

Review Article

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Red Stripe/ Top Rot Disease of Sugarcane: A Review

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ABSTRACT

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Sugarcane (*Saccharum officinarum* L.) is one of the world's most important cash crop cultivated in more than 80 countries around the globe. There are several impediments which contribute to low cane yield and one of the factors is plant diseases. The crop is mostly constrained by diseases of fungal, bacterial and viral origin. Bacterial Red stripe/top rot incited by *Acidovorax avenae* subsp. *Avenae* once considered to be the minor disease is gaining importance these days. The disease mostly occurs in two forms i.e., leaf stripes and top rot, which may occur singly or together under field condition during relatively high atmospheric humidity. The bacterial nature of the disease was first established by Lee and Jennings in 1924. The pathogen has wide host range and is spread by wind and rain in warm humid weather causing a true vascular disease in sugarcane.

Introduction

Sugarcane (*Saccharum officinarum* L.) is one of the world's most important crop plants and is cultivated in tropical and subtropical areas in more than 80 countries around the globe. The important sugarcane producing countries in the world are India, Cuba, Brazil, Mexico, Pakistan, China, Philippines, Columbia, Argentina, Australia, USA, Thailand, and South Africa. In India it is grown on 5.0 million hectare with total production of 338.963 million tonnes that contributes nearly 75 per cent to the total sugar (Anonymous

2015). It is one of the most important cash crops, contributing about 7.5 per cent of the gross value of agricultural production in the country. Cultivated sugarcane might have originated in Oceania, most probably in New-Guinea, where some closely related forms of thick, tall canes and wild species of *Saccharum spontaneum* are still found. The sugarcane is an important source of sugar and related products. Sugarcane in India is being cultivated throughout the country except in certain hilly tracts in Kashmir and Himachal Pradesh. The main cane growing states are Uttar Pradesh, Uttaranchal, Bihar, Punjab and

Haryana. Uttar Pradesh is the leading state in growing sugarcane in India but average yield per hectare is highest in Tamil Nadu, Maharashtra and Karnataka. In Punjab it is cultivated in about 94 thousand hectare of land with an average cane production of 7.05 million tones (Anonymous, 2015). There are several impediments which contribute to low cane yield in India and one of the factors is plant diseases. Sugar production is constrained by diseases of fungal, bacterial and viral origin. The bacterial disease namely leaf scald, ratoon stunting, gummosis and red stripe are found sporadically in many sugarcane tracts of the country. Often, these diseases become epidemic to cause considerable loss to the crop. Thus, this commercial crop which supports our agro-based industry suffers loss and with further intensification of cultivation of the crop, might lead to more loss to the nation, unless adequate steps are taken to control the diseases (Rangaswami, 1975). Red rot (*Colletotricum falcatum*), smut (*Ustilagoscitaminea*), wilt (*Cephalosporium sacchari*), grassy-shoot disease (mycoplasma like bodies) and ratoon-stunting disease (*Clavibacter xyli* sub sp. *xyli*) are important under Punjab conditions.

Red stripe/top rot disease

Red stripe/top rot disease once considered as a minor disease of sugarcane is gaining importance as a major disease due to considerable changes in the climatic factors. This disease mostly occurs in two forms i.e., leaf stripes and top rot, which may occur singly or together under field condition having relatively high atmospheric humidity. Red stripe first appears on basal part of the young leaves of the spindle/crown as water-soaked, long narrow chlorotic streaks usually midway in the leaf and near the midrib but in some instances the stripes are concentrated towards the leaf base and mostly the lower

half of the leaf is generally more affected than the upper half. These stripes may be 0.5 to 1 mm in width and 5 to 100 mm in length (Rangaswami and Rajagopalan, 1973). In Hawaii (Martin, 1938), Java (Bolle, 1929), Taiwan (Okabe, 1933) and Louisiana (Rands and Dopp, 1932) young ratoon were found to be more subjected to infection than plant canes of the same age but in Australia, Cottrell-Dormer (1932) reported the opposite case. Fors (1978) observed red coloured blotches on stalks in the region of root primordia extending towards the internodes in the form of thick red lines in B 4362. Red stripe occurs mostly on the young and middle-aged leaves, rather than on the older leaves of the plant. The disease may attack the youngest leaves which are partially unrolled and, if incidence is severe, causes a top rot. Top rot on the other hand may result from stem or bud infection without exhibiting leaf symptoms, as well as from leaf infection. As the name indicates, this stage of the disease refers to the rotting of the terminal portion of the stalk. Leaf sheaths attached to affected internodes often manifest reddish discolouration on the outside and reddish splashes on the inner surface which reach almost to the leaf joint (Cottrell-Dormer 1932). Affected internodes frequently exhibit sunken areas which are first water-soaked in appearance and which later turn brown-to-red in colour. Stalks with top rot are retarded in growth and usually die, the tops frequently break off and fall to the ground. Canes infected with top rot emit a characteristic unpleasant odour (Martin and Wismer, 1961). In North India symptom were reported to appear from July to August and the infection may result from stem, bud and / or leaf (Rana and Shukla, 1968).

Occurrence, distribution and losses

Red stripe disease was first observed in Hawaii by Lyon (1922) and there after it was

reported from most of the cane growing area (Ricaud *et al.*, 1989; Martin and Wismer 1961). It was subsequently named red stripe or bacterial red stripe (Lee and Jennings, 1924). Tryon (1923) reported top rot condition of sugarcane in Queensland and later reported from 50 sugarcane growing countries in the world. The red stripe disease is generally considered as minor importance (Edgerton, 1959; Martin and Wismer, 1961) but the pathogenic potentiality of pathogen to cause epidemics has also been reported (Chona and Rao, 1963; Fors, 1978). In 2006 Patro and his co-worker considered it as one of the most important and economically a dreadful disease of sugarcane. The disease has also been reported from Louisiana (Christopher and Edgerton, 1930), Florida (Rands and Dopp, 1932), Cuba (Faris, 1927), Philippines (Lee and Pierce, 1928), Puerto Rico (Cook, 1929) Brazil (Grillo, 1938), India (Subramaniam, 1936), and Taiwan (Matsumoto, 1952). In India its first appearance was reported by Desai in 1933 and was subsequently reported from several other states on many sugarcane varieties (Dange and Payak, 1973; Agnihotri, 1990). Chona and Rao (1963) reported the occurrence of Red stripe disease in an epidemic form around Delhi and in the eastern districts of Punjab.

They further reported that cane variety Co 312 was affected most heavily. Rangaswami (1960a) reported the occurrence of disease in some parts of Madras on the sugarcane varieties Co 449, Co 527 and Fiji B. Thereafter, red stripe have been reported from several states on many varieties in India such as in Maharashtra on Co 419 (Bhide *et al.*, 1956; Albuquerque and Arakeri, 1956; Summanwar and Bhide, 1962), in Punjab on Co 312, (McRae and Desai, 1933; Padwick, 1940; Chona, 1956; Chona and Rao, 1963) in Uttar Pradesh on Co 443, Co 453, Co 527, Co 617, Co 991, Co 1007, Co 1081, Co 1111, Co

1148, Co 1158, Co 1223, Bo 10, Bo 17, and CoS 510 (Rana and Shukla, 1968) and in Bihar on Co 419, Bo 10 and Bo 17. Recently, a high incidence of Red stripe phase was observed in the promising clones at Shakarganj Sugar Research Institute (SSRI), Jhang Pakistan (Hussnain *et al.*, 2011). They reported that, out of 27 variety tested, 16 were found resistant, four moderately resistant, five moderately susceptible and two susceptible. There were no highly susceptible clones. Iqbal and his co-workers (1995) reported that the performance of sugarcane clones by artificial inoculations with the red stripe pathogen varies from natural infection under field condition. Grillo and Azevido (1939) observed that the disease symptoms developed only when inoculation were done at relative humidity higher than 85 per cent. In Rio de Janeiro, Grillo (1938) concluded that Top rot is a characteristic symptoms under very humid condition and may cause appreciable injury. Chaudhary *et al.*, (1999) reported up to 38 per cent and 40 per cent reduction in cane yield and recoverable sugar respectively by Top rot. They further observed that the disease incidence was higher in the month of June and July when temperature and humidity were high. Ahmad *et al.*, (1993) reported that red stripe caused a significant reduction in cane weight by 11.71 and 38.11 per cent at the leaf stripe and top rot phase respectively. He further reported that sucrose content of the juice was adversely affected ranging from a sugar loss of 16.13 to 48.39 per cent. In Rio de Janeiro and Grillo (1938) reported the greatest loss from the top-rot phase, where field losses up to 15 per cent or more have been reported (Egan and Hughes 1958, Martin and Wismer 1961, Vesminsh *et al.*, 1978). Based on the survey in the major sugarcane growing districts in Punjab (India) Kumar *et al.*, (2014) reported maximum prevalence of top rot disease (56.0% and 54.3%) in Amritsar district on variety CoJ 85 in 2011 and 2012. The further

concluded an early variety CoJ 85 more susceptible to the top rot disease.

Taxonomic position

The taxonomic position of the pathogen of Red stripe (Top rot) has been a lot of controversy among the researchers. The bacterial nature of the disease was established by Lee and Jennings in 1924. The bacterium which causes red stripe was first classified as *Phytomonas rubrilineans* by (Lee *et al.*, 1925) and then was renamed as *Pseudomonas rubrilineans* by Stapp (1928) and *Bacterium rubrilineans* by Elliot (1930). Following the establishment of *Xanthomonas*, Starr and Burkholder (1942) transferred the red stripe organism to this genus and the taxon accordingly became *X. rubrilineans*. They however, noted that as far as lipolytic activity is concerned the organism does not agree with typical *Xanthomonas*. Werham (1948) also included it in doubtful species of *Xanthomonas*. In spite of such doubts in the 7th edition of Bergey's Manual (Breed *et al.*, 1957) the pathogen was listed as species of *Xanthomonas*. Martin and Wismer (1961) also followed Bergey's disposition of this organism. They summarized information on this disease as it occurs on sugarcane. This includes history, geographical distribution, symptomatology, morphological characters, biochemical and physiological characters of the pathogen, alternate host, transmission and control. Cotterill-Dormer (1932) noted that the thermal death point of the red stripe pathogen is about 51^oC. Hayward (1962) after a detailed study concluded that it is erroneous to include red stripe organism under *Xanthomonas*. He stated that the valid name of this is *Pseudomonas rubrilineans* (Lee *et al.*, 1925) Stapp. Subsequently, Dye (1963) supported Hayward's conclusion and Bradbury (1967) adopted the *Pseudomonas rubrilineans*. Summanwar and Bhide (1962) noted that the pathogen is indistinguishable

from *Xanthomonas rubrilineans* in most of the morphological, cultural and physiological characters but differed in not being capable of infecting maize. Chona and Rao (1963) isolated both *Xanthomonas rubrilineans* and *Pseudomonas rubrilineans* from diseased plant of variety Co-312. According to them the later appeared to be more virulent than the former. Dange and Payak (1972) reported that the red stripe disease in sugarcane and stripe disease in maize were caused by the same pathogen and that the earlier reports from India (Desai, 1933; Albuquerque and Arakeri, 1956; Bhide *et al.*, 1956; Rangaswami 1960 a and b; Summanwar and Bhide, 1962; Chona, 1958; Chona and Rao, 1963 and Ullasa *et al.*, 1967) of *Xanthomonas rubrilineans* on both sugarcane and maize are probably erroneous. Vesminsh *et al.*, (1975) from Cuba reported that the disease is caused by a number of bacteria viz., *Pseudomonas floridana*, *Xanthomonas rubrilineans*, *Pseudomonas* taxon, *Bacillus sacchari* and *Phytomonas sholoi* (*Pseudomonas syringae*). Dange and Payak (1973) reported that the red stripe pathogen should be classified under the genus *Pseudomonas*. Esquivel (1975) recorded red stripe disease due to *Xanthomonas rubrilineans* in Panama. Hughes (1978) has reported that the red stripe disease is caused by *Pseudomonas rubrilineans* (Lee *et al.*, 1925) Stapp. Rangaswami (1960a, 1960b) identified the pathogen as *Xanthomonas rubrilineans* (Lee *et al.*, 1925) Starr and Burkholder. In Bergey's Manual (1957), 149 species of *Pseudomonas* have been listed. A detailed review of *Pseudomonas* has been published by De Ley (1964). The genus includes saprophytes, plant, animal and human pathogens. It encompasses heterotrophic, gram negative, asporogenous, fluorescent and non-fluorescent rod like bacteria with a tuft of polar flagella and forms not too sensitive to Erythromycin, Chloramphenicol etc. It has often been confused in the past with

Xanthomonas. Chona and Rao (1963) reported that *Pseudomonas rubrilineans* produced green fluorescent pigment, although they have not specified the medium in which fluorescence was observed. Sands *et al.*, (1970) studied plant pathogenic *Pseudomonas* including three strains of *Ps. rubrilineans* (359, 118, 920) from the National Collection of Plant Pathogenic Bacteria, Harpenden, England and they were classified in non-pigmented, slow growing non-fluorescent group along with strains of *Ps. solanacearum*(Smith), *Ps. setariae* (Okabe) Savulescu and *Ps. rubrisubalbicans* (Christopher and Edgerton) Hayward. Thus Chona and Rao (1963) are the only authors who have found fluorescence in *Ps. rubrilineans* but since the isolates have not been studied by others therefore the report thus remain unconfirmed. Hussnain *et al.*, (2011) on the basis of morphological appearance and biochemical characterizations identified the bacteria as *Acidovorax avenae* subsp. *avenae*. They reported the bacteria as gram negative, citrate utilization positive, oxidase negative, catalase positive and urease negative. Ramundo and Calafin (1990) reported that the strains of *Pseudomonas avenae* (Manns) and *Pseudomonas rubrilineans* (Lee *et al.*). Stapp (1928) observed a minor difference between the physiological and biochemical characteristics but no differences were reported in pathogenicity, host range, cellular protein profiles, direct fluorescent straining and dot-immuno binding assays of the two pathogen strains but were distinctly different from other non-fluorescent pseudomonads. They further proposed that the two strains be regarded as a single species, retaining the name *Pseudomonas avenae*. Shivaji *et al.*, (1989) first identified *Pseudomonas fluorescens*, *Pseudomonas putida* and *Pseudomonas syringae* from continental Antarctica based on their morphology, biochemical and physiological characteristics and mole present

G+C of their DNA. Cottrell-Dormer (1932) showed that top rot and red stripe were manifestation of the same disease and were caused by the same organism (*Pseudomonas rubrilineans*). Orian (1956) reported a disease with symptoms similar to those of red stripe (*Pseudomonas rubrilineans*) on Mauritius in 1954 on Barbados varieties B3337 and B37161. Patro *et al.*, (2006) reported that the pathogen associated with the top rot phase of sugarcane red stripe disease in India as *Acinetobacter baumannii*.

Host Range

This pathogen has wide host range. Apart from sugarcane (*Saccharum officinarum* L.) it is known to attack Sweet corn [*Zea mays* var. *saccharata* (Sturtev.) Barley], field corn [*Zea mays* var. *identitata* (Sturtev.) Barley], Johnson grass [*Sorghum halepense* (L.) Pers.], brown corn [*Sorghum vulgare* var. *technicum* (Koren) Jav.], Sudan grass (*Sorghum sudanense* (Piper) Stapf.), Tambuki grass [*Sorghum verticilliflorum* (Steud) Stapf.], *Sorghum plumosum* Beauve., *Sorghum plumosum* Pers. (var. *Imphee* and *Sacchaline*) (Lee *et al.*, 1925). Cotterll-Dormer (1932) and Orian (1956) reported that the red stripe pathogen also exists on *Paspalum nutans* Lam. and *P. paniculatum* L. in Mauritius. In India, *Ps. rubrilineans* has been found to infect *Zea mays*, *sorghum vulgare*, *Pennisetum typhoideum*, *Panicum antidotale*, *Brachiaria mutica* and *Hordeum vulgare* (Rangaswami, 1960b; Summanwar and Bhide, 1962; Ullasa *et al.*, 1967). Dange and payak (1972) reported *Paspalum nutans*, *Paspalum paniculatum*, *Pennisetum purpureum*, *Setaria verticillata* and *sorghum halepense* also to be the host of *Pseudomonas rubrilineans*. Hu *et al.*, (1997) investigated the relative virulence of strain of *Acidovorax avenae* to their hosts and reported that the strains of *Acidovorax avenae* subsp. *avenae* were more virulent to sweet corn than maize

and sugarcane, but less virulent or avirulent to oat. He also reported that the passage of weakly virulent strains of subsp. *avenae* through sweet corn did not affect strain virulence. He further reported that the *Acidovorax avenae* subsp. *cattleyae* did not caused symptoms in *Cattleyae* sp. and the strains of *Acidovorax avenae* subsp. *citrulli* were more virulent to cucumber than to melon. They were more virulent in the young tissues of their respective hosts (sweet corn and cucumber) at 27-30°C, with expression at higher temperatures being limited by the thermal tolerance of the plants. He further developed a general equation relating symptom expression to inoculum concentration where simple linear equation related the logarithm of lesion number to the logarithm of inoculum concentration. He concluded that the intercept values in the equation for each strain can be considered to be an expression of the heterogeneity of pathogenicity of inoculums, whereas the gradient gave an expression of the relative virulence of infective cells. Xie *et al.*, (2011) reported *Acidovorax avenae* subsp. *avenae* formerly *Pseudomonas avenae* as a phyto bacterium which causes several plant diseases with economic significance including rice, corn, oats, sugarcane, millet, and foxtail. He further reported that the draft genome sequence of strain RS-1, which was isolated from rice shoots in rice causing bacterial stripe of rice field in China.

Perpetuation and survival of the pathogen

Barnum (1925) reported that pathogen of sugarcane survived for 37 days in unsterilized soil and 41 days in sterilized soil. Lee (1925) observed that out of 1000 setts taken from diseased plants, only one transmitted the disease. Thus it does not cause a true vascular disease and therefore is rarely carried through setts. The organism is found more in the parenchyma and sheath cells than in the

phloem and xylem. Transmission of the disease by using infected knives in the preparation of the seed either failed to occur or occurred in only a very small percentage of cases. Rangaswami and Thirunavukarasu (1964) reported that *Xanthomonas (Pseudomonas) rubrilineans* from sugarcane survived 84-112 days in sterile soil and 3-63 days in unsterilized soil as suspension. Longevity was shorter when these species were added with their respective host tissues.

Environmental factors in relation to disease development

The pathogen is spread by wind and rain in warm humid weather. Bell (1942) reported that because of the failure of the usual monsoon late summer rains, red stripe (*X. rubrilineans*) and top rot were not at all prevalent but the dry spring of 1941 included some stem rot in over mature canes, in a field at Maringa where patches of severe top rot were present. Heavy dressing of filter press mud was made on these places, with the result that top rot gradually declined. Lee *et al.*, (1925) stated that the red stripe of sugarcane is a wet weather disease. In an epidemiological study, carried out by Yonzone *et al.*, (2014) reported that the maximum lesion length of 32.28 cm on CoJ 85 and 27.72 cm on CoJ 88 was found 32 days after inoculation. They further reported the incubation period of 7 days and 9 days on development of disease symptom and ooze formation when inoculated with four isolates RS-2, RS-3, RS-6 and RS-8 on variety CoJ 85.

Sensitivity of the pathogen to antibiotics

Pseudomonas has been found less sensitive to Erythromycin, Erythrocinelactobinate and Chloramphenicol. Dange and Payak (1974) found that *Pseudomonas rubrilineans* is quite sensitive to Terramycin as well as

Streptocycline. However Hussnain *et al.*, (2011) reported that the bacterium *Acidovorax avenae* subsp. *avenae* showed best results with Ampicillin and Vancomycin at 75 and 25µg/ml, respectively when compared with other saprophytic bacteria. Thind *et al.*, (1984) reported that Streptocycline alone and its combinations with Glycerine or Copper sulphate proved more effective for controlling leaf stripe of maize than Agrimycine-100, Potassium permanganate and Blitox-50. Patro *et al.*, (2006) reported that causal organism of red stripe was highly resistant to Ampicillin, but was susceptible to the rest of the antibiotics tested (i.e., Streptomycin, Kanamycin and Rifampicin).

It may be concluded from the foregoing discussion that the Red stripe/Top rot disease once considered as the minor disease is gaining its importance in many recommended varieties as well as in areas with changing climatic conditions. Therefore a proper adaptation measures, as well as development of resistant cultivar for proper management of this disease should be adopted so that the economy of farmers remains unaffected.

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