Chapter 1

Introduction

Sugarcane

Sugarcane is an important commercial crop grown over an area of about 5.0 million hectares (Mha) in India. It is being cultivated in almost all the states except those in mountain ranges. About 500 sugar mills utilize nearly 50% of sugarcane produced in the country, producing 20-22 million tonnes (Mt) of white sugar. About 40% of cane is being utilized by “Jaggery” and “Khandsari” making units. Sugarcane has contributed in developing Indian economy of way of sourcing Rs. 15,000 crores every year (Srivastava, 2006; Solomon, 2011).

The cultivated varieties of sugarcane in India and abroad are interspecies of *Saccharum* involving of *S. officinarum*, *S. barberi* and *S. spontaneum* and the somatic chromosome number (2n) varies from 100 to 120. It is for this reason that the sugarcane varieties are botanically described as *Saccharum spp.* complex hybrid.

Sugarcane (*Saccharum sp. hybrids*) is the most important cash cum industrial crop of the tropical and sub tropical areas of the world. It provides useful raw material to industries which utilize its different part to produce sugar, Jaggery (Gur), Khandsari and a number of agro-byproducts viz; alcohol, paper, chemical, ethanol, cattle feed and electricity for socio-economic development of rural masses and national economy by providing direct and indirect employment about 35 million people in our country. Owing to its perennial nature and dependable and remunerative crop, it is considered as the backbone of farmers.

Sugar industry is the second largest agro-based industry in India and contributes significantly to the socioeconomic development of rural population. It supports 50 million farmers and their families and provides direct employment to over 0.5 million skilled and semi-skilled persons in sugar mills and integrated industries. The Indian sugar industry plays a leading role in global sugar market being the world’s second largest producer after Brazil, producing nearly 15 and 25% of global sugar and sugarcane, respectively. The sugar industry which encompasses 599 operating sugar mills, 309 distilleries and 180 cogeneration plant and numerous pulp, paper and chemical making units is supported by four leading sugarcane
research institutions, twenty-two state sugarcane research stations, world class sugar machinery manufacturers, suppliers and technical experts. Currently, the industry produces around 300–350 Mt cane, 20–22 Mt white sugar and 6–8 Mt jaggery and khandsari to meet the domestic consumption of sweeteners (Solomon, 2011). Besides, about 2.7 billion liters of alcohol and 2,300 MW power and many chemicals are also produced. The industry is able to export around 1,300 MW of power to the grid. Indian sugar industry is fully capable of meeting demand of potable alcohol as well as 10% blending in gasoline. Industry is gradually transforming into sugar complexes by producing sugar, bio-electricity, bio-ethanol, bio-manure and chemicals; these contribute about 1% to the National GDP. Emerging businesses like fuel ethanol, raw sugar and structural changes in global market have provided new horizons for the Indian sugar industry. The sector today has transformational opportunities that would enable it not only to continue to service the largest domestic markets but has also emerged as a significant carbon credit and green power producer and has the potential to support an ethanol blending programme of E10 and beyond (Solomon, 2011). The bulk of the Indian sugarcane cultivation and hence location of the sugar mills is in the states of Uttar Pradesh, Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh, Gujarat, Punjab, Haryana and Bihar. The annual production in the range of 300 to 350 million tons of sugarcane out of which about 30% is used for gur and chewing purposes and balance for producing sugar.

In India, Uttar Pradesh occupies a premier position of sugarcane cultivation accounting for 42.22 and 30.02% of the area and production, respectively. Average cane yield of Uttar Pradesh (58.2 Mt/ha) is lower than the national average (66.9 Mt/ha). Similar to yield, sugar recovery in Uttar Pradesh is also lower 9.51% than the national average (10.27%). Besides the important reasons for the low cane yield in Uttar Pradesh, are the climatic factors like short duration for growth and maturity (8-12 months) of the crop than tropical states (12-16 months) and having extreme weather in different months of a year.

**Diseases of sugarcane**

Being as cash crop and playing major role in sugarcane economy in India this crop has affected by several pathogens viz; virus, phytoplasma, fungus and bacteria. About one hundred diseases of sugarcane caused by fungi, bacteria, viruses, phytoplasma and nematodes have been reported from different parts of the world (Agnihotri, 1990; Rott et al., 2000) and sixty diseases have been reported from India (Rao and Viswanathan, 2000; Viswanathan and Rao, 2011 ). Among the fungal diseases, the important ones are red rot (*Colletotrichum falcatum* Went.), wilt (*Fusarium moniliforme* Sheldon), downy mildew (*Peronosclerospora*
sacchari (T. Miyake, Shirai & K. Hara), eye spots (Biopolaris sacchari (But1.), Shoemaker; Curvularia lunata Boedijn, C. pallescens (Tsuada & Ueyama) Sivan., pineapple disease (Ceratocystis paradoxa, Dade Moreau), smut (Sporisorium scitamineum), rust (Puccinia erianthi Padw. & Khan) and various leaf spots (Periconia atropurpurea (Berk & Curt.) Litinov, Rhizoctonia solani Kuhn, Piricularia oryzae Cav. etc.

Red-rot disease of sugarcane

In fungal diseases red rot disease which is known as ‘Cancer’ of the sugarcane is most important one and the oldest and dreaded disease affecting adversely the production of millable canes. The disease is caused by the fungus Colletotrichum falcatum Went (Perfect state: Glomerella tucumanesis (Speg.) Arx and Muller). It was first reported and described from Java in 1893 and within a decade it was reported in several other countries; India (1901), West Indies (1904), Hawaii (1908), USA (1910), Australia (1925) etc. The disease was first observed in India by Barber (1901) in the cultivar Red Mauritius in the Godavari delta of Andhra Pradesh. Butler (1906), the Imperial Mycologist, critically studied this devastating disease in relation to the causal organism and its portals of entry into the cane stalk (Viswanathan, 2010; Singh and Singh, 1989).

The havoc of red rot epidemic in Gangetic plains during 1938-41 resulted in the widespread failure of Co 213, the chief commercial variety of the tract. Several sugar factories in the badly affected areas could crush only one-third of their normal “crush” of cane owing to poor supplies. Sudden and complete failure of many promising varieties reported, which had faithfully served the cane sugar industry in India for nearly one decade, over such a wide area in a tract where it had flourished for several years (Chona, 1980). The sub-continent faced many such red rot epidemics in the past resulting in elimination of many popular sugarcane varieties from cultivation (Viswanathan and Samiyappan, 1999, 2000; Duttamajumder, 2002; Viswanathan, 2010). These epidemics happened when the ruling varieties previously rated as resistant succumb to the disease owing to the development of new variants.

Red rot may affect any of the vegetative parts of sugarcane plant but is of principal importance, as a disease of standing stalks and the planting seed pieces or seed sets. The diagnostic symptoms of the disease is best seen by splitting the stalk longitudinally, where the affected tissues show characteristic slightly acidic, alcoholic odour and dull red appearance, interrupted by occasional white patches stretched at right angles to the long axis of the stalk.
Amongst the major limiting factors red rot of sugarcane incited by *Colletotrichum falcatum* Went.; is the most serious and devastating disease not only in Uttar Pradesh but in the whole of the Northern subtropical belt of India. It is chiefly a stalk disease. The injury to stalks of susceptible varieties is sometimes so severe that translocation of the sap to the leaves is interrupted. It is one of the most widespread sugarcane diseases in the country and has been a constraint for sugarcane productivity for the past 100 years in India. The disease is responsible for the elimination of many commercial varieties in India in the earlier decades. Epidemics of the disease have been very common ever since its occurrence in India. Currently the disease occurs in all the sugarcane growing states in India except Karnataka and Maharashtra states. Recently reports of red rot occurrence in CoC 671 in parts of Kolhapur and Solapur Districts in Maharashtra were reported. In the recent years break down cultivars, viz. CoS 8436, CoSe 95422, 92423 and BO 138, the important commercial varieties of subtropical region to red rot occurred. Severe damage to crop stand is found in these varieties due to disease epidemics in the states of Haryana, Uttar Pradesh and Bihar (Viswanathan and Rao, 2011).

The pathogen is mainly sett-borne (enter in the field along with the planting material) and thus affects the cane plant from the germination. The damage starts with germination failure, settling mortality to the dying of the full-grown cane. In full-grown cane the disease appears as the yellowing of the crown leaves. On splitting open the cane of such affected plants, interrupted red and white patches (white spot) along with sour alcoholic odour. In later stage numerous acervuli develops on the rind. The pathogen mainly spreads during the rainy season and if environment favors it can wipe out entire sugarcane plantation.

The infected cane sets carry the primary infection to the field. Depending on the nature of infection and availability of favorable environment, pathogen starts taking toll by killing the bud. This affects the germination and initial establishment of the crop. Poor germination leads to a gappy crop stand and reduction in yield. If, at all, the buds of the infected sets are able to sprout and grow, then above ground symptoms appear. The type of symptoms varies depending on the prevailing weather conditions. At first, symptoms appear as the death of young and emerging shoots without any conspicuous identifiable symptom (in March-April-May in north Indian condition, spring planting). Occasionally spindle infection also appears with heavy sporulation. However, in ratoon crop spindle infection appears much earlier. The dying symptoms are often confused with the damage of young shoots by rats / termites, especially in the ratoon crops. However, a close microscopic examination of these dying
shoots, if affected due to red rot reveals the presence of fruiting structure of *C. falcatum* in the form of acervuli and chlamydospores in the leaf folds. The seed piece transmissible red rot disease is one of the oldest known diseases of sugarcane and has a far-reaching influence on the economics of sugar production in several countries (Viswanathan, 2010).

The perfect stage of *C. falcatum* Went. has been described as *Physalospora (Glomerella) tucumanensis* Spegazzini, Arx and Muller. Infection of the disease is caused wither by spores or ascospores. The pathogen makes its entry into the host tissues through any sort of injury infected by insects or borer or natural growth cracks, leaf scars, bud or root primordial at the nodal region. After the entry, the infection thread develops a normal hypha which grows within the host tissues for some time and then emerges out through the cells to the outer surface and develops acervuli. Rains and heavy dews usually wash the acervuli developed on nodes and internodes and the spores get lodged around the nodes behind the leaf sheath. The spores germinate and the mycelium gets established in bud scales, root primordial or leaf scars and later within the plant tissues. The spores are hyaline, one celled, falcate or sickle shaped, with one end slightly blunt and the other end pointed. The acervuli possess pink spore mass and long black setae (Duttamajumder, 2008).

Strains or biological races of the fungus have been found to occur that differ in pathogenicity or virulence towards different sugarcane varieties. Chlamydospores are also formed by the fungus on the surface of the stalk, within the cane tissues or culture media. These remain viable for sometime. They germinate to form infection thread capable of penetrating unbroken surfaces and tissues of the cane plant (Edgerton and Carvajal, 1944; Viswanathan, 2010).

Transmission of the disease is chiefly by the spores produced externally on internodes which are disseminated by rain, dew drops or by air. The infection also occurs through the movement of air disseminated spores during strong wind currents or rain flush. Irrigation water is also a source for spread of the disease. Infection in planted sets occurs from the soil or cane debris present in the soil. The fungus does not survive long in the soil without host and is not a true soil borne fungus.

The disease is currently managed through host resistance, as fungicides do not get adequate entry (conc. is less to effect eradication) into the stalk. Application of biocontrol agents like *Trichoderma* has shown promise in the containment of the disease through antibiosis and induced systemic resistance (Viswanathan, 2010). Agrochemical practices, use of resistant varieties and thermotherapy of infected cane sets are usually adopted as
prophylactic measures to reduce the chances of red rot epiphytotics. During recent years, a large number of red rot resistant/tolerant varieties have been developed but as soon as a resistant variety is released for commercial cultivation, it soon becomes susceptible to red rot due to development of new races of the pathogen causing breakdown of resistance (Waraitch, 1984, Viswantahan and Rao, 2011). According to Satyavir (1994) knowledge about the variability of the pathogen in nature is a pre-requisite for developing resistance variety against red rot.

Since, new races of red rot pathogen appear regularly in nature due to mutation, heterocaryosis and parasexuality, it is necessary for pathologists to keep a constant watch on such new races, so that the information may be exploited for breeding resistance against the evolved mutant.

Different isolates of red rot pathogens of Uttar Pradesh, India have not yet been satisfactory classified and characterized. Consequently, we still do not have precise measures for their quick identification in field as well as in applying quarantine measures. The present study was planned with an attempt to study the diversity among red rot pathogens isolates affecting commercial grown cultivars in Uttar Pradesh based on their cultural, morphological, and molecular characteristics. This characterization of sugarcane red rot isolates affecting sugarcane varieties in Uttar Pradesh would facilitates the authentic identification of existing red rot isolates, which would serve as exact yet handy measure for quick detection of these pathogens in field laboratories and at quarantine centers. Molecular variability information of red rot isolates at sequence level is also scanty; therefore, there is also need to characterize the isolates through molecular techniques. This will give the exact scenario of the diversity of the isolates found in the Uttar Pradesh.

Aims and objective

- Survey of sugarcane fields of Uttar Pradesh, India for collection of different isolates of *Colletotrichum falcatum*; Maintenance of isolates in culture; Study of cultural characteristics of *C. falcatum* isolates.
- Morphological studies of isolates of *C. falcatum*; Pathogenicity of different isolates on a set of host differentials.
- Isolation of protein from mycelium, SDS PAGE analysis for separation of protein profiles; Grouping of identified isolates of *C. falcatum* and preparation of their distribution map in Uttar Pradesh.
Preparation of polyclonal antisera of different isolates of *C. falcatum*, Serological characterization of different fungal isolates on the basis of ELISA; Categorization on collected isolates in different virulent and non-virulent group on the basis of their biological and serological properties.

**Expected deliverables / outcome**

Since the red rot pathogen is causing significant alarming losses to our important commercial sugarcane cultivars all around the country, the development of knowledge on morphological and pathogenic variability of red rot isolates would provide a handy and authentic diagnosis of these pathogens at very early stage.

Different isolates of red rot pathogens of Uttar Pradesh, India have not yet been satisfactory classified and characterized. Consequently, we still do not have precise measures for their quick identification in field as well as in applying quarantine measures. The proposed work envisages developing an exact classification of existing isolates of *Colletotrichum falcum* occurring in Uttar Pradesh based on their cultural, morphological, biochemical, protein and molecular profile characteristics. This characterization of Indian sugarcane red rot isolates would facilitates the authentic identification, which would serve as exact yet handy measure for quick detection of these pathogens in field laboratories and at quarantine centers.

**References**


