperaceae are a family of graminoid (grass-like), monocotyledonous flowering plants known as sedges (Larridon et al., 2021). They are annual or perennial plants, mostly aquatic and growing in still or slow-moving water up to 0.5 m deep (van-Vliet, 2021). *Cyperus rotundus* and *Cyperus esculentus* species are a problem in agricultural production areas in tropical, subtropical, and temperate regions. Nutsedge is perennial grass-like lawn grass. Although it is sometimes referred to as a nutgrass, it is not technically grass. This is a reed. Its leaves are herbaceous and yellow-green, and the spiny flower or seed head is yellow.

Nutsedge grass can be distinguished from good grasses by its V-shaped stem. It is a difficult weed to control as its tubes can grow 8-14 inches deep in the soil. Since these species are tuberous, they are very difficult to control by mechanical control. On the contrary, mechanical methods cause the proliferation and dispersal of these weeds. When nutsedge species are not controlled, they can cover the entire area and threaten agricultural production. The control of these species is based on herbicides. However, integrated weed management can ensure successful control of this weed.

3. Crabgrass [*Digitaria sanguinalis* (L.) Scop.]

Figure 4. Crabgrass (RoundUp, 2021)

Digitaria is a genus of plants in the grass (Poaceae) family native to tropical and warm temperate regions but can occur in tropical, subtropical, and cooler temperate regions as well (Boonsuk et al., 2016). Common names include crabgrass, finger-grass, and fonio. They are slender monocotyledonous annual and perennial lawn, pasture, and forage plants; some are often considered lawn pests. Digitus is the Latin word for "finger", and they are distinguished by the long, finger-like inflorescences they produce (Bajo, 2017). Although it contains more than 300 species, crabgrass (*Digitaria sanguinalis*) is the prominent species. These weeds are seen in summer field crops, vegetables, vineyards, and fruit fields. Crabgrass species can reduce the yield of the product, disrupt the landscape management in grass areas. In the control of these species, herbicides are preferred first. However, mechanical and biological alternative methods can be used where necessary.

4. Barnyard grass [*Echinochloa crus-galli* (L.) P.Beauv.]

Figure 5. Barnyard grass (RoundUp, 2021)

Echinochloa is a very widespread genus of plants in the grass family (Poaceae) (Hruševar et al., 2015). Some of the species are known by the common names barnyard grass [*Echinochloa crus-galli* (L.) Beauv.] and *Echinochloa colona* (L.) Link is another common species (Costea et al., 2002). This weed species, which likes water very much, is notorious as a weed in rice, but it is seen in other agricultural areas, too.

Barnyard grass is common to other nutrients, especially nitrogen. It is important to control this weed, propagated by seed, at an early stage. This weed is controlled with herbicides. Resistance mechanism has developed as a result of excessive use of herbicides. Alternative methods should be integrated into chemical methods for the management of the durability problem.

5. Johnson grass [*Sorghum halepense* (L.) Pers.]

Figure 6. Johnson grass (RoundUp, 2021)

Sorghum is a genus of about 25 species of flowering plants in the grass family (Poaceae) (Bhattacharya, 2011). Native to Asia and North Africa, johnson grass (*Sorghum halepense*) is considered a weed that reproduces by rhizomes and seeds, although it has been used for forage and to stop erosion, it is undesirable in fields (Price et al., 2005; Paterson et al., 2020). Sorghum halepense comes to the fore as the most important grass weed, which is a problem in industrial plants, especially cotton (Uludag et al., 2007; Gunes et al., 2008).

In addition to the high competitiveness of this species, they are also hosting diseases and insects. It causes significant yields in agricultural products. It is seen as a problem in vegetable, vineyard, and fruit fields as well as field crops. Johnsongrass is a large perennial rhizome that can reach 2-3 m in length and produce thousands of seeds per year. Since it is tall, it can be easily seen among cotton plants. Hand or tractor hoe helps to reproduce and spread weeds instead of suppressing them. Therefore, herbicides are generally used to control this weed. Herbicide dependence has resulted in the formation of herbicide resistance. There is a need to identify areas where Sorghum halepense is concentrated and to try to improve these areas using modern methods.

6. Pigweed [*Amaranthus palmeri* S.Wats.]

Figure 7. Pigweed (UC Weed Science, 2021)

Amaranthus is a genus of pigweed (Amaranthaceae) family (Assad et al., 2017). Most of the *Amaranth* species are summer annual weeds and are commonly referred to as pigweeds. *A. palmeri, A. retroflexus, A. annus, A. hybridus, A. spinosus* and *A. tuberculatus* belonging to the *Amaranthus* genus, which are adapted to different climate and soil structures, cause yield and quality loss in field crops such as cotton and corn, as well as in vegetable and fruit gardens. are some important species. Appropriate control tactics of pigweeds can be developed when the biological characteristics and ecological demands of these species are known. Limited dormancy, rapid growth, and high seed set. The control of pigweed (amaranth) species is usually carried out depending on herbicides and this situation brings with it the problem of resistance (Culpepper et al., 2010). Integrated foreign control strategies including good agricultural practices need to be developed for sustainable pigweed management.

7. Wild gooseberry (*Physalis angulata* L.)

Figure 8. Wild gooseberry (Weeds of Australia, 2021)

Physalis is a genus of the nightshade family (Solanaceae), which grow in warm temperate and subtropical regions of the world. Many gooseberry species are called gooseberry or goosecherry (Sullivan, 2004).

Wild gooseberries are spread in agricultural lands. These plants range from annual and perennial herbs to vines, lianas, epiphytes, shrubs, and trees, and include a number of agricultural crops, medicinal plants, spices, weeds, and ornamentals. Shortly, this species is a weed of cropland, gardens, and plantations. It is also a host to many viruses of cotton, clover, tobacco, potato, pepper, and okra. Among these species, *Physalis angulata*, which is an annual summer plant, is seen as a common species (Mahklouf, 2019). The seed setting and spreading ability of gooseberries is high. In recent years, it has become an important problem, especially in cotton. It is found in other irrigated agricultural areas other than cotton. Due to the ineffectiveness of herbicides in cotton against such weeds, the frequency and intensity of their occurrence in cotton fields increase every year and the problem grows. There is a need to develop applications in which hand hoe, tractor hoe, and other mechanical techniques are integrated for this species, where chemical control is insufficient.

8. Goosefoot (*Chenopodium album* L.)

Figure 9. Goosefoot (Josh Fecteau, 2021)

Chenopodium is a genus of numerous species of perennial or annual herbaceous flowering plants known as goosefoots (Chenopodiaceae) family, which occur almost anywhere in the world (Kühn et al., 1993). *Chenopodium* species have spread all over the world with the agricultural activity of people and settled in agricultural production areas and has become an important problem especially in temperate climates (Grozeva, 2007). Goosefoot is the most problematic species. The management of this weed is usually done with herbicides. This accelerated the development of herbicide resistance of goosefoots. Preventive measures should be taken against this weed, cultural processes should be done, physical-mechanical applications and biological-biotechnical alternative control methods should be integrated into herbicide applications.

9. Blackberry nightshade (*Solanum nigrum* L.)

Figure 10. Nightshade (Brisbane City Council Weed Identification Tool, 2021)

Solanum is a large and diverse genus of flowering plants known as the nightshade (Solanaceae) family (Jagatheeswari, 2014), which includes three food crops of high economic importance: the potato, the tomato, and the eggplant (aubergine, brinjal). It also contains nightshades and horse nettles, as well as numerous plants cultivated for their ornamental flowers and fruit (Ogg et al., 1981; Shah, 2012).

The family has a worldwide distribution, being present on all continents except Antarctica. *Solanum nigrum* appears to be the most important species. *Solanum* species cause a significant decrease in the yield and quality of the product. For this reason, the control of these weeds in industrial plants and vegetable fields, especially cotton, is inevitable. Knowing the biology and life cycle of this weed is important for determining the control method. It is known that the frequency and density of summer weed have increased in cotton fields in recent years. Control of blackberry nightshade is based on herbicides. However, in recent years, biotypes resistant to herbicides have begun to be registered. In order to achieve the desired success in weed control, it is necessary to develop alternative methods such as mulching with herbicides, alternation, smart cultivators, thermal methods, and allelopathy.

10. Cocklebur (*Xanthium strumarium* L.)

Figure 11. Cocklebur (Carbon County Weed & Pest, 2021)

Cocklebur genus of aster (Asteraceae) family, commonly referred to as the aster, daisy, composite, or sunflower family (Rahman et al., 2008; Kurdyukova and Tyschuk, 2017).

Among these species, rough cockleburs (Xanthium strumarium) and spiny cockleburs (Xanthium spinosum) are the most important species. It is the scourge of cotton fields. In addition to affecting cotton yield, it also causes a decrease in fiber quality by mixing with cotton mass during harvest. In addition to cotton fields, it is a problem in other field crops, vegetables, vineyards, and fruit fields. Chemical control in cotton fields is difficult. It is known that limited licensed herbicides (Trifloxysulfuron sodium and Pyrithiobac-sodium) are not effective enough. Hand hoe and tractor hoe are recommended as well as herbicides since it is known that chemical methods of control are insufficient. New herbicides for the control of this weed need to be developed and licensed.

CONCLUSION

The first step in sustainable integrated weed management in cotton fields is the identification of problem weeds. It can be said that there are weeds specialized in production areas in cotton as in other cultivated plants. However, factors such as climate change and applied agricultural processes can sometimes cause new species to be transmitted and settled. For this reason, it is important to keep product-based specialized weed records. While johnsongrass and bermudagrass are common as grass weeds in cotton fields, the covering areas and densities of cocklebur, nightshade, gooseberry (groundcherry), and pigweed (amaranth) species are high as broadleaf. However, it is known that there are problems in different weeds such as nutsedge, purslane, dyer's croton, puncture vine, Syrian mesquite, European heliotrope in some areas. Identifying weeds that are a problem in cotton and making their digital catalogs will contribute to making the diagnosis more practical.

Pre-sowing, pre-emergence, and post-emergence herbicides should be preferred for weed control in cotton fields, respectively. Pre-sowing spraying should be done 3 weeks before if possible. Post-emergence spraying should be completed within 3 days after planting, if possible. Post-emergence herbicides can be applied within 3 weeks post-emergence. Since there is less weed competition in the planting, germination, and first development period of cotton, care should be taken to ensure that the field is free of weeds during these periods. It is a fact that the use of herbicides improves the resistance mechanism in weeds. Durability has become an important problem in Amaranthus species. Soil herbicides should be preferred for weed control in areas with resistance problems to other Glyphosate herbicides. Consideration should be given to crop rotation and herbicide rotation to increase yield and maintain quality. It is important for the management of weed species and density to pay attention to the following issues related to weeds that are a problem in cotton fields.

- It is to keep records of weeds in the cotton field. Thus, it is possible to predict which species are more intense or what new threats may be, and the appropriate mechanical or chemical control method can be determined.
- It is important to control weeds during the first 6-9 weeks. They may not affect the yield in the next period, but it should not be forgotten that weeds can reduce the quality and production should be continued in a clean field.
- If there are weeds that are a problem in the cotton, the applied methods should be reviewed, and weaknesses and disruptions should be determined. Alternative methods should be tried.
- Certified, delinted, highly competitive, tolerant seeds should be used.

- The ways of transmission of weeds to the field should be determined, for example, if irrigation water or non-disinfected agricultural equipment causes contamination, preventive measures should be taken.
- Weekly weed controls should be carried out in the cotton field, starting 1 month before planting and until one month after harvest, and weeds that may cause spreading and covering area problems should be tried to be controlled.
- If possible, cotton should be alternated with weeds of the Poaceae, such as wheat or corn.
- Photosynthesis at PS II inhibitor fluometuron, Very Long-Chain Fatty Acid Synthesis inhibitor Metolachlor, ALS inhibitor Bispyribac, Trifloxysulfuron, herbicides with a different mechanism of action can be used instead of herbicides such as microtubule inhibitor dinitroaniline group pendimethalin, benfluralin, and trifluralin used in cotton before planting or exit. Repeated overuse of glyphosate-type products should be avoided.
- Herbicides should be used according to the label information, and experts should be consulted when in doubt. Otherwise, wrong applications may be ineffective against weeds or cause damage to the product. Especially in herbicide mixtures, a preliminary jar test should be done if possible. Herbicides should not be used in unlicensed products and attention should be paid to which weeds they affect. If necessary, a spreading adhesive or safener should be used. It should not be ignored that there may be antagonism in

herbicide mixtures. Herbicides should be applied with suitable sprayers and a t-jet (fan) nozzle.

- Local applications can be made to areas where weeds are dense in the field. For this reason, the places where the weeds are dense and the changes in the fields should be monitored.
- In order to prevent contamination from the edges of the field, weeds at the edge of the field should also be controlled. If necessary, trenches should be dug or fenced.
- The seed bank in the soil must be managed. Weeds should not be allowed to set and shed seeds again. Pre-harvest herbicide use can reduce the seed bank.
- Interventions can be made for species that exceed the economic threshold. In general, wear control studies should be started for 10 pieces of coating or 10% of coating per m^2.
- The right fighting method should be applied at the right time.
- Resistance to herbicides in weeds has become an important problem for agricultural products in Turkey as well as all over the world. The incidence of herbicide-resistant weeds is increasing faster than predicted The rapid development of weed resistance to current herbicides is a concern for crop production. For this reason, the identification and management of resistant weeds is important for sustainable agricultural production.
- The use of the same herbicide for many years suppresses some weeds and provides the opportunity to spread to others.

- It is known that weeds have a high ability to multiply, disperse and settle. No single control method should be relied upon for the weed threat. Integrated weed management should be implemented.

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CHAPTER 11

COTTON IN TURKEY: A REVIEW

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INTRODUCTION

Cotton is an important multipurpose cash crop in many countries which produces lint, oil, seed meal and hulls. Cotton is a suitable fiber with its price, quality and comfort for many textile products. Turkey is an important cotton producing country which is cropping non-GMO (genetically modified organisms) cotton. Sustainable and profitable production of the crop is essential for the growth and development of the cotton industry and textile sector.

This review is prepared for a better understanding of history, growth, production and marketing of cotton in Turkey in a short presentation with main aspects.

Cotton (*Gossypium hirsutum* L.) is a strategic crop grown worldwide in 88 different countries. This industrial crop has high economic value with direct and indirect utilisation in many sectors (Karli et al., 2017). Cotton is mainly a raw material for textile industry which has an important place in agriculture and economy of Turkey. Cotton product is strategic for the economy of the country due to provided income and employment (Bashimov, 2015). Cotton provides nearly two million employments in textile and agriculture sectors. Support programs and premium payments for cotton production and cotton farmers are crucial and critical which is affecting market prices (Solakoglu et al., 2013). Turkey has an important contribution to global textile industry with cotton production, textile and cloth manufacturing capacity (Günaydin et al., 2019).

Cotton cultivation zones are between 32 N–36 N in the world under warm climate. Turkey is on the north board of that cotton cultivation zone. Cotton cultivation is in four regions (Aegean, Çukurova, Southeastern Anatolia and Antalya) in Turkey (Günaydin et al., 2019). Cooperatives has prominant role in Turkey compared to United States Cooperatives and are in "semi-governmental" structure in Turkey. This organizational structure is effecting pricing and utilization of cotton lint in the country. Cooperatives have a significant control on farmer prices because cooperatives buy the main portion of the produced cotton in farms. Cooperatives deals in four types of cotton products: 1) gin (seed) cotton, 2) lint, 3) yarn, 4) waste. Three cooperatives are active in Turkey located in major crop production regions. As an example, Aegean Region (Western Anatolia) cooperative Tariş is dates back to 1913 and composed of 54 cotton grower cooperatives (65,000 cotton growers). Tariş markets cotton lint domestically or internationally with the aim to meet lint requirements of domestic market. Tariş is also a cooperative for figs, raisens, olives and olive oil. Cotton is purchased by Turkish government (by Ministry of Trade and Industry) through Tariş or by own account of Tariş and prices set monthly by government. If market prices are lower than government set price, anyone can sell their cotton to Tariş. Operational profits and losses accrue to the government. Tariş cotton purchase prices are based on quality scale (related to color and gin turnout) of the cooperative (Hudson, 2010).

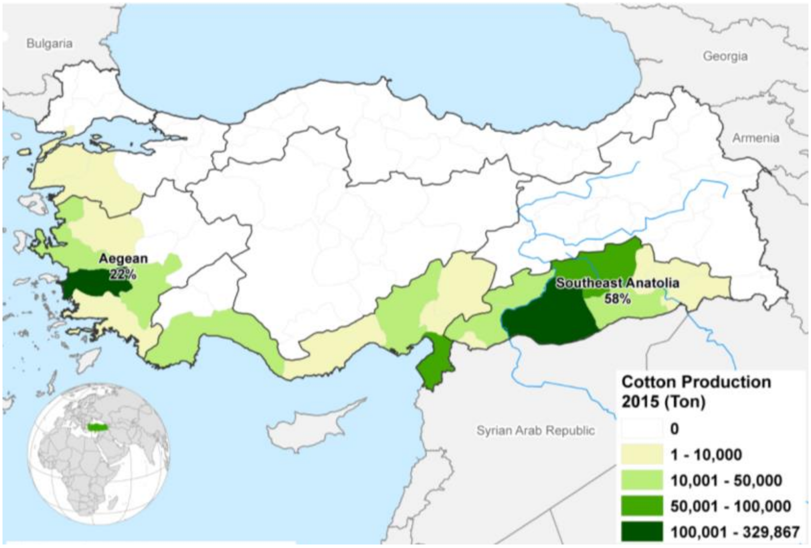

Fig. 1. Major cotton cultivation zones in Turkey

Historically, Western Anatolia was an important zone as cotton and textile producer until the "Industrial Revolution" in England in the beginning of 19th century. After the revolution, cotton production in the Western Anatolia region was reduced and started to produce mostly local requirements. But the "American Civil War" during 1860-1870 resulted with raw material supply crisis for English cotton textile industry. In the beginning of the war, English textile industry was supplying 80% of its raw cotton from US. After war stopped the raw material transport, Manchester Cotton Supply Association started to organize agricultural training and machinery support to cotton producers in many countries and regions including Western Anatolia of Turkey to increase cotton production. Dense cotton production started in the region due to high cotton prices on market after that progress. Total 6 thousand bales of cotton production in 1861 increased 10 times to 60 thousands in two years in this region where most were exported to England. Ottoman Empire brought cotton seed from Egypt in the first stage and then from USA and distributed to cotton farmers. Exemptions of some taxes were also received by cotton producers (tax ratio was decreased from 8% to 2%). But export was mainly raw materials; not finished products (Damlibağ, 2011).

Statistics for Cotton Production in Turkey

As of 2020, cotton cultivation is carried out in 23 provinces in Turkey (Table 1).

Table 1. Seed cotton production in 2018, 2019 and 2020 years in 15 provinces with a cultivation area of more than 1.000 ha in Turkey (tons) (TUIK, 2021)

No	Provinces	Seed cotton production (tons)		
		2018	**2019**	**2020**
1	Şanlıurfa	1.027.625	813.258	567.251
2	Aydın	279.377	246.382	271.627
3	Diyarbakır	244.497	233.707	217.642
4	Hatay	263.901	219.581	174.843
5	İzmir	156.077	141.920	148.769
6	Adana	206.143	205.670	122.994
7	Manisa	61.192	54.918	55.580
8	Denizli	42.517	38.200	49.986
9	Mardin	56.916	65.365	39.747
10	Adıyaman	40.635	35.073	27.021
11	Antalya	24.832	20.224	24.529
12	Mersin	31.117	26.254	19.992
13	Gaziantep	38.525	27.972	16.320
14	Şırnak	35.445	32.794	13.863
15	Kahramanmaraş	44.931	23.692	13.014
	TOTAL	**2.177.620**	**1.860.518**	**1.503.126**

The seed cotton production amounts, cultivation areas and yields of 15 of these provinces, which have a cultivation area of more than 1.000 ha, in years 2018, 2019 and 2020 (TUIK, 2021) are given in Tables 1, 2 and 3.

Total seed cotton production in Turkey in 2018, 2019 and 2020 was 2,2 million ha, 1,9 million ha and 1,5 million ha, respectively. There was a significant decrease from 2018 to 2019 (15% drop) and from 2019 to 2020 (19% drop). Drop in the biggest cotton producer province Şanlıurfa was 21% in 2019 and 30% in 2020 compared to previous years (Table 1).

Table 2. Cotton acreages in 2018, 2019 and 2020 years in 15 provinces with a cultivation area of more than 1.000 ha in Turkey (ha) (TUIK, 2021)

No	Provinces	Seed cotton production (ha)		
		2018	**2019**	**2020**
1	Şanlıurfa	231.430	208.792	128.747
2	Aydın	53.689	46.466	54.467
3	Diyarbakır	48.037	47.687	40.383
4	Hatay	48.539	45.627	33.155
5	İzmir	27.743	25.291	27.729
6	Adana	36.254	37.467	22.991
7	Manisa	10.263	9.036	9.153
8	Denizli	8.444	7.202	9.540
9	Mardin	10.782	13.017	7.442
10	Adıyaman	8.006	7.230	5.537
11	Antalya	4.975	4.031	4.837
12	Mersin	5.222	4.824	4.275
13	Gaziantep	7.428	5.725	3.486
14	Şırnak	5.893	5.534	2.739
15	Kahramanmaraş	8.507	6.769	2.538
	TOTAL	517.232	476.715	359.038

Drop in total acreages in Turkey in 2019 compared to 2018 was 8%. Highest ratio of drop in acreages was in Gaziantep (23%), Kahramanmaraş (20%), Antalya (19%) and Denizli (15%) in 2019 compared to 2018 (Table 2). Instead, there was a 21% increase between these years in Mardin for cotton acreages (Table 2).

Decrease in total acreages in Turkey in 2020 compared to 2019 was 25%. Highest ratio of decrease in acreages was in Kahramanmaraş (63%), Şırnak (53%), Mardin (43%) Gaziantep (39%), Adana (39%), Şanlıurfa (38%), Hatay (27%), in 2019 compared to 2018 (Table 2). Instead, there was a 32%, 20% and 17 increase between these years in Denizli, Antalya and Aydın for cotton acreages (Table 2).

Table 3. Seed cotton yield in 2018, 2019 and 2020 years in 15 provinces with a cultivation area of more than 1.000 ha in Turkey (t/ha) (TUIK, 2021)

No	Provinces	Yields (t/ha)		
		2018	**2019**	**2020**
1	Şanlıurfa	4.4	3.9	4.4
2	Aydın	5.2	5.3	5.0
3	Diyarbakır	5.1	4.9	5.4
4	Hatay	5.4	4.8	5.3
5	İzmir	5.6	5.6	5.4
6	Adana	5.7	5.5	5.4
7	Manisa	6.0	6.1	6.1
8	Denizli	5.0	5.3	5.2
9	Mardin	5.3	5.0	5.3
10	Adıyaman	5.1	4.9	4.9
11	Antalya	5.0	5.0	5.1
12	Mersin	6.0	5.4	4.7
13	Gaziantep	5.2	4.9	4.7
14	Şırnak	6.0	6.0	5.1
15	Kahramanmaraş	5.3	3.5	5.1

Manisa and Şanlıurfa provinces have the highest and lowest cotton yields respectively, in 2018, 2019 and 2020 years (Table 3).

Major cotton supplier of Turkey are United States, Brazil, Greece and Mexico. Turkey's cotton exports are mainly to China, Pakistan and Bangladesh. Turkey purchase cotton yarn mostly from Turkmenistan, Uzbekistan, India, Azerbaijan and Pakistan. The main destinations for Turkish cotton yarns are Italy, Portugal, Egypt, Pakistan, Bangladesh, Germany and Spain. Major fabric suppliers of Turkey are Pakistan, Turkmenistan, China and Egypt. Main buyers of the Turkish cotton fabric are Italy, Pakistan, Belgium, Spain, France and Portugal (USDA FAS GAIN 2021a). International trade data for cotton products of Turkey in 2019 are given in Table 3 (FAOSTAT, 2021).

Table 3. International trade data for cotton products of Turkey in 2019 (FAOSTAT, 2021)

Item	Import Quantity (tonnes)	Import Value (1000 US$)	Export Quantity (tonnes)	Export Value (1000 US$)
Cotton lint	946.000	1.585.807	131.371	229.206
Cotton waste	15.300	11.400	62.880	63.796
Cotton linter	561	91	28.588	7.462
Cake, cottonseed	34.700	5.310	18.560	3.197
Oil, cottonseed	47	33	9.986	8.121
Cotton, carded, combed	14	100	4.869	4.167
Cottonseed	103	203	2.986	7.394

In 2016, Turkish Government imposed 3% anti-dumping duty on U.S. cotton imports for five years and this duty is removed on 16 April, 2021 (USDA-FAS-GAIN, 2021b).

Cotton Growth Season 2021 in Turkey

Cotton is planted between mid-March and mid-May in Turkey. Its harvest starts from mid-August till end-November. There are three main areas for cotton plantation nationwide: 1) Southeastern Anatolia region 2) Aegean region, 3) Çukurova region. Yields are increasing every year due to modern equipment usage and shift of croppings to irrigatable larger fields at economic scales. Increased use of certified quality seeds (about 95% of total used seeds) also has a strong addition to the yield improvements.

Drought conditions affected cotton production in western Anatolia (Aegean region), significantly, especially in Söke and surrounding region in 2021 growth season. Normally cotton gets irrigated three times during summer in this region, but dry weather in 2021 sharply reduced water in reservoirs, which resulted with miss of third irrigation. This is expected to decrease yields in this area compared to normal seasons.

2021 was a good year for cotton production in the GAP region (Southeast of Turkey). Urfa area was well irrigated by GAP irrigation systems and countrywide drought did not effected this region. The heat and wind conditions were appropirate, too. Also absence of problems related to special pests helped cotton farmers to use less pesticides compared to previous years which also improved profitability of cotton cultivation in this region (USDA-FAS-GAIN 2021a). Cotton production increases in Turkey is dependent on the progresses in GAP Project. “Harran Plain” of Urfa province is the heart of cotton acreages in the GAP region. Conflict on Syrian border is delaying the progress of the Project and cotton acreage increases (USDA-FAS-OGA, 2015).

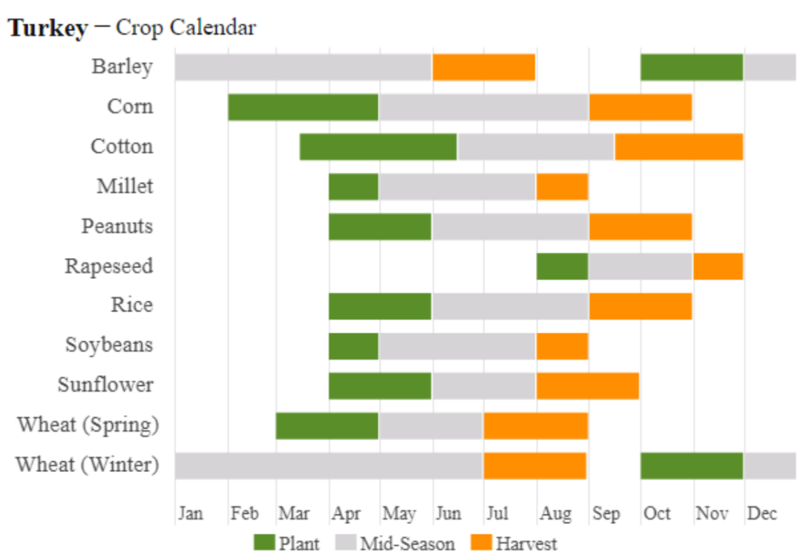

Fig. 2. Cotton crop calender in comparison with other major crops in Turkey (USDA-FAS-IPAD, 2021).

Input use, cost, profitability and productivity analyzes of cotton production in Manisa province by using questionnaire method were analysed in a research by Ugurlu, (2020). Data was obtained from cotton growers during 2018 growth season. Seeded cotton yield were varied between 4,3-6,9 t/ha (average 5,7 t/ha). Highest share of production cost of farms was the labor costs (36%) and input costs (19%). Share of variable costs in total cost was 60%. Gross production value was 26.900 TL/ha. Production cost of seeded cotton was 2,2 TL/kg (Ugurlu, 2020).

Another survey was conducted in Diyarbakır, Mardin and Şanlıurfa province (GAP region) with 233 cotton producers between years 2011 and 2012 by Bayhan et al., (2015). Results revealed that 52% and %35 of the growers receive advices on plant protection from pesticide dealers and technical experts, respectively. 76% of the growers use pesticide in accordance to label instructions during treatments (Bayhan et al., 2015).

CONCLUSIONS

Drought, pests, governmental supports, cooperatives, international prices, border conflicts are determiners of cotton acreages, yields and production amounts in Turkey.

South East Anatolia region has huge potential to improve cotton production and reduce cotton import to feed well develeoped textile sector of Turkey.

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CHAPTER 12

COTTON EXPORT AND CULTIVATION STRUCTURE OF CHINA

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INTRODUCTION

Cotton is the major fiber crop worldwide for textile industries. The USA has a pivotal role in the global cotton market as an important producer and exporter of cotton but world cotton price is determined in China. India, Brazil, Pakistan, Uzbekistan and Turkey are other countries dominant in cotton market. China, which is dominated by genetically modifed varietal utilisation in cultivation has a leading role in global cotton market and has a different structure for cotton cultivation. Here in this review, reader may find infos on the characteristics of China after presentation of current global cotton market.

Cotton (*Gossypium hirsutum* L.) is a major crop worldwide which supplies fibers to textile industries across the world (Liu et al., 2010). Cotton is a leading cash crop, and genetic improvement for higher fiber yield and quality are primary objectives of breeding programs (Zhang et al., 2013). Today, world cotton price is the price at ports of China. Trading firms store cotton as international commodity in large volumes in China. The Zhengzhou Commodity Exchange No:1 Cotton futures contracts are followed by global traders for market information (MacDonald et al., 2015). China generated revenue of $14.3 billion by cotton production in fields in 2018. Cotton industry is under effect of competition from synthetic fiber manufacturing, lower price levels and imported cottons. The US has a pivotal role in the global cotton market as an important producer and exporter of cotton. US provides a third of the global cotton exports and facilitate marketing cotton to the world (Maqbool & Mahmood, 2020).

India also plays a key role in cotton exports due to strong overseas demand from China. Cotton is considered a cash crop in Pakistan but its share to GDP is 1.4%. The share of cotton and cotton made products contributes 55% to the foreign exchange earnings of Pakistan (Maqbool & Mahmood, 2020).

Top three countries in production amount of seed cotton in 2019 were China (23,5 MT), India (18,6 MT) and USA (13,0 MT) (Table 1).

Table 1. Cotton production amounts, yields and acreages for top 15 countries in the world in 2019 (FAOSTAT, 2021)

Rank	**Country**	**Item**	**Production (million t)**	**Yield (t/ha)**	**Area harvested (million ha)**
1	China	Seed cotton	23,5	4,9	4,8
2	India	Seed cotton	18,6	1,2	16,0
3	USA	Seed cotton	13,0	2,7	4,8
4	Brazil	Seed cotton	6,9	4,2	1,6
5	Pakistan	Seed cotton	4,5	1,8	2,5
6	Uzbekistan	Seed cotton	2,7	2,6	1,1
7	Turkey	Seed cotton	2,2	4,6	0,5
8	Australia	Seed cotton	1,6	5,4	0,3
9	Argentina	Seed cotton	0,9	2,6	0,3
10	Benin	Seed cotton	0,8	1,1	0,7
11	Mali	Seed cotton	0,7	1	0,7
12	Burkina Faso	Seed cotton	0,7	1,2	0,6
13	Turkmenistan	Seed cotton	0,6	1,1	0,5
14	Côte d'Ivoire	Seed cotton	0,4	1	0,4
15	Tanzania	Seed cotton	0,3	0,6	0,4
	TOTAL		77,2		43,5

Top three countries in yield of seed cotton in 2019 were Australia (5,4 t/ha), China (4,9 t/ha) and Turkey (4,6 t/ha). Top three countries in area harvested for seed cotton in 2019 were India (16 million ha), China (4,8 million ha) and USA (4,8 million ha) (Table 1).

Top three countries in export quantity for cotton lint in 2019 were USA (3,6 million tonnes), Brazil (1,6 million tonnes) and India (0,6 million tonnes). Top three countries in export value for cotton lint in 2019 were USA (6,1 Billion US$), Brazil (2,6 Billion US$) and India (1,1 Billion US$) (Table 2).

Table 2. Cotton lint export and import quantities and values for top 7 countries in the world in 2019 (FAOSTAT, 2021)

Country	Item	Export Quantity (1.000 tonnes)	Export Value (Billion US$)	Import Quantity (tonnes)	Import Value (1000 US$)
USA	Cotton lint	3.562	6,1	528	1533
Brazil	Cotton lint	1.613	2,6	1657	4471
India	Cotton lint	615	1,1	686.815	1.320.897
Uzbekistan	Cotton lint	159	0,3	295	425
Turkey	Cotton lint	131	0,2	946.099	1.585.807
China	Cotton lint	54	0,1	1.967.871	3.754.031
Pakistan	Cotton lint	15	0,02	399.428	708.505

Top three countries in import quantity for cotton lint in 2019 were China (2 million tonnes), Turkey (0,9 million tonnes) and India (0,7 million tonnes). Top three countries in import quantity for cotton lint in 2019 were China (3,8 Billion US$), Turkey (1,6 Billion US$) and India (1,3 Billion US$) (Table 2).

For high quality cotton fiber, consumption of top 3 countries are India (33%), China (32%) and Egypt (9%) which together consumed 74% in 2013/14. Pakistan (6%), Peru (3%), Turkey (3%) and Bangladesh (3%) are following countries for high quality cotton fiber consumption (Fernandez-Stark et al., 2016) (Fig. 1).

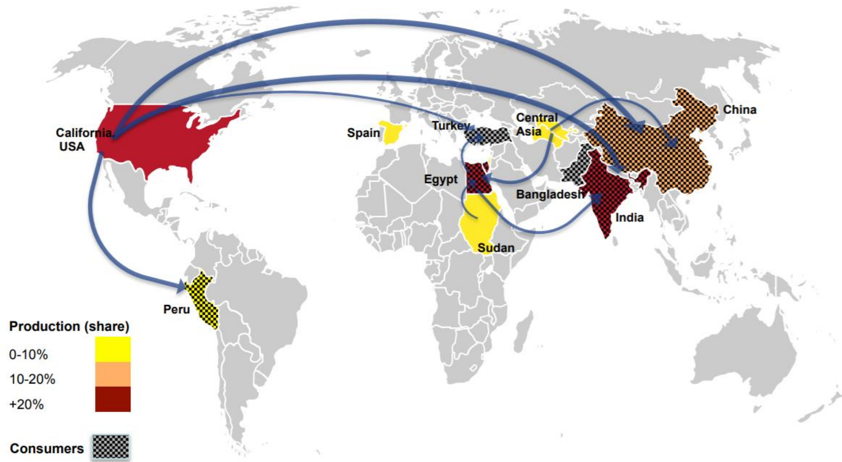

Fig. 1. Map of global high quality cotton production, consumption and trade in 2013/14 (Fernandez-Stark et al., 2016).

In a study conducted by Boansi et al., (2014) on seven-year values (prices, domestic resource costs and market structure) between 2005-2011 it was determined that Burkina Faso, Mali, Uzbekistan, Chad, Cameroon, Benin and India were "Highly Competitive"; US, Australia and Cote d'Ivoire were "Competitive"; Brazil and China were "Weakly Competitive".

Global cotton production and export industry experienced protests from various producers and exporters on distortionary measures (notably subsidies) instilled by US, India and China and pressure on global cotton prices. These distortionary measures were instilled to protect locals but harms other economies (Boansi et al., 2014).

Cotton Export of China

China is the world's largest importer, consumer and stockholder for cotton. China is largest importer in the world since 2003. Cotton covers 2% of total acreages in China. Cotton growing farms are small (average 0.5 hectare) and half of this area is farmed for cotton. Traditionally cotton was grown in eastern China in Henan, Hebei, and Shandong provinces (close to the Yellow River) (Fig. 2).

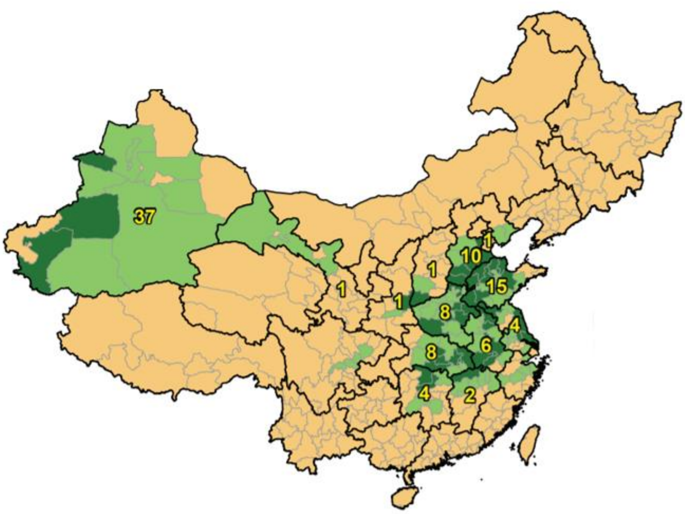

Fig. 2. "Geographic distribution" of cotton areas in China. Yellow numbers indicate the percent of each province contributed to the total national production (MacDonald et al., 2015).

Cotton was grown also in in Anhui, Hubei, Hunan, and Jiangsu provinces (the Yangtze River) but after 2005, Xinjiang Uygur Autonomous Region has become dominant cotton-growing region in China (Fig. 2) (MacDonald et al., 2015).

In China nearly all grown cotton in the eastern regions are GM (genetically modified). But in Xinjiang, only a small part is GM due to climate and geography of Xinjiang which limit the bollworm infestations. This makes introduction of GM varieties unnecessary. With rapidly rising wages in China in recent years, cotton production costs are rising faster compared to other countriesin the world. Rising costs shifted policy to increase price support for cotton and in 2014. China began switching producer support to direct subsidies in the largest producing region (Xinjiang). Policy of China will continue to impact the rest of the world significantly. Also lower import quotas of China for cotton may reduce world prices significantly (MacDonald et al., 2015).

Upland cotton was introduced in China at the period of 1920–1950. Hundreds of inbreed cultivars was developed since this period (Nie et al., 2016). Quality improvement of cotton fiber is important to increase the capacity of competition of cotton in the global market but, method to increase fiber quality without reducing cotton yield is still a challenge (Hou et al., 2021).

Cotton is an economically important crop in China, but insect damage is a major limiting factor for cotton cultivation (Luo et al., 2014). Since the 1980s public sector agri-biotech investments increased in China.

Major benefits of GM cotton determined by the early socioeconomic studies has proven as true: GM cotton still controls bollworm in China. The major impact was reduced pesticide consumption in China (Pray et al., 2011). In China, GM cotton (Bt-cotton) varieties was started to be marketed in 1997 to control some cotton pests, especially *Helicoverpa armigera*. Bt-cotton is estimated currently to be grown on 70% of the cotton acreages in China. This varieties reduce pesticide use but increase seed prices (Fok & Xu, 2011). Economic benefit of GM cotton usage in short term is well documented. By using national panel data for 1997–2012 period, Qiao (2015) showed that the economic benefit continues 15 years after the commercialization of GM cotton. Despite that, insect-resistant Bt cotton has been lauded for its ability to reduce the use of pesticides, study of Liu & Huang, (2013) was shown that Bt cotton farmers in China still use pesticides in excessive amounts.

Cotton Cultivation Macro Structure of China

Since the beginning of 21st century, accelerated urbanization and rapid economic development of China changed cotton cultivation technology. China did not repated the full mechanized approach experienced in developed countries. As having an underdeveloped economy and small family scaled cotton growing condition, they implemented a simplified and light system which involves modern agricultural equipment and technology usage. China adapted these to the local level and prefered management of production instead of manual operations. Target was to reduce labor intensity, simplify cultivation, reduce field operation frequencies, application of agricultural machinery and technology, usage of high quality seeds and reduce production costs. Key technologies used for this aims were 1) single-seed precision sowing, 2) simplified plant pruning, 3) low and simplified fertilization, 4) integration technology usage for irrigation and fertilization, 5) plant population control (Dai et al., 2017).

Single seed precision sowing technology controls hook formation and hypocotyl elongation at germination stage. High plant density inhibits vegetative branches. Simplified and low fertilization of nitrogen is concentrated during 20 days after flowering to deliver nitrogen to reproductive organs and increase nitrogen use efficiency. Water saving partial root-zone irrigation was applied to reduce lost water. Application of new cultivation technologies, new materials and equipment, and integration of technology and materials provided support to promote sustainable cotton production in China (Dai et al., 2017).

Intensive farming technologies in China for cotton production include seedling transplanting, double cropping, plastic mulching, plant pruning, ultra-high plant density technique, various kinds of chemical fertilizers and pesticides. These played important roles to increase yield and production (Dai et al., 2014). Cotton cultivation requires high nitrogen input and irrigation (Liu et al., 2010). Intensive cotton plant pruning is targeting to remove vegetative branches, topping, reducing old leaves, excessive buds and empty fruit containing branches in China. This practice is a time-consuming and labor-intensive process (Dai et al., 2014).

GM cotton was effective to control the cotton bollworm (Helicoverpa armigera) however, in recent years, in northern China, frequent outbreaks of the non-target pest Apolygus lucorum is becoming a major problem (Li et al., 2011). *Aphis gossypii* aphid is the main pest for cotton production in central China at the “Yangtze River Valley Cotton Planting Zone” (Han et al., 2014). Aphids are also major pest for cotton cultivation in the Xinjiang Uygur Autonomous Region in China (Li et al., 2018). Soil-borne pathogenic fungi diseases Fusarium and Verticillium wilt are major constraint in cotton production for China like as worldwide. The dynamics of these diseases are closely associated with the intensive cropping, introduced cotton varieties and weather conditions (Li et al., 2017).

To solve water crisis of China, extensive researches are undertaken for water management in cotton cultivation as a major water consumer of scarce resources in arid Northwestern part of China. However, actual irrigation productivity is still low (Feike et al., 2017). Xinjiang is the main cotton cropping zone in China, but limited water resources and low fertilizer consumption restrict its agricultural development (Wang et al., 2018). Xinjiang is the largest arid / semi-arid region where drip irrigation under plastic mulch is common (Bai et al., 2015). Cotton-Jujube intercropping is a common practice in Xinjiang (Wang et al., 2021). Also in hyperarid desert-oases in northwest China, if water shortage is effectively managed, these terrains will add significant contribution in total cotton production of China due to favorable climate (Shareef et al., 2018).

CONCLUSIONS

Top three countries in production amount of seed cotton in 2019 were China, India and USA. Top three countries in export quantity for cottonlint in 2019 were USA, Brazil and India. China, which is dominated by genetically modifed varietal utilisation in cultivation has a leading role in global cotton market and has a different structure for cotton cultivation.

China has huge acreages of cotton production but as an irrigated crop, possible water shortage sourced from changing rain patterns at the age of global warming is putting this crop under risk especially under partial rootzone irrigation applied areas of the country.

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