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Effect of bacterial blight disease on ionic contents of cotton and its management

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Abstract

The bacterial blight disease caused by *Xanthomonas citri* pv. *malvacearum* (Xcm) has been reported across the globe. Disease prevalence under warm weather causing upto 26-30% yield loss. Xcm infected plant show symptoms on seeds, stems, bolls and leaves at any stage of the growth by invading through wounds or stomata. The survival time of pathogen is about 22 months in seeds and can also live in crop debris throughout winter. Nutrients uptake from soil greatly affected by this disease and also impair water translocation. Therefore, use of resistant varieties is a control measure. Besides, there are chemical and plant extract options present in the management of bacterial blight disease in cotton.

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Introduction

Cotton belongs to *Gossypium* which is a genus of flower bearing plants, in Malvaceae family. (Ali, 2007) In the world, it is graded 1st among fiber and 2nd for oil seed crops (Gul *et al.*, 2014). Its genus comprises of 52 species in which tetraploid are *G. barbadense* and *G.hirsutum* while diploid genomes surrounds of *G. herbaceum* and *G. arboretum* (Bakhsh *et al.*, 2015). In more than 80 countries, *G. hirsutum* is of maximum cultivation among these species (Shakeel *et al.*, 2011). Moreover, in the worldwide production of cotton, *G. hirsutum* is ranked 1st, regards to yield and quality thus the share is 90%. However, in the production of the world's cotton the share of *G. herbaceum* and *G. arboreum* is 2%, whereas the rank of *G. barbadense* is 2nd and its share is 8% (Khan *et al.*, 2015). In the recent growing season of 2018 and 2019, cotton seeds were implanted over a vast area of 2373 thousand ha. About 110 million bales of cotton were produced worldwide annually and 9.861 million bales were produced only from Pakistan. This crop also has its remarkable value in oilseed industry (GOP, 2018-19). *Gossypium hirsutum* seed is typically an oilseed and a good quantity of oil extracted from cotton seed is utilized in manufacturing of soaps and vegetable oil etc (Proto *et al.,* 2000). Approximately 23% quality protein and 21% oil contents are supplemented by cottonseeds (Sunilkumar *et al.*, 2006). Several living and non-living factors are responsible for its poor quality and yield. Many diseases attack on cotton crop but bacterial blight of cotton is a potential danger for its production which is caused by *Xanthomonas citri* pv. *malvacearum* (Xcm) (Shah *et al.*, 2010).

The current study focused on the effect of bacterial blight disease on cotton plant which greatly reduces the ionic contents and cause great yield loss but different management strategies used to control or overcome this disease discussed below.

History

Xanthomonas citri pv. *Malvacearum* pathogen at first was reported in 1892 in Alabama, USA (Atkinson, 1892). Its occurrence was firstly observed in Tamil Nadu in 1918 while in Pakistan, it was appeared in Burewala near Multan region (Evans, 1965). During 2003, a survey was conducted and observed the presence of bacterial blight in about 27 locations of cotton growing areas of Marathwada (Harlapur *et al.*, 2004). But generally it was present in subtropical and temperate region of the world. The extensive spreading of pathogen and high unevenness made its control more difficult (Kamal and Naim, 1983).

Symptoms

Xcm invades through wounds or stomata and causes infection at any growth stage. Initially spot like symptoms appear on leaves which are irregular, small and dark which later turns into dark brown (Liberato *et al.*, 2007). Early leaves and stem senescence, stunted plant growth and abrasions on bolls are the major symptoms of bacterial blight disease (Rungis *et al.*, 2002).When bacterium enter into leaves it cause hypersensitive reaction (HR) in many resistant plants in which tissues collapse, desiccation and necrosis occur after 24h (Delannoy *et al.*, 2005). It also caused black arm, defoliation, girdling, boll shedding, stem blighting and weakened stem. It greatly reduces its quality from lint staining leads to yield losses (Verma, 1986). Moreover, fruiting positions exposed to black arm lesions due to the fragile infectious stem (Innes 1983; Akello and Hillocks, 2002). The bacterium over-wintered on plant residue, seed and infected lint,even after harvest and have survival rate of 4 months on the seed lint and 22 months on the seed (Kirkpatrick and Rothrock, 2001).

Losses

The bacterial blight disease in cotton by bacteria is a devastating disease that causes major yield loss in rainy season (Delannoy *et al.*, 2005). Xcm is a pathogen of bacterial blight of cotton which requires high humidity for its proliferation and spread (Voloudakis *et al.*, 2006). Underfavorable environmental conditions it causes 40% yield losses and also exceed up to 50% (Verma, 1986). Yield loss different at different growing areas of the world upto 26-30% (Chattannavar *et al.*, 2006). The disease was most severe in semi-arid and sub-humid areas which practiced high rainfall (25.4-76.2mm), dust events and wind blowing during growing season of cotton (Kirkpatrick and Rothrock, 2001). Due to this disease, Asian countries faced 10 to 30% yield loss annually. In African countries it was recorded upto 50% (Bayles and Verhalen, 2007). About 40% yield losswas observed at Faisalabad district (Khan *et al.*, 1999). The disease invasion was at high relative humidity which favored spread and growth of the pathogen (Xcm) (Voloudakis *et al.*, 2006). During harvesting stage, disease ranges from 1-7% which rely on crop variety. In general, losses were less in leaves infection but in case of stem infection they increased up to 90% (Singh *et al.*, 2007).

Effect of bacterial blight on ionic contents and biochemical compounds

Biotic and abiotic stresses can affect yield and growth of cotton plant. Plants take up and utilize nutrients which lessen during stresses and diseases. So deficiency of plant mineral is compensated by nutrition management which changed plant responses to disease incidences (Walters and Bingham, 2007). In general, disease tolerance can be increased or decreased as nutrients might cause changes in plant growth characteristics (anatomical and chemical composition) (Athar *et al.*, 2011). Use of mineral nutrients to mitigate the disastrous effects of diseases on plants was proposed by numerous scientists (Hubler, 2012).

These nutrients also affect disease susceptibility through changes in metabolism and amplification of favorable environment for the development of disease. When a plant is infected by a pathogen, it causes alterations in the physiology of plant particularly in translocation, assimilation and utilization of mineral uptake. Nutrients become immobilized in the soil and in infected tissues due to pathogens. They utilizes nutrients, thus lowering their accessibility to the plant ultimately increasingthe chance for plants getting infected. Soil borne pathogens commonly infect plant roots and plant's vascular system, thus lessening the plant's ability of water and nutrients uptake from soil and impair nutrient or water translocation (Spann *et al.*, 2010).

Changes in ionic contents due to disease

Nitrogen is an essential nutrient for all plants obtained from soil and decaying organic matter. A huge amount of N was required by the plant for formation of different types of enzymes, proteins and structures and its presence in balanced form was helpful for resistance towards bacterial blight of cotton. Decrease in N quantity favored the occurrence of bacterial blight of cotton (Dordas, 2008). Low phosphorus quantity facilitated the growth and incidence of Xcm. Similar results were reported by Dordas (2008) who observed that low level of P favored the development of bacterial blight while its balanced application reduced the disease incidence.In infected susceptible genotype the phosphorus content reduces significantly while this reduction remain non-significant in resistant genotype. Sahi *et al.* (2007) also documented the decrease in phosphorus concentration in cotton which increases the pathogen attack. Decrease in K enhanced the severity of bacterial blight by favoring the growth of Xcm (Mishra *et al.*, 2005; Dordas, 2008). Balanced amount of K in plants and soil boost up resistance in plants and also help plants to produce different types of physiological and biochemical resistance abilities against Xcm (Sharma and Duveiller, 2004; Mishra *et al.*, 2005). Diseased leaves of susceptible genotypes have less calcium accumulation and they show severe symptoms like crinkling and puckering as in contrast to healthy leaves. While leaves of inoculated plants of resistant genotype have also reduced calcium accumulation but are lower as compared to the susceptible genotype. Plants absorbed calcium as a Ca^{2+} form and played a significant role in stimulation of roots and leaf development, microbial activity and uptake of other nutrients.

It prevented the penetration of pathogens and developed resistance in host plant which strengthened plant structure (Mishra *et al.*, 2005). Reduction in Ca^{2+} was observed in inoculated leaves of resistant and susceptible cultivars of cotton which enhanced the disease (Marschner, 1995; Mishra *et al.*, 2005). Mg was a vital element of structural tissues and takes part in different physiological and biochemical processes. It plays an important role in respiration, DNA and RNA formation, energy transfer reactions and also acts as a co-factor for many enzymes (Marschner, 2011). Due to Xcm attack it cause great reduction in Mg concentration in cotton leaves and leads to yield loss (Hubler, 2012) Zn plays a vital role in uptake and efficient use of water and worked as a catalyst in different metabolic and biochemical processes. It plays a significant role in starch and protein formation. Because Zn was an activator of *superoxide dismutase*, so it was involved in protection of membrane against reactive oxygen species (ROS) through detoxification of superoxide radicals and damaged membrane due to free radicals which led to leakage of membrane which favored pathogenesis (Cakmak, 2000).

Low level of Zn increases severity of disease due to accumulation of amino acids and reducing sugars, which helped in disintegration of plasma membrane and increased pathogenesis (Dordas, 2008). Chlorophyll contains iron which plays a key role in metabolism of nucleic acids. Reduction in iron content reduces chlorophyll contents of plants (Imran and Gurmani, 2011). Fe^{2+} concentration was decreased due to bacterial attack because plant pathogens generally had higher requirement of Fe^{2+} and acted as virulence factor during the course of disease development because Fe^{2+} activated the enzymes which were involved in the infection process of the host by the pathogen (Dordas, 2008). Copper is an imperative component of lignin and has a key role in protein and carbohydrate metabolism and acted as catalyst in different metabolic activities of the plant (Imran and Gurmani, 2011). When plant becomes infected, its defense system activated and starts secreting certain types of phenolics and flavonides both at the infection site and away from the site. Productions of these substances were controlled by nutrients of the plant. Therefore, shortage of elements like Cu, Fe, K and Zn were take place at the infection site.

Changes in biochemical compounds due to disease

Development stages of plants and their biological processes were influenced by total chlorophyll and the proportion of its components. Decrease in chlorophyll contents with the increase in disease incidence. (Sain and Gour, 2008). The quantity of total sugar were significantly higher in healthy leaves of the highly susceptible cotton than those of resistant and immune cotton cultivars/varieties. The total sugar concentration decreased much faster as a result of infection in susceptible plants than in the resistant plants (Chakrabarthy *et al.*, 2002) It was also observed that there was decline in the total sugar content in the non-Bt genotypes due to attack of Xcm (Govindappa, 2007). Total soluble phenol was present in more concentration in susceptible plants in contrast to the resistant ones. Due to attack of bacterial blight disease, there was an increase in total soluble phenols. Enhanced level of total soluble phenols advocated a preliminary effort by the host defense towards Xcm (Kumar *et al.*, 2013) Gallet *et al.* (2004) showed a substantive increase in phenolics and flavonoids in the leaves of highly resistant varieties. The induced accumulation of phenolics during infection protects the plant from further invasion and growth of the pathogens population. Decrease in protein contents indicated that bacterial infection increased and pathological, physiological and biochemical characterization of *Xanthomonas citri* and concluded that bacteria not only decrease protein contents of the host plant but also causes decrease in total nitrogen, chlorophyll and sugar contents (Sain and Gour, 2008).

Management

Several environments friendly managements against bacterial blight of cotton are used which reduce the use of chemicals by placing more dependence on resistant varieties, use of plant extracts and other non-chemical methods. Use of the resistant cultivars is the most efficient and eco-friendly method for the management of bacterial blight of cotton (Iglesias *et al.*, 2010; Jacobs *et al.*, 2010).

Through chemicals

Streptomycin at the concentration 100ppm with 0.3% copper-oxy chloride was found most effective against bacterial blight of cotton (Pathak, *et al.*, 2006).

Chattannvar *et al.* (2006) evaluated seven fungicides (copper oxychloride, wettable Sulphur propineb, mancozeb, carbendazim, ziramand and tridmorph which were sprayed thrice at 15 days interval for the control of bacterial blight disease. Singh *et al.* (2007) evaluated twelve fungicides and two antibiotics against bacterial blight disease. Among all chemicals streptomycin sulphate expressed significant results both in vivo and in vitro. The same kind of results were also reported by Jagtap *et al.* (2012). Efficacy of various chemicals i.e. streptomycin sulphate, Bordeaux mixture and copper oxychloride was evaluated against bacterial blight of cotton. These chemical were applied alone and with combination to each other. Result revealed that Copper oxychloride was efficient and gave significant results for the controlling of bacterial blight as compared to other chemicals (Sana *et al.*, 2012).

Through extracts

In managing the plant diseases and microbial contaminations effectively, pesticides have made great contribution in several agricultural commodities. Toxicity of such synthetic pesticides may harm the life supporting systems if used in continuous and excess amount (Campos *et al.*, 2005). Therefore, there was need for some other agents alternative to such toxic synthetic pathogens for the management of pathogenic microorganisms (Mahajan and Das, 2003).

Thus a green plant represents a pool of effective chemotherapeutants and can give worthy sources of natural pesticides (Gibbons, 2005). Reports are present where such active agents from higher plants are used instead of chemical fungicides, which are more systemic, non-phytotoxic, and easily biodegradable (Gottlieb *et al.*, 2002). Neem (*Azadirachta indica*) is an antifeedant and antimicrobial which acts as a biopesticide and as antifeedant i.e. when a pathogen feed on the leaf which is treated with neem product, the presence of azadirachtin, salanin and melandriol, decreased the activity of pathogen as the pest does not feed the neem treated surface(Lokanadhan *et al.*, 2012). Tobacco (*Nicotiana tabacum*), is an alkaloid (active ingredient is nicotine) present in vacuoles of leaves of tobacco plant, transported from roots where it is produced. These toxic molecules disturbthe pathogenic metabolism and cellular structure, bind to salivary proteins and digestive enzymes including trypsin and chymotrypsin resulting in inactivation of pathogenic protein (Freeman and Beattie, 2008). Khan *et al.* (2000) managed bacterial blight of cotton by applying plant extracts through application of Neem seed oil (*A. indica*), leaf extracts of *Datura alba* and neem seed bitter at three different concentrations 1, 2 and 3% against the development of Xcm in lab and green house. *Datura alba* reduces the development of bacteria at 3% concentration as compared to others. Neem (*A. indica*) had complex tetranortri-terpenoid limonoid which was responsible for toxic effects pest repellent and pest reproduction controller (Saadabi *et al.*, 2006). Various types of compounds such as ascorbic acid, flavonoids, phenolics and carotenoids are present in Moringa leaves thus making it a natural source of antioxidants (Anwar *et al.*, 2005). Sajid *et al.* (2013) evaluated different plant extracts against growth of Xcm and found that maximum inhibition of bacterial growth was expressed by *N. tabacum*. Effect of Drava on angular leaf spot of cotton sowing resulted in decaying of blight (Vinay *et al.*, 2007).

Management of disease through plant extracts had been reported by different scientists in different crops because these are environment friendly. Effectiveness of different plant extracts having various concentrations were checked in an experiment namely *Moringa oleifera* (Sohangna), *Azadirachta indica* (Neem), *Mangifera indica* (Mango), *Mentha piperita* (Mint), *Aloe vera* (Gavargandal), *Syzygium cumini* (Jaman) and *Citrus limon* (Lemon) against colony growth of Xcm though poisoned food technique. Three replications were set for each plant extract with concentrations of 05, 25, 50 and 75ppm. The results showed that *Mentha piperita*, *Aloe vera, Azadirachta indica* and *Syzygium cumini* showed encouraging results under in-vitro conditions against the infectivity of Xcm at all the tested concentrations (Hasan *et al.*, 2014).

Induced resistance

A new research in which systematic resistance is acquired against many diseases of plants caused by pathogens with the help of artificial molecules of lower molecular weights, aiding the defense mechanism of plants. Against the diseases in which infection occurs by various microorganismsi.e. bacterial, viral and fungal infection causing agents, offering a systematic resistance against continuous infection, this systemic acquired resistance (SAR) is the most important component of plant defense (Gaffney *et al*., 1993). To enhance the cotton plant's resistance against bacteria, Ahn *et al.* (2005) successfully used chemical salicylhydroxamic acid, cadmium, salicylic acid, riboflavin, antimycin A, 2,6-dichloroisonicotinic acid and vitamin B1. An eco-friendly alternative, non-biocide and non-conventional approach where the disease control would not be achieved by synthesizedtoxic chemicals but by induced resistance, for the protection of plants against the pathogen causing disease(Soylu *et al*., 2003). Induced resistance is usually dependent on the pressure enforced by plant and presence of a pathogen on the site of infection. Systemic induced resistance (SIR) produced by the use of nutrients is a substitute approach to decrease the seriousness of disease. Furthermore, there is a product that hasacibenzolar-S-methyl (actigard) is now available commercially which triggered the response of defense mechanism against the enhancement of pathogen. The chemical as the best SIR can control the adverse pathogenic effect on host. In addition to these macronutrients, micronutrients can also be used in NPK fertilizers to control the disease (Cristos, 2008). Blowing sand was a general means to disseminate the pathogen. Dust and storms firstly produced wounds in the tissues of the plant which later cause infection in plants. For pathogen transmission, seeds, machines, insects and animals are also responsible (Thaxton *et al*., 2001).

Moreover, resistant varieties also avoid the damage caused by other management strategies like acid delinting of seed and use of synthetic chemicals (Thaxton *et al*., 2001). In the absence of durable resistance in varieties, seed treatment with chemicals or acid delinting is recommended due to its quick action and readily availability (Singh *et al*., 2007). Although use of synthetic chemical is easy, direct and rapid means of controlling the disease but the continuous dependence on pesticides raise the problem of environmental pollution and degradation. So, there is a dire need to find the alternative of this method which is environment friendly and cost effective approach. Plant extracts can also use as an alternative of synthetic chemicals as these are non-phytotoxic, more systemic and easily biodegradable (Gottlieb *et al*., 2002). Plant extracts have minimal harmful effects on environment and human health as compared to the synthetic pesticides. Plant extract that based on therapeutics affect are easily available and cost effective (Kiran and Raveesha, 2006).

Future prospects

- Induce resistance against bacteria by modifying it genetically or by Recombinant DNA Technology methods by which we can insert genes that can produce expression causing resistance against bacteria.
- We can also avoid the disease by changing the cultivation pattern by changing planting time, planting locations and system of cultivation temporarily
- Elimination of over wintering pathogens by some methods like Quarantine, maintaining hygiene, seed cleaning, rotation, species treatment or by physical methods
- By improving the standards of healthy agri-ecosystems

Conclusion

It is concluded that all above mentioned measures can be implemented for the control of bacterial blight disease depending upon the conditions. Only way to check the disease is production and commercial cultivation of the bacterial blight resistant varieties. However, losses can be minimized by the cultivation of highly tolerant and tolerant varieties which are available for general cultivation.

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