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Editorial

Sustainable sugarcane production in India by managing major fungal diseases

Sugarcane is a major field crop essentially grown for sugar and other sweeteners in India and in many other tropical and subtropical countries. Sugarcane meets nearly 80% of white sugar requirement across the globe. In India, the crop is grown in ~5.2 M Ha across the states except J&K and Himachal Pradesh states. Sugarcane occupies 2.57% of the gross cropped area in the country and supporting about seven million farmers and their families, along with workers and entrepreneurs of over 550 sugar mills. In the country, sugar is an essential item of mass consumption and sugar and *jaggery* are the inexpensive source of energy, supplying ~10% of the daily calorie intake. Annually, sugarcane production is in the range of 370–400 million tons (MT) with white sugar production of 27–30 MT and 6–8 MT of *jaggery* and *khandsari*. Further, sugar industry generates ~3.2 billion litres of alcohol and 4700 MW of power and supports production of many downstream chemicals. Recently, the industry has supported Government of India's new biofuel policy of ethanol blending in petrol and achieved 12% blending target this year. This effort has also saved millions of foreign exchange.

Sugarcane is propagated through stalk cuttings referred, as 'setts' and after harvesting the plant crops, subsequent crops (ratoons) are raised from the stubbles. By this way, sugarcane is grown as a plantation crop for several seasons. However, under Indian conditions, usually one plant crop followed by two ratoons are taken up. Major reason for discontinuing ratoon crops is fall in cane yield in ratoon crops due to various diseases. Sugarcane diseases caused by fungi, bacteria, viruses, phytoplasma and nematodes seriously affect cane productivity in ratoons, hence multi-ratooning of sugarcane has become unsustainable in the country. Vegetative propagation favours carryover of various diseases through setts and infected setts serve as primary source for various diseases. Major fungal diseases affecting sugarcane in the country are red rot, wilt and smut and these diseases affect stalks that are the store house of sugar and economically valuable. Other than these diseases, twisted top (pokkah boeng), sett rot (pineapple disease), rusts and other foliar diseases are of great concern in different regions.

Red rot(*Colletotrichum falcatum* Went) is one of the most widespread sugarcane diseases in the country and it has been a constraint for more than 120 years in India and other South Asian countries. The first severe red rot epiphytotics was recorded during 1890s in the then Madras Presidency, where many of the imported *Saccharum officinarum* (noble canes) clones from Java were devastated. Dr. C.A. Barber, the Imperial Botanist of Madras Presidency investigated and identified red rot as the cause for crop losses. During the same time, Dr E.J. Butler, the Imperial Mycologist while working at Pusa (Bihar) discovered the disease in the subtropics and studied the life cycle of the disease. The task of managing red rot was assigned to Dr. Barber and his efforts led to establishing the present Sugarcane Breeding Institute (SBI) at Coimbatore in 1912 to breed sugarcane varieties resistant to red rot. As the founder Director of the Institute, he spearheaded sugarcane breeding in the country with his assistant Sir T.S. Venkatraman and developed inter-specific hybrids involving *S. officinarum* and its wild relative *S. spontaneum*. Their efforts led to developing the first hybrid sugarcane variety 'Co 205' and it was released for cultivation in Punjab in 1918. Coimbatore location was chosen for sugarcane breeding due to its favourable climate for flowering and abundant seed set, the initiative taken up during 1912 has been expanded now,and ICAR-SBI became the nodal centre for sugarcane breeding in the country. The institute supports all the 24 sugarcane research centres in the country to make desirable crosses and varietal selection for their regions. After Co 205, several varieties were introduced for cultivation in the country during different decades, they replaced all the poor yielding native clones of *S. barberi* in the subtropics, and thick *S. officinarum* clones in the tropics. The new varieties brought a sugar revolution in the country and India achieved self-sustainability in sugarand other sweeteners. However, red rot caused failure of important commercial varieties like Co 312, Co 419, Co 453, Co 658, Co 997, Co 1148, Co 6304, Co 7805, CoC 671, CoC 85061, CoC 92061, CoJ 64, CoLk 8102, CoS 8436, SoSe 92423, CoSe 95422 etc in different decades. Currently, the disease occurs in all the sugarcane growing states in India except Karnataka and Maharashtra states, more severely in the states of Uttar Pradesh and Bihar. In addition to losses to crop productivity, the infected stalks become unfit for milling due to inversion of sucrose

to reducing sugars. In the advanced stages of infections, entire stool dries up. Reddish patches of internal tissues with horizontal white spots are characteristic symptoms of red rot. Later, the affected canes show hollow pith cavities with dark grey mycelial growth of the fungal pathogen. Varietal resistance is the major strategy by which the disease is managed; therefore red rot resistance is a prerequisite for a sugarcane variety for its commercial release and cultivation. Hence, sugarcane breeding revolves around red rot resistance in the country. Sugarcane Pathology group at SBI developed efficient varietal screening procedures and identified resistant parents, germplasm and varieties. Varietal breakdown i.e. loss of resistance to *C. falcatum* in the commercial varieties were common during different decades, by which, hitherto resistant varieties succumbed to new variants of the pathogen. New *C. falcatum* variants emerge after each of the epidemic variants were characterized and categorized into ~13 *C. falcatum* pathotypes so far, and the designated pathotypes are used for red rot screening at different centres. Recently, complete genome and transcriptome of *C. falcatum* were reported from India for the first time.

Smut disease is caused by the fungus *Sporisorium scitamineum* (Syd.) M. Piepenbr., M. Stoll & Oberw. 2002 (Syn: *Ustilago scitaminea* H. & P. Sydow).In India, Dr Butler first reported the disease during 1906 in Bengal Presidency. The disease-affected stools are characterized by conversation of growing apex toa long blackish whip of 1 to 1.5 m. Affected clumps show profuse tillering with lanky tillerswith smut ships and sometimes smut whips are produced from axillary buds. The infected plants within a field often arise from planting systemically infected setts or from ratoons of infected stools of previous crop. The disease is very well adapted to aerial dispersal and spread. The disease prevails throughout the country and disease severity usually increases through ratoon crops. Like red rot, robust varietal screening is followed in the country and the disease is managed through host resistance.

Fusarium sacchari (E.J. Butler) W. Gams is the causative fungus of wilt in sugarcane. Dr. E.J. Butler first reported the disease during 1913 from Bihar. Currently, the disease occurs throughout the country and extensive crop losses are reported from UP and Bihar. Wilt affected stools turn yellowish and finally dry as in the case of red rot and internal tissue turns dull brown with linear pith cavities and desiccation. In red rot endemic regions, *F. sacchari* follows *C. falcatum* infection in the stalks and such combined infections cause severe crop losses as compared to their separate infections. Wilt fungi are weak soil borne pathogens. Abiotic factors like drought, waterlogging, drought followed by water logging weaken the root system and predisposes the plant for wilt infection. Subterranean soil pests such as white grub, insect pests like root/ stalk borers, mealy bug, scale insect, fungal pathogen like red rot weakens the plant and root system aggravate *F. sacchari* infection. Wilt has caused significant losses in India where several epidemics have occurred. It is responsible for the elimination of many popular varieties from cultivation. Wilt is very common in certain locations where conducive environment like the delta regions and subtropical plains, and susceptible hosts are available. Wilt incidence is always higher in ratoon crops compared with the plant crop. Earlier, it was thought that the disease occurs during maturity stages of the crop however, it is now established that the disease occurs during germination onwards and cause death of the germinated settlings or young plants.

Twisted top (*Pokkah boeng*) disease (TTD) occurs throughout the world and severe forms of the disease are recorded in high humidity areas in India. *Fusarium verticillioides* and *F. sacchari* are the causative fungi (Teleomorph:*Gibberella fujikuroi* (K. Sawada) H.W. Wollenweber). Recently, association of *F. proliferatum, F. andiyazi* and *F. nigamai* with the disease has been found in India. The disease manifests in two phases viz. twisted top (TT) and top rot (TR). The most common symptom is a malformed or twisted top, which gives this disease its name "*pokkah boeng*" from the Javanese language. Characteristic symptoms of the disease include pronounced wrinkling, twisting and shortening of the leaves in the spindle, chlorosis of leaf lamina on the proximal end or in twisted laminar regions and white mycelium on the affected laminawith longitudinal brownish streaks. In acute phase of the disease, top rot occurs due to killing of growing point. Upon recovery from the disease, varying intensities of retardation of internode growth, bud sprouting and 'knife-cut' symptoms on the stalks are observed. Recently, it was found that both the Fusarium diseases wilt and TTD are caused by the same fungal pathogen *F. sacchari*. This has added a new finding in epidemiology of the two diseases caused by *Fusarium*. Stalk infection of *F. sacchari* leads to foliar infections and *vice versa*. Such epidemiological behavior of the pathogen is also attributed to sudden emergence of TTD as a major disease in different states. This disease has been one of the examples of a minor disease suddenly becoming a major disease in India.

Sett rot (Pineapple disease)in sugarcane is caused by the fungal pathogen *Cerotocystis paradoxa.*It is common in germinating setts, where, the buds fail to sprout or sprouted settlings die. Usually, sett rot causes crop-free

patches in the field, hence the crop establishment is affected. Rotten parenchymatous tissues emit a stinky odour of pineapple, hencethe disease is referred as 'pineapple disease'. The disease is also found to cause damage to standing canes in the field. Severe waterlogging, lodging of canes and other stresses favour disease build up in the grown up crop in the field.

Apart from these stalk diseases, sugarcane encounters many foliar diseases such as rusts, eye spot, yellow spot, brown spot, brown stripe and ring spot in India. Among them, rusts considerably affect sugarcane in different states. Two rusts, brown and orange rusts caused by *Puccinia melanocephala* (Syd. &P.Syd)] and *P. kuehnii* (W.Kruger) E.J. Butler, respectively are regularly recorded on sugarcane. Among the two, brown rust occurs in epidemic form if susceptible varieties are grown in high humidity areas of Maharashtra, Karnataka, AP and Gujarat. Brown spot (*Cercospora longipes* E.J. Butler) is another foliar disease occurs in epidemic form and severely affects susceptible varieties like CoM 0265 in the areas of North Karnataka and South Maharashtra. Other foliar diseases of economic importance are brown stripe (*Bipolaris stenospilus,* teleomorph: *Cochliobolus stenospila*), eye spot (*Biploaris sacchari*), yellow spot (*Mycovellosiella koepkei*) and ring spot (*Leptosphaeria sacchari*). Unlike the stalk diseases, none of the foliar pathogens is sett-borne. High moisture or relative humidity following rains accompanied by low or cool temperatures favours their incidences. During this period, excess irrigation and non-removal of lower leaves leading to build up of high humidity within the crop. Such microclimatic conditions favour disease severity to epidemic levels. Overall, the pathogens causing foliar diseases are air borne and most of them survive on other collateral and weed hosts.

During the last several decades, many of these fungal diseases caused losses to several thousand crores of rupees to the farmers and industry in the country; however, many disease management strategies were developed time to time and the disease constraints were managed. Even today, a severe red rot epiphytotics on the popular cv Co 0238 occur in UP and Bihar, ravaging several thousands of hectares of sugarcane crop. New varieties with red rot resistance were developed and are being deployed to contain the disease. Impervious nature of cane rind to efficient fungicides, deep-seated fungal infections and nature of crop husbandry, prevent routine application of fungicides to manage these diseases. Recently, sett treatment with fungicides by mechanized sett treatment device was developed and this prevents pathogen infections from primary sources of inoculum. In addition, delivery of fungicides through drones and micro-irrigation systems has been standardized and put into use to manage the diseases in large areas. Biocontrol approaches are partly successful in managing red rot and wilt. Recently, molecular tools and NGS platform were applied in sugarcane pathology and these approaches brought out genomes/transcriptomes of *C. falcatum* and *S. sporisorium*, enhanced our understanding on the pathogens/ host-pathogen interactions, identified pathogenicity genes in *C. falcatum* and *S. sporisorium*, identified *F. sacchari* as the wilt associated pathogen etc. Continued research efforts using classical and modern tools have resolved many unresolved issues, developed efficient disease management strategies in sugarcane and opened new vistas in sugarcane pathology in the country.

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