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A REVIEW ON MAJOR DISEASES OF SUGARCANE (*Saccharum officinarum)* AND THEIR MANAGEMENT IN INDIA

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Abstract

Sugarcane (*Saccharum officinarum* L.), a vital cash crop in India and is the second crop producing of the world, faces substantial losses due to diseases like smut, red rot, and pineapple disease. Effective management strategies are imperative for sustainable cultivation. Breeding resistant varieties remains a cornerstone, complemented by cultural practices like sanitation and crop rotation. Chemical control, primarily fungicides and bactericides, is widely used, albeit with environmental concerns. Biological interventions, including biocontrol agents and beneficial microbes, offer promising eco-friendly alternatives. Integrated disease management approaches, incorporating multiple strategies, emerge as the most effective solution. Continued research and extension efforts are vital for mitigating disease impact and ensuring the longevity of sugarcane production in India.

***Index Terms*-sugarcane; major diseases; fungal diseases; bacterial diseases; viral diseases; Phytoplasmal disease; management; India.**

I . Introduction :

One of the important cash crops in India is sugarcane. India is the world's top producer, user and second largest exporter of sugar. In terms of area (4.91 mha), India is ranked first among the sugarcane growing countries worldwide, with production ranked second (69.5 tonnes/ha), despite the increase in substantial yield per hectare in our country, the productivity of sugarcane is still lower when compared to other countries. Various abiotic problems. such as water shortage, temperature differences, floods, nutritional lag, and alkalinity, are faced by the long duration crop. About fifty five diseases of sugarcane is mostly constrained by diseases of fungal, bacterial and viral and phytoplasmal origin. A reduction in the supply of raw material for sugarcane-

based industries is annually caused by an estimated loss in cane yield of about 10-15 per cent due to biotic stresses in India (Viswanathan and Rao, 2011).

Fungal diseases such as red rot, smut, pineapple, wilt, pokkah boeng, are observed in the most of the Sugarcane growing regions of the country. Red rot, regarded as the cancer of sugarcane, incites enormous damage to the sugarcane crop. Yield and sugar recovery are drastically reduced in susceptible varieties due to red rot (Satyavir, 2003, Sharma and Tamta, 2015). However, occasional outbreaks of red rot in the new genotypes of sugarcane are attributed to the emergence of new pathotypes in *Colletotrichum falcatum*, the red rot pathogen. Smut and wilt are observed as the other major fungal diseases in most of the sugarcane growing regions of the country. The height and girth of the cane, tillering ability of the plant, cane tonnage, total solids and sucrose content in cane juice, and the ratio of sugars to fiber are reduced by the incidence of smut, making sugar extraction difficult (Ramesh Sundar et al., 2012; Sandhu et al., 1969; Xiupeng et al., 2019). Similarly, sett germinability, number of tillers, number of millable cane, cane yield, juice quality, and commercial cane sugar are reduced by wilt infection in susceptible cultivars (Kumar et al., 2015). Pokkah boeng was not much noticeable disease, but from last few years, it is going to be major on basis of their rapid epidemiology is worrisome, From Uttar Pradesh, Sharma et al., 2014 during his survey in 2011-12 recorded Pokkah boeng incidences of 1.4-30%. Chlorosis is the very first symptom towards base of young leaves of Pokkah boeng affected sugarcane crop and due to this disease can be easily recognized.

Pineapple one of the sett borne and soil borne disease of the sugarcane. The symptoms associated with this organism include a smell of matured pineapple fruit, attributed to the production of ethyl acetate by the metabolic activity of the fungus (Coale 1989). The disease mainly affects the germination of the setts at early stages of planting and the most serious losses are through the failure of infected cuttings to germinate (Comstock et al. 1984), although standing cane may also become infected (Manzo 1975; Natarajan and Subba Raja 1976). In India the disease was reported from different varieties of the crop (Singh et al. 1990).

The bacterium primarily spreads through infected canes. Leaf-scald occurs in most regions where sugarcane is grown. It was first in South America in the 1940s (Hughes et al., 1964) and in southern Africa in the 1960s (Rott and Davis, 2000). As with ratoon stunting disease (RSD), disease infection can occur without symptoms being expressed, hence in the past leaf scald was probably often spread inadvertently during the exchange of varieties between countries (Ricaud et al., 1989). The stripes appear as water soaked, long, narrow chlorotic streaks and become reddish brown in few days. The bacterium also survives on sorghum, pearlmillet, maize, fingermillet and other species of *Saccharum.*

A major threat to a vegetatively propagated crop like sugarcane has been posed by viral diseases such as yellow leaf disease, sugarcane mosaic, due to the degeneration of popular sugarcane cultivars (Viswanathan et al., 2007).

Phytoplasmal disease like grassy shoot was found endemic to certain parts of the country and identified as the most important disease of sugarcane in India (Chona, 1958).

Sugarcane diseases often originate from either seeds or the soil, making them challenging to control once they have spread in the field, despite efforts with agro-chemicals. Worldwide, sugarcane crops suffer from a multitude of diseases, with approximately 10 of them deemed economically significant for specific countries or regions due to their direct impact. Various control measures can help diminish the incidence of these diseases. However, no single method proves entirely effective in controlling sugarcane diseases. Integrated disease management, which incorporates agronomical, cultural, and chemical and biological control measures, emerges as the most appropriate strategy for handling all the diseases.

II Major Diseases and their management:

Name of Diseases/ Causal organism	**Susceptible varieties**	**Epidemiology**	**Symptomology**	**Management And Control**	**References**
Fungal Diseases of sugercane					
1.Red rot (*Colletotrichum falcatum*)	CoS 8436, CoSe95422 BO138	Inoculum transmission primarily occurs through, Sett borne inoculum, spread via irrigation, rain, wind. (PCR) techniques are utilized for accurate detection of *C. Falcatum.*	Initial symptoms manifest as purple coloration on nodes, later progressing to reddish-brown patches Internodes.(Fig. 1)	Limited success with fungicides due to rind imperviousness and pathogen variability. Techniques like moist hot air therapy have proven effective in eliminating sett-borne infection. Prophylactic Measures focus on reducing pathogen build-up with Integrated disease management (IDM) recommended.	Agnihotri (1996); Anonymous (1980); Singh et al. Bharadwaj and Sahu (2014); Viswanathan et al.(2010).

				Species like *Trichoderma* spp. Particularly *T. Harzianum* and *T. Viride* show promise in bilological control by producing chitinase enzymes Essential oils and plant extracts.	
2.Smut (*Ustilago scitaminea)*	Co 1158, Co 740	Favorable conditions, such as hot, dry, weather ,contribute to increased whip development frequency. PCR techniques, especially nested-PCR, are widely used for rapid, specific and sensitive detection.	Crown leaves shorten and point, forming a fan-like structure, while affected plants exhibit thinning with elongated internodes. Whip-like structures (Fig 2), reaching up to 1m, initially covered with a silvery membrane, emerge.	Resistance breeding is crucial, with resistant varieties effectively managing smut Screening methods, including spore suspension dipping, add in selecting resistant varieties.While resistant varieties are developed, fungicides serve as a short-term solution. HWT is a control method, with temperature and	Comstock, Srinivasan, (1971); Steiner and Byther (1971).

				time combinations used.	
3.Pineapple (*Ceratocystis paradoxa)*	Co1285, Co1299, Co1310, Co13368, Co62101 Co62119	Soil moisture, pH, relative humidity, carbon and nitrogen sources influence fungus growth. Carbon and nitrogen sources impact biomass and sporulation.	Setts exhibit red discoloration, progressing to blackish-brown (Fig.3), with hollow internodes, rapid pathogen growth, sett rot, Association with white leaf disease observed.	Use of resistant cultivars, site selection, and seed piece treatment recommended. Increased seed piece length and proper site drainage help mitigate disease impact.	Singh et al., Adiver (1996); Yadahalli et al (2006),(2007).
4.Pokkah boeng (*Gibberella fujikuroi)*	Co7219, CoC671, CoS767, CoC671, CoC8014	Pathogen spreads in wind-blown rain, infected cane cuttings, pupae and adults of sugarcane stem borers. PCR based method offer rapid and accurate detection of pokkah boeng pathogens.	Symptoms include chlorotic patches on young leaves, stalk distortion (Fig. 4), and rotting of apical part of stalk. Variations in symptom development may occur under field conditions, ultimately resulting in malformed or damaged top and stalk.	effective control strategies involve fungicide application, spacing planting, and rouging out infected canes. Utilizing resistant varieties and implementing Integrated Disease Management practices are crucial for disease prevention and control .	Patil and Hapse (1987); Kamal and Singh (1979); Patil (1995).

5.Wilt (*Fusarium sacchari*)	Co527, Co975, Co1007, Co1253, Co1336, CoS245, Cos321.	Pathogen is transmitted through soil, seed cane, water, and wind. It can survive for up to three years. Wilt incidence increases with depletion, particularly in neutral to alkaline soils.	Symptoms such as yellowing and drying of leaves from base to upwards, culminating in withering of the top. The affected cane is killed in severe cases (Fig. 5).	Strategies for managing sugarcane wilt include sett treatment with Agallol, application of boron or manganese, and soil amendment with boric acid. Moisture stress exacerbates wilt incidence, especially during hot summers with low humidity, Implementing these measures is crucial for mitigating the impact of sugarcane wilt on crop yields and ensuring the sustainability of sugarcane farming.	Ganguly and Chand, (1963); Agnihotri (1983),(1990); Viswanathan and Rao(2011).
6.Eye spot (*Drechslera sacchari)*	Co419, Co421, Co331, B 34104, B37172	Six to seven-month-old plants of sugarcane are most vulnerable to eye spot, especially under humid conditions. Soil conditions also	The susceptible genotypes exhibit golden-yellow streaks that later turn reddish-brown, potentially coalescing to large patches (Fig. 6). In severe cases, the	Chemotherapy options include spraying copper oxychloride (0.2%) or using Bavistin (1 g/l) followed by Hinosan or Blitox. Moist	Rabindra and Kumaraswamy, (1978a, b); Agnihotri, (1983).

		play a role, with low potassium and high phosphorus and nitrogen levels promoting the disease.	pathogen may cause top root in the spindle, referred to as the acute form of the disease.	hot air treatment (MHAT) has also shown effectiveness in managing eye spot.	
Bacterial Diseases of sugercane					
7.Red stripe (*Pseudomonas rubrilineans*)	Co312, Co449, Co527, Co419, Co453, Co527, Co617	Disease incidence was higher in the month of June and July when temperature and Humidity was high.	The red stripe initially emerges at the base of young leaves as water-soaked, narrow chlorotic streaks, typically midway and near the midrib (Fig. 7). In some cases, the stripes concentrate towards the leaf base, with the lower half of the leaf being more affected than the upper half. Stripes, 0.5 to 1 mm wide 5 – 100 mm long.	Prompt removal and burning of affected plants. Cultivating resistant varieties and using healthy setts. Avoiding collateral hosts near sugarcane.	Bhide *et al;* Chona and Rao, (1963).
8.Leaf scald (*Xanthomonas albilineans*	Co419, Co114, Co1158, Co7301, BO24,BO7O, CoS659	The bacterium enters through cut stalk surfaces or contaminated implements, spreading through rainwater, insects, and rodents. It	Leaf scald manifests in chronic and acute phases, characterized by white stripes on leaf blades (Fig. 8) progressing to foliar tissue death and eventual plant	Control relies on resistant varieties and careful selection of parent plants for crossing. Screening programmes assess resistance based	Agnihotri, (1981,1983, 1990); Satyanarayana (1974); Persely,(1976); Hutchinson and Robertson, (1953).

		survives in soil and infects collateral hosts, with disease severity influenced by weather conditions and soil quality.	collapse Severe cases exhibit reddening of vascular bundles and lysigenous cavities in susceptible varieties.	on systemic infection symptoms. Disinfecting implements and employing quarantine measures are essential for disease prevention. Additionally, treatments like hot water and streptomycin solutions aid in reducing disease inciderice during crop cultivation	
9.Ratoon stunting Disease (RSD) (*Clavibacter xyli sub sp. xyli*	Q 28, Q 47, CoL9, Co658, Co975, Co997,etc.	Transmission occurs through infected seed pieces and contaminated tools, with grasses like *Johnson* grass and maize serving as carriers. The disease severity increases under moisture stress, with potential plant death in severely	Affected stools exhibit stunted growth, reduced tillering and stem yellowish foliage. Orange-red to pink dots appear on fibrovascular bundles (Fig. 9) in some varieties, while others may show salmon pink coloration on mature nodes.	Chemicals tried , so far, have proved ineffective to control RSD.	Agnihotri, (1990); Singh, (1973), Hughes, (1955).

		stressed, susceptible varieties.			
Viral Diseases of sugercane					
10.Sugercane Mosaic Virus (SCMV)	Co419, Co658, Co740.	Primary spread occurs through infected seed cane, with secondary transmission facilitated by aphids. Vector aphids transmit the virus rapidly, feeding on various grass species, which serve as reservoirs and contribute to vector population growth. Unlike other sugarcane pathogens, mosaic viruses infect multiple grass species.	Infected stalks exhibit a distinctive mosaic pattern of pale green to yellow streaks (Fig. 10) affecting growth and reducing sugar yield. Symptom severity varies with strain and sugarcane variety, occasionally manifesting on leaf sheaths and stalks. While it does not affect cane quality, it stunts growth significantly.	Planting resistant varieties is crucial in high-risk areas, with S. spontaneum serving as a key source of resistance genes. Screening new clones for resistance involves artificial inoculation or natural exposure trials. GM technology shows promise in developing resistant clones, though not yet commercially implemented. Additionally, field control practices and ensuring the use of healthy seed cane are essential for effective management.	Agnihotri, (1990).

11.Yellow leaf Syndrome (Sugercane Yellow leaf Virus and Sugarcane Yellows Phytoplasma)	CoC671, Co86032, CoV92101, Co84211.	Both forms spread via infected seed cane, distinguished from similar physiological conditions. SCYLV spreads via aphids, while SCYP transmission involves leafhoppers.	YLS symptoms include intense yellowing of leaf midribs (Fig. 11). sometimes with sucrose accumulation. Stress exacerbates symptoms, potentially causing severe stunting and yield losses of 2-20%, Serological tests identify SCYLV, while SCYP requires precise nested PCR.	Currently, there's no treatment for SCYP, but SCYLV can be eradicated through meristem culture, Selecting resistant varieties and studying transmission mechanisms are crucial for managing YLS and its impact on sugarcane productivity.	Viswanathan and Rao,(2011); Rao et al.,(2000,2001).
Phytoplasmal Disease					
12.Grassy shoot Disease (GSD)	Co419, Co453, Co740.	Transmitted through infected seed material, GSD spreads via aphid vectors like *Rhopalosiphum maidis* and leaf hoppers such as *Proutista moesta*. Dodder (*Cuscuta campestris*) also adds in disease spread.	Affected plants exhibit profuse tillering, narrow leaf blades, and stunting. imparting a grass-like appearance (Fig.12) Albinism may occur, inhibiting sproutirng of stubble and formation of millable canes.	Control measures include eradication of diseased parts, avoidance of setts from infected areas, and pre-treatment of healthy setts with hot water or air. Regular insecticide spraying and antibiotic application	Chona et.al., (1960) ; Verma,et al.,(1966) ; Singh and Shukla, (1966).

				show remission and potential for complete cure.	

III. Effective Disease Management in Sugarcane

Sugercane susceptibility to pathogen due to its prolonged growth cycle is influenced by various factors such as weather and plant genetics. Combating diseases requires a multifaceted approach rather than a singular strategy. Researchers advocate for a combination of measures to minimize losses. These include legislation to regulate seed cane exchange, development of resistant varieties, and proactive prophylactic practices like clean cultivation. Chemical and thermotherapy methods offer limited success, while a three-tier seed programme ensures disease-free seed production Implemented globally, this integrated disease management system ensures healthy seed production and is vital for sustaining sugarcane crops.

IV. Conclusion

The current study delves into India's sugarcane diversity, emphasizing the impact of major diseases and effective management strategies. Recognizing the pivotal role of disease management in global sugar production and food security, it highlights threats posed by diseases like smut, red rot, and mosaic virus to crop yield. The study advocates for research and innovation to drive sustainable solutions, including the development of disease-resistant sugarcane varieties. By compiling crucial insights, the paper serves as a valuable resource for farmers and research scholars seeking comprehensive understanding of sugarcane disease management and its implications for crop productivity and food security at a global scale.

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Figures showing Fungal Diseases of sugarcane

Fig. 1 Red rot (*Colletotrichum falcatum*)

Fig. 2 Smut (source Linkdin**) (*Ustilago scitaminea)***

Fig. 3 Pineapple (*Ceratocystis paradoxa)*

Fig. 4 Pokkah boeng (source- Plantix. in) (*Gibberella fujikuroi*)

Fig. 7 Red stripe
(*Pseudomonas rubrilineans*

Fig. 8 Leaf scald (source- J- H Daugrois)
(*Xanthomonas albilineans*

Fig.9 Ratoon stunting
(Clavibacter xyli sub sp. xyli)
Credit-Sushma Sood, USA

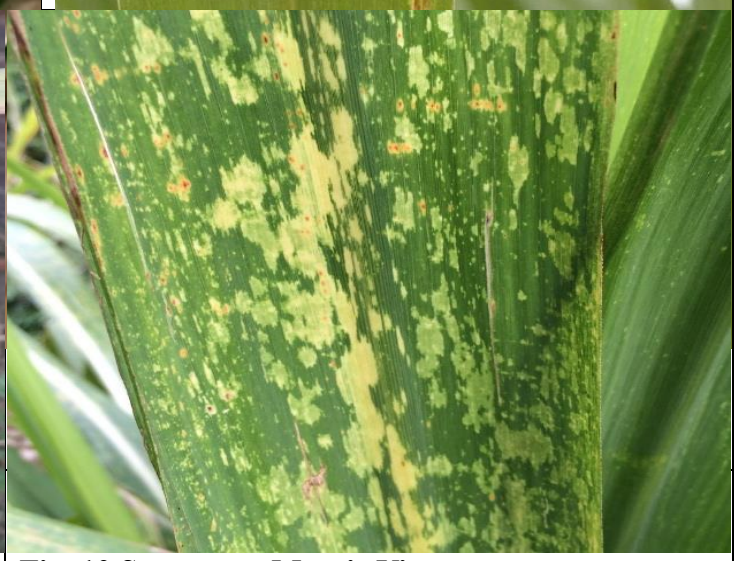

Fig. 10 Sugarcane Mosaic Virus
(SCMV) (source-pestoscope)

Fig. 11 Sugarcane Yellow leaf Virus
(SCYL)

Figure show Phytoplasmal Disease

Fig.12 Grassy shoot disease(agritech TANU)