Chapter

# Role of Biotic and Abiotic Factors for Sustainable Cotton Production

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## Abstract

Climate is changing globally nowadays because of extensive crucial human activities. This state along with stark in weather measures ultimately affecting the development and growth of crops due to various kinds of stressful field condition at the same time including biotic and abiotic stresses. Thus, various biotic factors including pathogens, weeds and pests and abiotic factors including temperature, humidity and drought etc. are involved in reduction of cotton yield due to which cotton production significantly reduced. Various biotic factors have direct effect on the cotton production and caused significant reduction in cotton crop yield estimated up to 10 to 30%, while as abiotic factors are even worse than biotic stresses and could cause 50% reduction. So, effective agronomic practices, optimal climate and integrated pest management leads to fruitful crop production to cover this yield gap. This chapter will be broadly useful to design projects aimed with inter and intra-disciplinary collaboration for sustainable cotton production.

**Keywords:** cotton pathogens and pests, climate change, biotic and abiotic factors, combined effect, sustainable production, IPM

## 1. Introduction

Cotton, *Gossypium hirsutum* is not only the most significant material yarn on worldwide basis, anyway is likewise the primary abroad exchange worker in underdeveloped nations [1]. The complete place that is known for Pakistan is 796,095 km$^2$, around twenty to million are developed and 8.3 million are non-developed soil. Around the globe Pakistan is among the foremost makers of cotton, wheat, sugarcane, rice, dates, mango and oranges. Our chief crops (includes cotton, wheat, sugar cane and rice) contribute 6.5% but trivial crops 2.3% of the nation's GDP. Pakistan's agriculture is based on chief crops which report for approximately 24% of the worth supplementary to generally agriculture and 4.67% of the GDP [2]. Developing countries including Pakistan have low yield production of seed cotton as compared to other technologically advanced countries like USA, Australia and China etc. Therefore, high yield of cotton is necessary on consecutive basis [3]. At present, the production of cotton yarn is approximately 25 million metric tons globally per annum basis while the current market value is around 12 billion U.S. dollars [4]. On worldwide basis, four major cotton species are cultivated to the known area for cotton production about 95%, but the key specie is *G. hirsutum* (upland cotton) that is dominant to other species as well [5]. The fast growing world population definitely demands high production of food and fiber [6]; to meet these requirements intensive agricultural practices have directed too many climatic issues importantly depletion and exhaustion of water and soil resources [7–10]. Effective agronomic practices, optimal climate and integrated pest management leads to fruitful crop production; as cotton is a perennial shrub from subtropical origin, it could even withstand harsh environmental factors e.g. drought and extreme heat [11]. Various biotic and abiotic factors are involved in reduction of cotton yield due to which cotton production significantly reduced [12]. Nowadays, breath taking climatological changes resulted in extreme weather that ultimately having direct impact on cotton production; while as plant growth reduced by facing various types of stresses in the field conditions. The dominant stresses include weather and soil factors; e.g. (temperature, humidity and rainfall) and (soil biology, altered physical and chemical properties). Generally these factors are consisted of two type's biotic and abiotic factors; biotic factors includes pathogens, weeds and pests while abiotic factors consists of temperature, humidity and drought etc. [13]. Various biotic factors such as pests and pathogens have direct effect on the cotton production and caused significant reduction in cotton crop yield estimated up to 10 to 30% [14]. While as abiotic factors such as temperature, humidity and drought etc. are even worse than biotic stresses and could cause 50% reduction [13]. GM cotton (BT cotton) was first developed in the mid-1990s and notorious for its adaptability, expressing his success story but still agronomic practices and soil system management is key spot to lessen the stressful field conditions. For sustainable productivity of cotton crop the interaction between genetics and crop agronomy is a worthy point [15].

In this chapter, our main focus is on the role of biotic and abiotic factors for sustainable cotton production. Here, we would also like to explore and summing up information about management of those factors for betterment of cotton production. We will also evaluate and identify some main reviews about the role of these factors in relation to plant response, their manifestation etc.

## 2. Biotic factors (biotic stress)

Biotic factors comprise chiefly insect pests and pathogens that are mainly responsible for reduction of cotton yield [14, 16, 17]; generally accounting the production losses of cotton yield due to insect pests around 84% [17] while for diseases and pathogens up to 30% [14]. The main biotic factors that leads to biotic stress for cotton field include insect pests (chewing and sucking pests) and some pathogens (viruses, bacteria and fungi) and weeds. While at the same time the abiotic factors particularly affect the occurrence of these pests and diseases [18]. Consequently, this situation is accountable for the emergence and incidence of the new pests and pathogens. Coupled with this we are viewing the main biotic factors, their key characteristics and incidence mechanisms and damage modes.

### 2.1 Categorization of major pests and pathogens of cotton crop

#### *2.1.1 Insect pests*

In the world over thirteen hundred and twenty six type of pests that mainly insects found as basis of infestation in cotton [19], whereas 162 different types of insect and mite pests in sub-continent [20]. The cotton crop is attacked by 96 different types of insect pests and mite species during its growth period. These insects and other pests normally observed to nourish on fiber crop in Pakistan [21]. Mainly insect pests of cotton crops consisting of two groups depending upon their mode of damage, insects with chewing mouth parts and insects with piercing sucking type of mouth parts [22]. Chewing insects generally chewed the different parts of cotton plant including cotton bollworms and leaf worms etc. e.g. pink bollworm, American bollworm, armyworm, spotted bollworm, cotton leaf worm etc. Mainly the immature stage of this group damages to cotton crop [14, 22]. **Table 1** includes the major chewing pests of cotton crop as given below.

The other group of cotton pests include pests with sucking mouth parts. In Pakistan, India, China, Japan, Trinidad, Puerto Rico, Australia and Europe the key pests of cotton crop had sucking type of mouth parts are thrips, jassid, whitefly and they cause considerable loss in cotton production [35, 36]. Insects with sucking type of mouth parts became primary pests of cotton crop from the time transgenic cotton (Bt cotton) commercialized in the world [37]. **Table 2** includes the major piercing sucking pests of cotton crop as given below.

### *2.1.2 Pathogens*

Different fungi, bacteria and viruses are the major pathogens in cotton farming system [14]. Bacterial blight is one of the notorious disease of cotton crop caused by bacteria, *Xanthomonas citri* pv. Malvacearum; most damaging and vital cotton

| Common Name | Scientific name, Order: Family | Damage | Reference |
|---|---|---|---|
| Pink bollworm | *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) | Larvae feed on flower buds, flowers, bolls and the developing seeds within damaged bolls, resulting in the boll rotting, premature or partial boll opening also affects lint quality | [23, 24] |
| Old world bollworm | *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) | Larvae feeds on reproductive parts of cotton, larvae also eat vegetative parts when reproductive parts are not available | [25, 26] |
| Corn earworm | *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae) | Fruiting structures are damaged; feeding facilitates entry of diseases, Young shoots and leaves are damaged, in the absence of fruiting parts | [27, 28] |
| Spiny bollworm | *Earias insulana* (Boisdual) (Lepidoptera: Nolidae) | Larvae feed on bolls and buds of cotton, and cause. Heavy damage decreases the quantity, quality and fiber length | [29, 30] |

| Common Name | Scientific name, Order: Family | Damage | Reference |
|---|---|---|---|
| Spotted bollworm | *Earias vitella* (Fabricius) (Lepidoptera: Nolidae) | Larvae usually appear at the fruiting stage on cotton, damages buds, shoots, | [31, 32] |
| Fall armyworm | *Spodoptera frugiperda* (J. E. Smith) *Spodoptera exigua* (Hübner) *Spodoptera littoralis* (Boisd.) (Lepidoptera: Noctuidae) | Infestations occur sporadically across production regions and within fields. Neonates typically exhibit gregarious feeding behavior on the leaf near the site of oviposition, older larvae can feed within reproductive structures | [33, 34] |

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**Table 1.**
*Major chewing pests of cotton.*

| Common Name | Scientific name, Order: Family | Damage | Reference |
|---|---|---|---|
| Lygus bug | *Lygus Hesperus* (Knight) Hemiptera; Miridae | Pierce squares, damage anthers and other tissues, bolls shrivel, turn brown, and drop from the plant | [38–40] |
| Green mired | *Creaontiades dilutes* (Stal) Hemiptera; Miridae | Both adults and nymphs feed on meristem tissue, loss of squares, damage growing tips, immature balls and delay maturity ultimately delay growth | [41–43] |
| Mirid plant bug | *Adelphocorus saturalis* (Jakovlev) Hemiptera, Miridae | Fed on newly formed tissues, shedding of squares, immature bolls and delayed maturity | [41, 43, 127,] |
| Stink bug | *Nezara viridula* (L.) Hemiptera, Pentatomidae | Abscise small bolls and damage lint quality, seed germination and overall yield | [44–46] |
| Dusky cotton bug | *Oxycarenus faetus*, (F.) Hemiptera, Lygaeidae | Suck sap from immature seeds and reduce lint quality, reduce weight and viability of seeds | [47] |
| Whitefly | *Bemicia tabaci* (Gennadius) Homoptera, Aleyrodidae | Sucking of sap, transmission of various viruses, honeydew associated with fungal growths | [47] |

| Common Name | Scientific name, Order: Family | Damage | Reference |
|---|---|---|---|
| Jassid/Leafhopper, leafhoppers | *Amrasca biguttula biguttula* (I.)<br>*Austroasca viridigrisea* (P.)<br>*Amrasca terraereginae* (P.)<br>Hemiptera, Cicadellidae | Ingest cell sap from cotton leaves and inject toxic substances, leaf curling, stunting growth, distortion of plants | [48–50] |
| Aphid | *Aphis gossypii* Glover<br>Hemiptera, Aphididae | Ingest cell sap from leaves and transmit viral diseases, secrete honeydew that cause sooty mold | [49] |
| Thrips | *Thrips tabaci* (L.)<br>*Frankliniella occidentalis* (P.)<br>*Frankliniella schultzai* (T.)<br>Thysanoptera, Thripidae | Feed on terminal growth and underside of leaves, lower surface shows silvery appearance | [51, 52] |
| Mealy bug | *Phenococcus solenopsis* (T.)<br>*Pseudococcus corymbatus* (M.)<br>*Pulvinaria maxima* (G.)<br>Saissetia nigra (N.)<br>Hemiptera, Pseudococcidae | Suck sap from leaves, flower buds, twigs even from stem, reduce chlorophyll and water contents | [53, 54] |

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**Table 2.**
*Major piercing sucking pests of cotton.*

diseases caused by bacteria [55]. Bacterial blight affected the cotton crop in worst manner resulting in defoliation of the plants, stems becomes dark and swollen and even detached that ultimately leads to decrease of fiber quality, decreased coloration and death of plant [56]. Fungal diseases of cotton crop are also much more dynamic caused by various fungal pathogens, for example, *Fusarium oxysporum* is responsible to cause Fusarium wilt of cotton [57], *Verticillium dahlia* cause Verticillium wilt of cotton [58], *Colletotrichum gossypii* cause anthracnose of cotton while *Colletotrichum gossypii* var. cephalosporioides is reason for ramulosis [59], *Mycosphaerella areola* source root ramularia gray mildew [60]. The root rots of cotton crop are started by *Sclerotium rolfsii* and *Rhizoctonia solani* [61], *Alternaria macrospora* leads to leaf blight disease [62], while leaf spot of cotton caused by *Cercospora gossypina* [63] and the target spot of cotton caused by *Corynespora cassiicola* [64]. The viral diseases of cotton crop mainly includes viruses from Begomovirus family, Begomovirus acts as foundation for disease spread in cotton crop which commonly includes curl disease, leaf crumple and cotton mosaic disease [65]. While as cotton blue disease and atypical cotton blue disease introduced by Polerovirus [66, 67]. Viral diseases of cotton crop are insect transmitted and need vector for transmission in general [65].

## 3. Abiotic factors (abiotic stress)

Climate is changing globally nowadays because of extensive crucial human activities, while Abiotic stresses are a direct consequence of climate change. Whereas as it's foreseen to be more breathtaking increase then the average universal temperature [68]. Abiotic factors are of particular importance in regard to sustainable cotton production, because from sowing to harvest all the development stages of cotton plant depend upon abiotic factors for optimum level to grown normally. Abiotic stresses (extreme temperature, relative humidity etc.) cause distress to cotton crop and resulted in substantial decrease in yield of cotton and damage the lint quality [69, 70]. Yield loss in cotton due to the influence of abiotic factors is around 50% [13]. The major particular characteristic of abiotic tensions is their occurrence and acquaintance at the same time, simply they act same upon plant growth and plant defense behaviors that makes it more complex [71]. Keeping in view the roles of abiotic factors (abiotic stresses), here, we will analyze and summarize the effect of those in relation to sustainable cotton farming system.

### 3.1 Temperature impact

All crops depends upon the optimum temperature for the proper growth and development, so temperature is a chief dynamic for farming of different crops. The growth rate of cotton crop mainly dependent on the temperature, although the cotton plant is basically from tropical origin and can survive in high temperature environments but extremely hot climatic situation resulted in reduction of cotton yield [72]. Extreme temperatures either its cold or hot can ultimately affect the growth or development of cotton crop and could delay or even reduce the cotton production. Minimal changes from optimal conditions could severely effect plant growth, even 2–3°C increase from optimum temperature reduce plant growth and cause decline in yield and biomass along with increase of fiber micronaire [69]. High temperature directly or indirectly affects the growth and development of cotton and leads to drought stress because of higher evaporation from the fields. A study from Arkansas USA proposed the negative correlation between high temperature ranges and cotton production [73]. They found that the high temperature unswervingly disturbs the biology (vegetative ad reproductive stages) of cotton. This influence eventually leads to increase the production of more vegetative portion and lowering the reproductive portion of cotton plants [74]. Particularly reproductive stage of cotton crop also be strongly influenced by some other heat stress related other severe effects; in general the maturing of reproductive parts could be impacted more and cause reduction in the yield. If the temperature is higher than optimum or regular temperature, the first square formation or flowering start and first boll formation or boll opening rate decreased. Retention phase for the squares and bolls mostly decreased under high temperature [75]. Same as high temperature, low temperature also badly effect cotton growth. The development of cotton could be delayed by extreme drops of temperature under 11°C that further resulted into prolonged growth period [16]. Yadav discusses plant reactions to cold stress as well as physiological reactions and strategies for cold tolerance [76]. While at present the main focus of authors for sustainable cotton production is on high temperature under changing climatic situations.

### 3.2 Drought and salinity effects

Globally changing climate resulted in increase of mean temperature on per annum basis that ultimately leads to more evaporation of water from the soils and directly causing drought. Osmotic condition refers to drought and salinity stress [71]. At present, drought stress is considered among top factors that are responsible for reduction in cotton yield worldwide. Scientists foreseen that the agricultural fields strongly impacted by the drought stress will be double in the current era [77]. They also predicted that the urban, industrial and agricultural lands will face the water short comings and their will be strong competition for the water resources [78]. Cotton production strongly impacted by drought and salinity stress; drought or salinity are the main reason for reduction in cotton yield damage to the lint quality [79, 80]. Cotton plants show notable changes in their morphological and physiological characters in response so severe abiotic stresses. All the parameters including from seed germination to bolls development are impacted negatively by above stresses [69, 79, 80]. Furthermore, if the cotton crop experience those abiotic stresses for long periods of time, ultimately it faces the reduction in yield and damage to lint eminence by decreasing the boll's mass and fiber development. Thus, it faces already negative impact, also its catabolic processes like photosynthesis also got disturbed that lead to reduction in yield [69, 79, 80]. In general, plants are adaptable to drought stress or other water scarcity conditions by a variety of different internal processes, but most importantly the closing of stomatal glands is first response by numerous crops [78]. Farooq et al. suggested the comprehensive guide on the effect of drought against different crops and their physio-biochemical response [81]. Luis et al. described different biotic and abiotic stresses that could affect plant health (**Figure 1**) [82].

### 3.3 Combined effect of abiotic factors

The typical peculiarity of abiotic factors or abiotic stresses is that they affect the plants concurrently and causing a lot of internal and external changes simultaneously [71]. As above described cotton crop is indeterminate in nature, they have a series of systems to adapt the stressful environment. Thus, in stressful environment, for example drought or salinity problem, high temperature or soil with less minerals and nutrients, cotton plant change their behavior to face those critical environment by cracking and detaching the bolls, squares and flowers etc. [83]. Thus, under such stressful circumstances the growth of cotton roots is also limited that could be

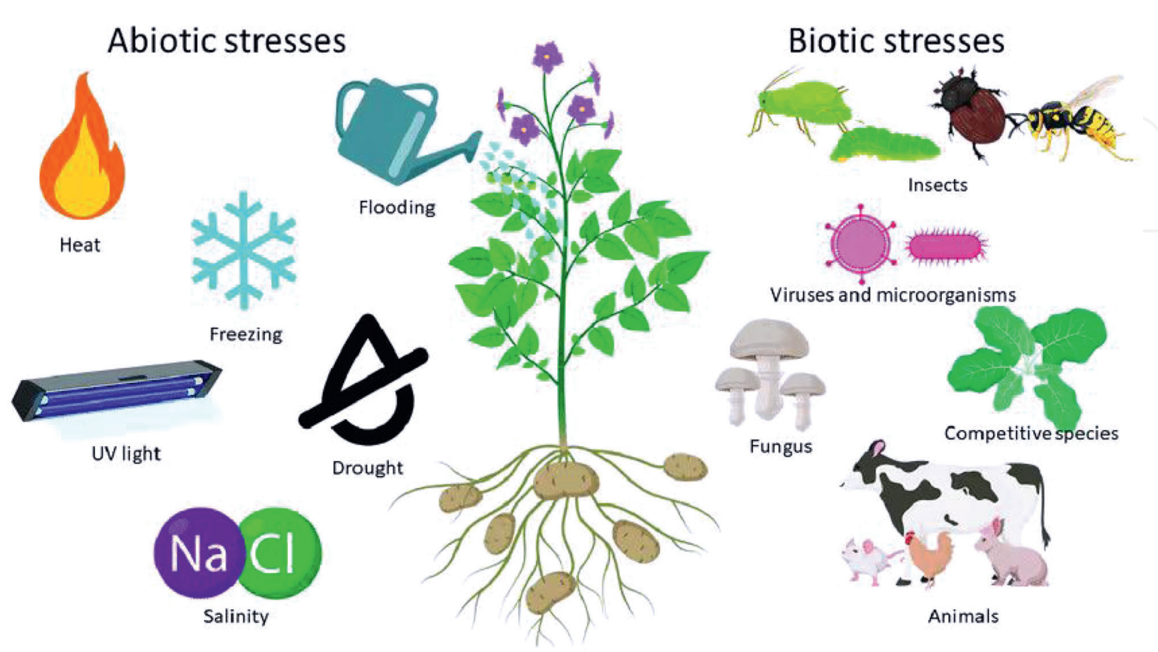


**Figure 1.**
*Different types of biotic and abiotic stresses that can affect plants. Source: Luis et al. [82].*

resulted in low yield [84]. The soils that affected by drought stress have many changes in their physiochemical properties resulting in cracking in the upper portion, superficial crusting and altered soil structure. Thus, in some cases if the coil clay content lowers to minimal level and the kind of clay micronutrients present in it sometimes leads to more than 1 m deeper cracking in soil surface. The lower level of organic matrix in soils lead to soil crusting by damaging soil hydrology [85]. The altered soil structure imparts negative effects on the interaction of soil, plant and water ultimately leading to low efficient irrigation [86]. This caused the deprived development of root network that decreases the biomass production [87].

### 3.4 Combined effect of biotic and abiotic factors

Various biotic and abiotic factors are involved in reduction of cotton yield due to which cotton production significantly reduced [12]. On worldwide basis, promptly increasing rate of population highly demands the food and fiber needs to be covered by the rigorous agro-farming practices [6]. But simultaneously this situation have become the big cause of global climatic change that lead to severe environment impacts particularly the water and soil resources deployment [7–10]. This state along with stark in weather measures ultimately affecting the development and growth of crops due to various kinds of stressful field condition at the same time including biotic and abiotic stresses.

The insects are highly dependent on abiotic factors and type of crop for their proper growth and development. The population growth rate is very much during suitable environmental situations and populace abundance is too high. Temperature and relative humidity plays a role in affecting the incidence of these insect pests [88]. Temperature plays a key role in controlling the development of insects and outbreaks of their population [89]. The positive relationship has been found between the population of cotton thrips and environmental factors including degree of hotness, relative humidity and rainfall [90, 91].

Rigorousness of different diseases directly associated with individual functional state of plant, the type of medium or soils, diverse changing weather situations, alike temperature, humidity or rainfall. E.g. during the wet weather condition in sandy type of soils the wilt diseases of cotton occurred more. Same as, high level of moisture and low temperature situation highly favor the growth of blight disease triggered by the *P. exigua* [92]. While on the other hand, severely cold climatic condition or chilling pressure directly influence the vulnerability of cotton crop by the attack of *A. macrospora* [93]. Likewise cold weather with low temperature range and high humidity level favor the diseases caused by *R. solani* and hot weather condition with high degree of hotness with low level of humidity leads the infection by *R. bataticola* in cotton crop [94].

High degree of hotness have direct impact on the sustainable production of cotton crop while indirect effect is increasing the rate of transpiration of water from the soil that ultimately led to drought stress [95]. Thus, the health of soil or soil condition directly influence the relative degree of drought and hotness stress the plants. While as the lower stomatal activity by plants was observed under highly fertile soils in comparison with low fertile soil [96]. Suzuki et al. described the complete survey of combined biotic and abiotic stress effect to cotton crop [97]. Pandey et al. comprehensively reviewed the Impact of Combined Abiotic and Biotic Stresses on Plant Growth and Avenues for Crop Improvement by Exploiting Physio-morphological Traits (**Figure 2**) [98].

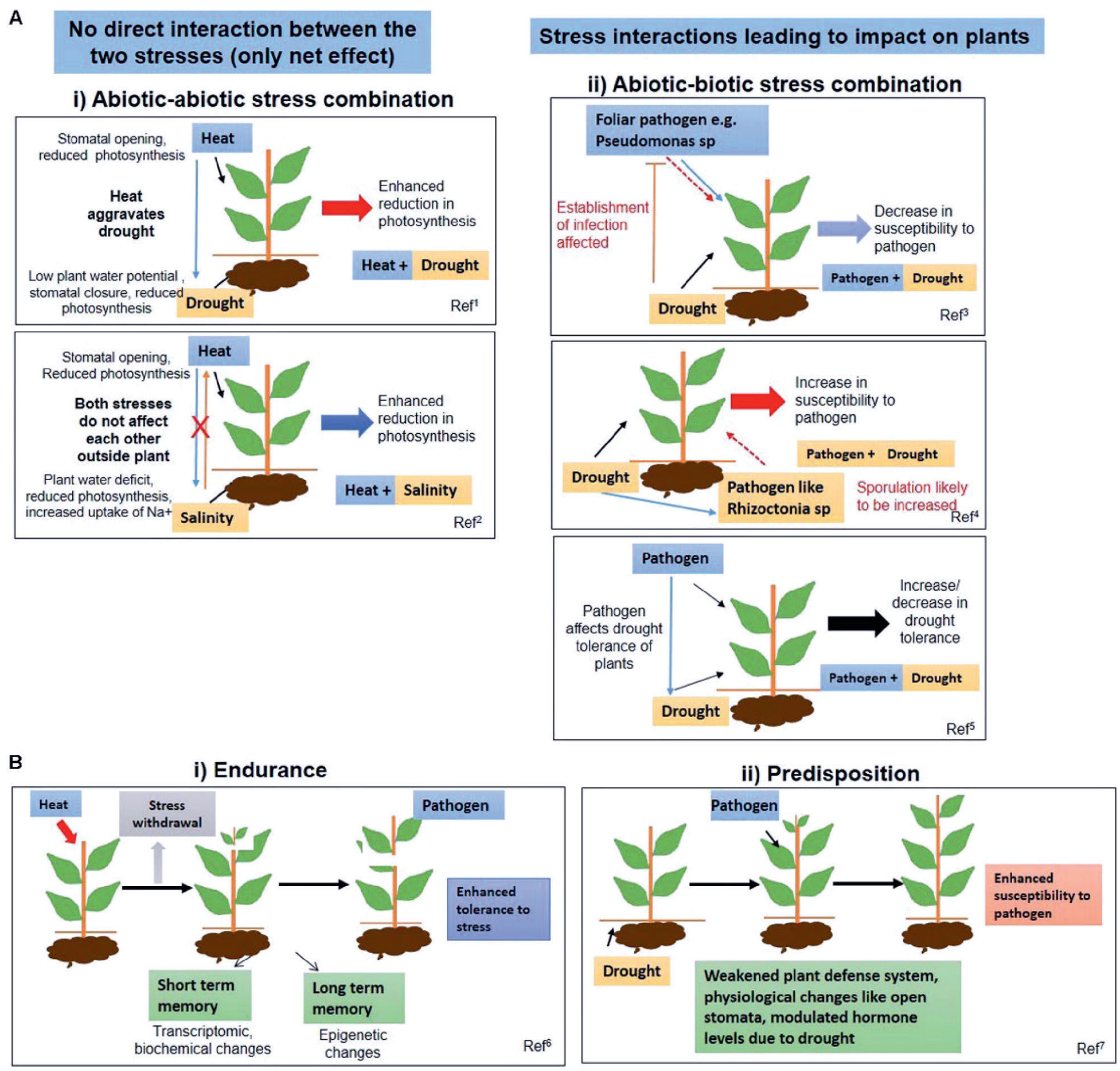


**Figure 2.**
*Schematic representation of effect of stress combinations on plants. Source: Pandey et al. [98].*

## 4. Management of biotic factors

In the current scenario, chemical control is the main tactic for pest and disease control, mostly farmers rely on use of synthetic insecticides, fungicides, bactericides and nematicides etc. to reduce pest infestation and disease control. On worldwide basis, to control or manage the pests and diseases conventional chemicals used. Bu however the non-judicious or inappropriate use of these synthetic pesticides have severe impacts on climate overall by damaging human and animal health, environmental degradation, resistance problem among insect pests and killing non target insects. Thus, in this regard it is necessary to design some ecofriendly and effective pest and pathogen management techniques [99] by following pre planned IPM program.

### 4.1 Integrated pest management

IPM simply refers to management of pests by using multiple control tactics with manipulation according to needs, that is environment friendly and effective management program for agro-ecosystems. The chemical control is the final step in

IPM. Because many insecticides have severe environmental hazards, they could have impact on beneficial insects, human health and ecosystem degradation, so in this program selective products could be used. IPM program basically have three major parts; first is the avoidance of pests; second is post sampling and monitoring; the conservation of beneficial factors and other is use of chemical and non-chemical methods to control pests in efficient way [100–102].

### 4.2 Pest's avoidance

For pests avoidance basically one must have comprehensive information about the behavior of particular insect pest, its ecology and biology. This tactic is broader in range and effective against different commodities according to area based pest management programs. The basic purpose of it's to keep the population of that pest below threshold level, because if the population of that particular pest is above economic threshold, the crop would be damaged by unrecoverable loss. It is important in this tactic to must study well and identify the natural enemies of that pest and also alternative hosts etc. Then management tactics could be designed according to need its set basically the foundation of effective management program. The control measures must include use of pheromones or semio-chemicals and other bio-pesticides in combination for mass trapping by disturbing reproduction cycle of that pest [103, 104].

### 4.3 Cultural management

For sustainable cotton production cultural control of pests is also of equal importance according to agro based region and climate. Before the sowing of genetically modified cotton, BT cotton, delayed planting in Pakistan was used to manage the pink bollworm to reduce its infestation [105]. Late season planting of cotton in Australia was avoided because of low yield and more vulnerability of cotton to be attacked by late season outbreak of sucking pest and bollworms. The destruction of pupae was followed by plowing to control *Helicoverpa armigera* [106]. Hussain et al. found high abundance of thrips on early planted cotton in Pakistan. They suggested that because the temperature have positive role in development of thrips and other sucking pests, so, by managing the agronomic factors cotton yield could be enhanced by reducing the infestation of thrips [107]. Regarding these factors pre-planned IPM practices could be designed for effective pest management.

### 4.4 Crop rotation

Crop rotation is also a conventional method use by many farmers on large scale cotton farming areas. But in different cotton farming systems, crop rotation have both negative and positive impacts on biotic stress factors according to the crop selected [10, 108]. To destruct the disease cycle and pest chain, choice of most appropriate crops for rotation purposes is key in integrated disease management (IDM), however, the release of disease suppressive microbes to dominate the disease are yet a challenge due to various factors [109].

### 4.5 Host plant resistance (HPR)

Resistance among different kinds of insect pests is an emerging challenge in effective pest management crop as cotton plants confer it due its several traits. While some varieties of cotton that have high leaf hair structure and less gossypol glands are somehow resistance against thrips, although exact mechanism is not clear. Same as some cotton cultivars with okra shaped leaves showed partial resistance against whitefly [106]. So by increasing host plant resistance could be effective as well to manage insect pests. In this regard, [14], summarized detailed biotechnological solutions for sustainable cotton production.

### 4.6 Sampling and monitoring of pests

The fundamental step in studying population dynamics and decision making for effective pest control strategies is sampling. For different agro farming systems sampling considered to be as primary tool. Correct sampling measures at right time not only helpful in effective pest management program but also used to check and evaluate the management options and their efficiency. In Arizona, with the effective sampling tactics and their implementation, the successful control of whitefly have been achieved [102]. In present situation as Bt cotton have been grown on worldwide basis, so by following efficient sampling procedures beneficial insects (natural enemies) could be conserved as well.

### 4.7 Conservation of major beneficial insects

Many beneficial insects for cotton farming system have been reported from different countries including Australia that predates and parasitize on cotton pests especially hymenopterans mainly including spiders, true bugs, lacewings, some beetles and hymenopteran parasitoids etc. [110–112]. But because of limited available methods to increase their populations for their effective use as bio control agents make them hard in this scenario. But it have been found that under unsprayed cotton fields these pests generally effective to low the pest infestations [113], but it depends on the type of pests [114, 115]. The vegetative area is extremely low in many cotton growing regions including Australia [112] that ultimately showing the no provision of refuge sites for natural enemies. That's why the beneficial insects prefers to migrate to other places for their better survival, for over wintering stage to pass and less competitive food resources [111, 112, 116]. So by planning effective agro farming systems these beneficial insects could be conserved by providing them refuge crops, provision of food baits, inoculative releases, tolerating early season pest attack, resistant varieties, use of selective and appropriate insecticides etc.

### 4.8 Judicious insecticidal use

Use of synthetic insecticides is the last option in IPM programs, while even the use of different botanicals and other bio pesticides are also avoided to spray in early cotton season, thus the beneficial insects could be conserved. But when the pest population exceeds to economic threshold level, then by relying and designing the appropriate time and schedule of applying sprays only with selective chemicals according to their minimal impact on non-target could help to conserve beneficial insects. Avoidance by blind sprays could also help in IPM program, because the spot treatments within field could conserve natural environment for beneficial insects.

## 5. Management of abiotic factors

Climate changing is a global issue now and it causing a range of abiotic stresses. The notorious characteristic of abiotic factors is that they occur simultaneously in the environment. In this regard, long term exposure to abiotic stresses resulted in reduced yield ultimately. While adaptability is a major function of living beings. To fight against abiotic stresses or to minimize the effects of different abiotic factors, many plants particularly cotton have developed some defense mechanisms to overcome the impacts of abiotic stresses. These adaptabilities by cotton plants are based on physiological or molecular mechanisms. However, still an integrated management is still needed to overcome these harsh environmental stresses.

### 5.1 Drought stress management

Drought is among the key limitation factor to suppress sustainable cotton production all over the world. In this regard, to overcome the effects of drought meaningfully, one must know comprehensively the soil conditions by exploration deeply [117]. The growing of commercial scaled upland cotton always show positive association with adequate water supply whenever grown in dry lands [118]. Cotton growing farmers always rely on altered row configuration to minimize the effects of drought stress as basic agronomic measure [119]. While the crop rotation tactic with cereal crops improve the soil health overall by increasing its water storage capacity and accessibility to respective crop [120]. Botanists who are working on plant physiology or molecular technologists should must keep in mind these factors when they are working to develop new innovative tools for management of drought stress. However, Farooq et al. have described the comprehensive review of drought impact on plants and their physiological response [81]. It is scientifically proofed that the highly efficient approach to overcome drought effects and increase the production rate of cotton could only be attained by the appropriate or judicious use of vital natural resources water and soil [121, 122].

### 5.2 Temperature stress management

Climate change is a global issue now. While this challenging the environment overall by causing abiotic stresses directly. The globally increasing temperature is mainly due to excess carbon dioxide contented in the atmosphere. Thus, the mean increase in degree of hotness globally per annum basis leads to water transpiration from the soil that ultimately resulted in drought and salty soils [71]. Temperature stress directly damages to reproductive and vegetative phase of cotton resulting in low yield [74]; although cotton is a tropical crop and have the ability to absorb severe radiation from the sun, and resulting in high temperature of the crop during high solar intensity. While in this regard, some of the plants show adaptable behavior and respond to temperature stress by developing waxy surfaces to imitate the strong radiations from the sun. But the cotton plants responded by absorption of solar radiation that intensifies osmatic (drought) pressure. Varieties with some appropriate and desired features including dense cuticle structure and profound hairs to lower down the temperature or heat stress could helpful in this regard (CICR 2016). Frequent watering could help to overcome water stress. Recently, some new innovative plant based irrigation systems have been developed by means of temperature sensing remotes through canopy [95]. While the other adverse behavior from cotton plants is the closing of stomata in the night ties that does not allow the cooling effect. In this context, plant breeders and biotechnologists may focus on developing such verities or cultivars that could fight against heat stress. As the roots are vital part to supply water to whole plant, so studying their structure and role is of equal importance and the types of soils as well. Because the sandy soils have less ability to store water for long so this could also aggravate the water and heat stress.

### 5.3 Role of root morphology to combat above stresses

To overcome the drought effects management tactics may be applied according to soil or plant type. Soil type and state is vital to play key role to help to develop deeper, denser and stronger plant roots to increase the use of available resources. This could ultimately helpful to significantly overcome the severe impacts of heat and drought stress. A comprehensive description on the impacts of different dry lands on roots in relation to development of crop was covered by Whitmore and Whalley [117]. Roots have different morphology among top layer of soil and sub layer of soil according to its thick structure, it could have strong influence on the behaviors of plant; how could they manage different stresses. The plants with roots who have ability to grow more bottomless or deep layers in the soil fight drought stress in a better way [123]. Some latest findings from Australia confirmed that the fine root structure of Bollgard Roundup Ready® genetically modified cultivar, was less than conventional cotton. The production of fine roots was much lower [124]. Bell also found that the cotton roots acquire phosphorus from subsoil instead of topsoil. It is proposed that under drought conditions plants roots could active in bottom and deeper soil layer while inactive at topsoil [125]. But this stressful situation ultimately depleting the P resources among cereal crop soils in Australia where the cotton is also grown [126].

### 5.4 Role of soil condition to combat above stresses

Different biotic and abiotic factors are directly or indirectly related to occurrence of different diseases, outbreak and survival of insect pests and could lead to complex situation in relation with different crops to manage those pests and pathogens. Thus, the soil type, structure and composition also could adversely affect these factors. In this regard, the altered soil texture severely affects the plant-soil-water relationship and cause the low water uptake by plant roots [86] that ultimately leads to poor growth and development of plant [87]. The adverse impacts of high temperature, dry and saline soils under field could be lessened or by adopting many technological measures. These measures are generally comprised of latest irrigations systems, soil health betterment by different management approaches, and management of crop residues and selection of particular crop cultivar. All the above approaches are usable but not limited to overcome the biotic and abiotic stress. Tillage have facility to alter the soil structure in favor to keep balance between hotness and soil humidity level. Thus, tillage have direct effect on transpiration of water from soil to air and infiltration through deep soil. So, some previous findings have supported that the soils with zero or minimum tillage have bettered structure to fight these stresses by helping undisturbed root development [127]. However, in some specific conditions due to use of heavy machinery on farmland resulted in hard or compacted subsoil layer needs deep tillage for better soil structure for farming. Summing up, the integrated management of biotic and abiotic stresses entails attentive use of available tactics and strongly demands development of stress tolerant varieties by keeping in mind the

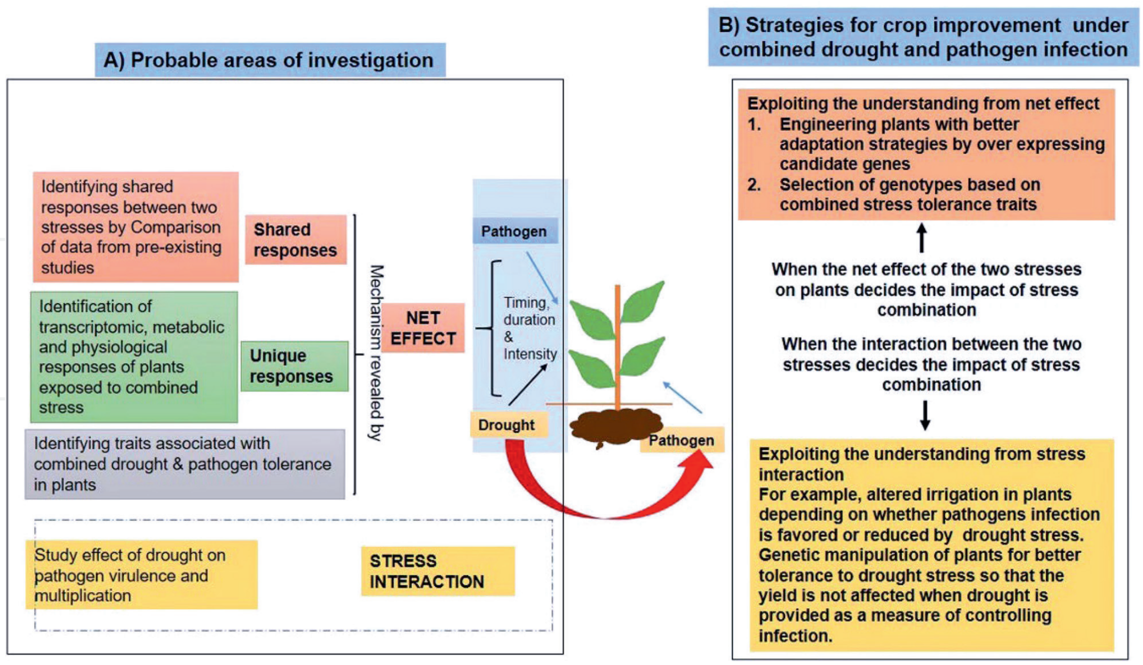


**Figure 3.**
*Outline of strategies for improving crop performance under combined drought and pathogen stress. Source: Pandey et al. [98].*

above described factors. While as Pandey et al. suggested in detail to overcome the combined effect of these stresses (**Figure 3**) [98].

## 6. Conclusion

Globally changing climate ultimately resulting in adverse agro-eco environments. Presently, the multi-dimensional and concurrent impacts of different biotic and abiotic factors limiting the crop growth. Raising of crop nowadays facing multiple stresses at the same time in the field. It makes ultimately hard to find tangible solutions to stand against this situation. Nevertheless, Sustainable management techno-solutions will be necessary to meet the societal requirements in this regard in the cotton-growing areas of the world. Reduction in yield of cotton crop due to multiple stresses in the field condition occurred. Different abiotic factors favoring biotic factors (insects and pathogens) to grow and survive. These factors are intermingled at some point and be reason for strong reduction in cotton yield. Co-occurrence of many stresses affects more to a plant as compared to single stress factor. Integrated pest management, integrated soil and crop management and effective agronomic practices could play a key role to combat the adverse effects of biotic and abiotic factors. Different molecular breeding methods are often used to develop cotton varieties that are resistant to abiotic stresses, whereas various transgenomic techniques mends resistance against different insect pests and pathogen. So, Plant breeders, plant physiologists, and microbiologists should must ponder over this complex situation when they forecasting their investigation approaches. Research on new innovative combinations of agro-eco systems and introduction of bio-techno solutions and persistent stewardship from farm to global farming culture is vital for sustainable cotton production.

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