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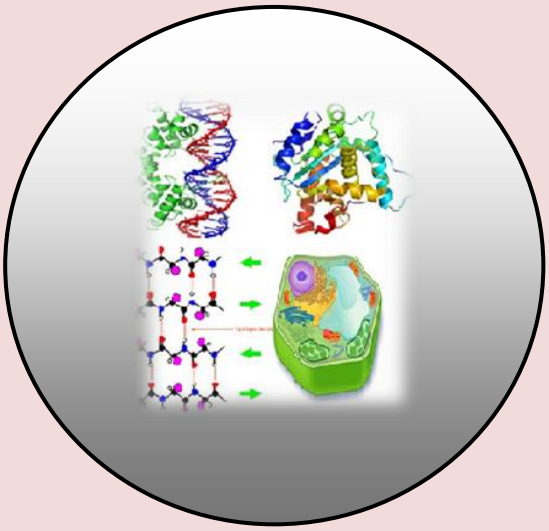
ISSN 2319-3077 Online/Electronic
ISSN 0970-4973 Print

UGC Approved Journal No. 62923
MCI Validated Journal
Index Copernicus International Value
IC Value of Journal 82.43 Poland, Europe (2016)
Journal Impact Factor: 4.275
Global Impact factor of Journal: 0.876
Scientific Journals Impact Factor: 3.285
InfoBase Impact Factor: 3.66

J. Biol. Chem. Research
Volume 36 (1) 2019 Part D, Pages No. 197-204



Journal of Biological and Chemical Research

An International Peer Reviewed / Referred Journal of Life Sciences and Chemistry

Indexed, Abstracted and Cited in various International and National Scientific Databases

Published by Society for Advancement of Sciences®

J. Biol. Chem. Research. Vol. 36, No. 1: Part D, 197-204, 2019
(An International Peer Reviewed / Refereed Journal of Life Sciences and Chemistry)
Ms 36/01/8808/2019

ISSN 2319-3077 (Online/Electronic)
ISSN 0970-4973 (Print)

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REVIEW ARTICLE

Received: 18/04/2019 Revised: 28/05/2019 Accepted: 29/05/2019

Red Rot: Threatening Disease of Sugarcane

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ABSTRACT

Red rot infection is a severe, devastating and life threatening disease of sugarcane from many several decades. It is one of the most common and important disease of sugarcane whose first incidence has been reported long back in 1895-1901 in India. Heavy losses in sucrose content causing losses in cane yield and sugar recovery is the main concern of this disease. Once the crop field is infected with this infection (when no proper management strategy adopted) will lead to complete death of whole crop field resulting in high loss to farmer. Identifying the disease at right time and taking precaution from the very starting of planting will help in managing this infection. Though many researches before have been done and still going on to develop resistant variety/ies which stays long but due to its changing virulent nature none of the promising high yielding varieties are resistant to this disease for not more than 8-10 years. This review article focuses on the various symptoms of this infection and its management strategy which may help the crop to flourish without this infection.

Keywords: Red Rot, Sugarcane, Sugar Loss and Yield Loss.

INTRODUCTION

Red rot of sugarcane is a dreadful and life threatening disease of sugarcane (Kumar *et al*., 2018). It is caused by *Colletotrichum falcatum.* Sixty eight countries of sugarcane have been known to report incidence of red rot infection (Bharti *et al*., 2012). Sugarcane infected with this infection causes heavy losses in sucrose yield in sugarcane growing areas. About 5-10 per cent loss in sucrose or sugar recovery and cane yield has been reported due to its infection in canes all through world. Viswanathan and Samiyappa (2008) had showed that Australia, Taiwan, Pakistan, Bangladesh and USA are the main countries where red rot infection was surplus. Viswanathan *et al.* (2008) had showed that this infection in canes is the ones that constrain sugarcane production. The primary incidence of red rot infection in India has been reported in 1895-1901 followed by several other outbreaks in subsequent years (Satyavir, 2003). It is a disease which spreads from one place to other through infected sugarcanes or through setts (Malathi *et al*., 2012). Infection of this disease pathogen is responsible for poor stands of plant and ratoon crop leading to deterioration of setts and stubble (Abott, 1938). Further, sugarcane infected with this disease had heavy losses in sucrose content as deterioration of sucrose takes place (Went, 1893). Hussnain and Afghan (2006) had illustrated that loss of 29.07 per cent in cane yield and 30.8 % in sugar recovery was due to canes infected with this infection.

In susceptible varieties such as PoJ 213, Co281, decrease in juice extraction per cent, sucrose and total soluble solids have also been reported (McKaig and Fort, 1936). Further, purity coefficient also gets lowered in infected canes which further accentuate other changes in sugarcane (Abott, 1938). Babu *et al*. (2010) had reported that this disease is so severe and devastating that it was prominent in major sugarcane producing areas in India covering large areas of eastern U. P., North Bihar and some portions of Punjab even. Tiwari *et al.* (2010) had illustrated that its devastating nature has also been seen in north western part of India. This is due to positive environment conditions such as high humidity and 29.4^{O}C to 31^{O}C ranging temperature.

Several studies had been conducted on red rot infection in sugarcane varieties (Ansari, 2012; Tiwari *et al.*, 2010) and researches are still being on in developing new varieties tolerant to this infection as well as its incidence rate in varieties presently commercially being cultivated (Kumar *et al*., 2018). This review highlights the various aspects of red rot infection starting from its symptoms, demise of various varieties to its management.

Symptoms and favorable conditions for red rot infection

Red rot infection is hard to identify on external examination on symptoms at initial stage of infection. The first and foremost symptoms is seen when vegetative growth has been stopped but sucrose formation is initiated. This generally takes place after rainy season. Red rot pathogen can affect any portion of cane whether it is leaf, stalk, roots or buds. Life cycle of this pathogen starts and completes in leaf of sugarcane and generally leaf damage does not causes much affect to plant (Duttamajumder, 2008).

Favorable conditions for red rot infection are as follows:

(i) The most important condition for any infection is the temperature at which it occurs. For red rot infection optimum temperatures ranges between 29.4^{O}C to 31^{O}C. This temperature is considered to be the optimum temperature for this infection (Singh *et al*., 1988; Beniwal and Satyavir, 1991).

(ii) In environmental condition humidity is another aspect for this infection. This infection occurs at very high humidity, i.e. 90 % (Sharma and Tamata, 2015).

(iii) Acidic or alkaline environment inside sugarcane also influences this infection. pH should be between 5-6 for occurrence of this infection in canes (Sharma and Tamata, 2015).

(iv) At initial stages of growth, occurrence of drought in cane fields also attracts this infection to occur in canes (Yin and Hoy, 1997).

(v) Furthermore, if water logging conditions also prevail, this infection flourishes at higher pace (Sharma and Tamata, 2015).

(vi) Agronomic mishandlings: Improper practices of cultural activities which initiates weed growth, continuous growth of canes in same field growing same variety gives rise to such infection (Sharma and Tamata, 2015).

(vii) Growth of susceptible varieties nearby healthy fields is also may be the reason for infection in healthy canes (Sharma and Tamata, 2015).

Incidence and demise of red rot infection in various varieties

Red rot infection had cause demise of various promising and prominent varieties. Following table illustrates the various varieties demise and downfall due to this infection (Table 1). The changing virulence of red rot infection will continue to demise and effect new tolerant varieties will be responsible for their downfall after 8-10 years of commercial cultivation.

Symptoms and impact of red rot on different portions

1. Cane stalk

In initial stages of infection, this disease is not clearly discernible from external examination. External symptoms appear only when stalk is completely damaged/rotted in interior. This leads to cause dull color of rind. This is termed as advanced stage of infection which is mainly seen when cane fields have not at all being taken care of from this infection (Abott, 1938).

Furthermore, if stalks infected with this infection are cut longitudinally, reddening of the normally white or yellowish white internal tissues in the internodal area is seen. An important characteristic is the white patches between these reddening portions at certain places which occur in cross way (Fig. 1). It is this whitish patches which make assurance of red rot infection in sugarcane without microscopic examination as reddening of tissues can be seen also when cane is injured or attacked by other disease or attack by stalk borers. Furthermore, these white patches may vary in size and number and may give blotchy appearance to tissues (Viswanathan *et al*., 2011; Kumar *et al*., 2018). As the infection becomes more vigorous the cane stalks become hollow and give a characteristic vinegar smell and its juice emits alcohol like smell which causes problem in setting on boiling as sucrose has been converted into glucose (Sharma and Tamata, 2015).

Table 1. Varieties demise due to red rot infection and new varieties prone to infection.

Varieties	Demise/downfall	Reference
Co210	Demise	Natarajan *et al*., 1998
CoC671		
CoJ64		
Co312		
Co453		
Co213		
Co419		Viswanathan, 2010
CoJ64		
CoC92061		
CoC85061		
CoC671		
Co1148		
CoSe92423		
CoS767		
Co997		
Cos87231		
Co6304		
CoS8436	Downfall	Kumar *et al*., 2018

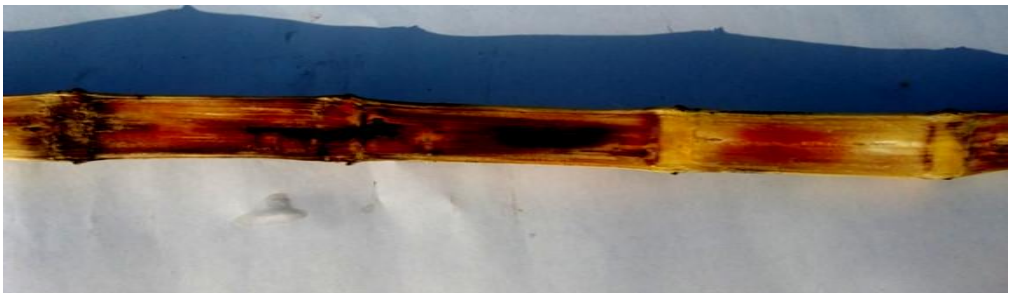

Fig. 1 Longitudinal section of red rot infection in sugarcane. The white patches in between the red infected portion are the characteristic feature of this infection.

2. Leaf midribs

Discoloration of leaves is the first symptom of red rot infection particularly spindle leaves show drying which later shows wilting of leaves at tips and margins (Sharma and Tamata, 2015). This pattern of drying continues till complete crown leaves have been wilted (Agnihotri, 1996). Dark reddish areas are seen on leaf lesions when matured. They elongate rapidly and may cover the entire leaf. The younger lesions appear bloody red in coloration having darker margins. The centre of lesions at times becomes straw in color with increase in age of lesion. In case of fructification of fungus, mass of conidia which appear in black powdery form covers the infected lesions.

In general, the lesions in leaf midrib appear in continuous form but at times it appears in discontinuous form as blotches (Abott, 1938).

Colony characteristics of *Collecotrichum falcatum*

Abott (1938) had identified two races on basis of cultural characteristics of this fungus. The first is light one which possesses white to light grey mycelia, cottony in texture and the second one is dark in color having compact velvety dark grey mycelia. Bharti *et al.* (2011) had showed that there is variability in characteristics of cultural and morphological aspect of *C. falcatum* due to hybridization, mutation in conidia and hyphen fusions.

Losses in red rot infection to sugarcane

A. Juice quality loss

Red rot infection is serious problem of sugarcane and causes substantial losses in quality which affects losses to farmers and millers. Loss in juice quality has been revealed to be a direct association with this infection as well as degree of resistant of cane varieties. Minnatullah and Kamat (2018) had assessed twenty varieties infected with red rot infection for losses in juice quality. Of all BO 128 was found to be highly susceptible with 20.80 % reduction in brix, 38.26 % in pol and 22.10 % in purity while resistant variety was CoP 11437 with 2 % reduction in brix, 6.10 % reduction in pol and 4.20 % reduction in purity % (Table 2).

Table 2. Juice quality losses in various varieties of sugarcane.

Varieties	Rating	Reduction (%)		
		Brix %	Pol %	Purity %
BO 128	HS	20.80	38.26	22.10
CoS 8436	S	19.70	36.45	20.20
CoSe 95422	S	18.86	34.32	19.00
CoSe 92423	MS	16.60	31.60	18.00
CoX 07137	MS	15.42	28.79	15.80
CoX 07141	MR	15.00	27.75	15.00
CoP 11438	MR	8.00	19.38	12.40
CoP 133	MR	7.63	18.72	12.00
CoP 11436	MR	7.41	18.09	11.50
CoP 09437	MR	7.20	17.76	11.40
BO 155	MR	7.00	14.94	9.20
CoP 11439	MR	6.80	14.60	8.36
BO 91	MR	6.37	14.08	8.20
CoP 11440	MR	5.71	13.41	8.16
BO 141	R	5.27	12.00	7.10
BO 110	R	4.20	11.51	7.60
BO 154	R	3.97	10.12	6.40
BO 153	R	3.81	9.60	6.00
CoP 9301	R	3.57	8.24	5.30
CoP 11437	R	2.00	6.10	4.20

(Source: Minnatullah and Kamat, 2018)

B. Nutrient loss

Nutrient loss is one of the commonest changes seen in canes affected with red rot infection. Different varieties respond in different way to red rot infection (Table 3). Gupta *et al.* (2018) had evaluated nutrient content (N, P, K, Ca, Fe, Cu and Zn) in eight varieties having red rot infection. Result revealed that BO 120 had highest changes in nutrient content while BO 130 had lowest changes in nutrient content. Losses in nutrient content in red rot infected sugarcanes directly affect yield and sugar recovery by impairing quality of juice (Recaud *et al.,* 1989).

Management of red rot infection

Following measures are needed to be followed for managing this life threatening infection of cane.

(1) **General agronomic measures:** Healthy cultural practices should be adopted at time of planting and even afterwards. If any infected clump is seen in field immediately it should be removed from the field and burned (Ansari, 2012). Further crop debris, trash stubble of the infected canes was also meant to be burnt for preventing this infection to spread. As it is a seed transmitted diseases healthy nursery should be maintained at farmer's field which could be attained by using heat treated crop or seed from certified nursery. Avoid transport of cane stalks from infected areas. Transportation of seed from one state to another state should be done only for breeding purpose and with phytosanitory certificate by experts. Favorable soil conditions (dry and wet soils) should also be avoided. Crop rotation should be done keeping in mind that canes should not been grown in the same field for 2-3 years. Irrigation supply should not be done from diseased area to healthy cane fields. For planting long setts should be preferred, *viz*., three to four setts for planting. In case of plant crop field infected with red rot infection, ratooning should not be done at all (Anwar *et al*., 2010).

(2) **Thermotherapy/heat therapy:** Heat therapy has been the effective therapy for managing various diseases which are sett-borne especially red rot. Studies had showed that complete removal of this disease has been achieved by treating setts with hot air treatment at 54^{o}C for 8 hours (Sinha *et al*., 1979; Singh, 1973). Combination of hot water treatment with chemical dip setts had also found effective for this infection (Agnihotri, 1983). Another hot air treatment known as moist hot air treatment (MHAT) which is developed by IISR Lucknow had also found to be effective in treating canes/setts (Temperature 54^{O}C; duration 4 hours, Relative humidity 95-100 %) against this infection (Srivastava *et al*., 1977; Singh et al., 1980; Dhilon *et al*., 1983; Agnihotri, 1984).

Table 3. Nutrient (macro and micro nutrients) changes in infected red rot canes of different varieties.

Varieties	Increase % in Nitrogen	Reduction % in phosphorus content	Reduction % in potassium content	Increase % in calcium content	Reduction % in magnesium content	Reduction % in iron content	Reduction % in copper content	Reduction % in zinc content
BO91	8.4	13.9	11.4	8.7	13.2	7.8	13.1	21.8
BO102	15.4	28.4	21.0	23.8	27.5	17.4	25.2	33.9
BO120	23.4	31.4	26.5	30.2	28.4	20.5	28.4	35.5
BO130	6.1	8.4	8.6	7.2	3.5	6.4	11.7	15.8
BO131	14.1	24.5	17.0	18.4	24.6	14.5	23.8	31.7
BO132	11.1	20.7	14.2	12.6	16.0	12.0	22.8	31.1
BO139	9.8	18.6	13.6	14.4	20.3	9.4	20.0	22.3
CoS767	15.3	26.1	18.2	19.1	25.0	18.7	25.8	34.6

(Source: Gupta *et al*., 2018)

(3) **Biological management strategy:** *Tricoderma harzianum* and *T. viride* is the most common biological control for this infection (Singh *et al*., 2008). The ability of producing chitinase enzyme by *T. harzianum* and *Pseudmonas* spp. had also been found to act as protectant against occurrence of this disease through soil (Malathi and Viswanathan, 2013). Also, Singh *et al*. (2013) had revealed that in case of *Tricoderma* spp. the gene responsible for controlling this red rot is ech42 gene. Furthermore, salicylic acid also acts as an additional protectant against this disease when applied with *T. harzianum*. In addition, ginger, *Ocimum*, onion and garlic had also found effective in inhibiting the mycelial growth of the pathogen. Even essential oils like patchouli oil, palmaroza oil, geranium oil, mentha oil and peppermint oil had also showed prominent results against mycelia of pathogen (Bharadwaj and Sahu, 2014). Other studies had illustrated that leaf extract of *Curcuma domestica* and *Datura metel* inhibit both conidia and mycelia growth of pathogen whereas smoke of dhoop and tobacco inhibit only germination of conidia of pathogen (Imtiaj *et al*., 2007; Sharma and Tamata, 2015).

(4) Chemical treatment: Treatment of sugarcane setts or stalks with various fungicides has been studied, however success have been attained in very few. The reason behind may be due to impermeable nature of sugarcane parts such as rind, presence of fibrous nodes at cut ends, existence of various nutrients, deficiency of broad spectrum of fungicides, etc. (Satavair, 2003; Agnihotri, 1996). Fungicides like carbendazim and benomyl were effective against this infection when canes were soaked for 1-2 hours (Anzalone, 1970; Chand *et al*., 1974; Waraitch, 1983). Vitavax and Agallal (0.5% for 15 minutes), bleaching powder had also been effective against the disease pathogen (Chand *et al*., 1974; Lewin *et al*., 1976; Agnihotri *et al*., 1995). Findings of Khan et al. (2009) had showed that Topsin M treatment on cane stalks helps cane in protecting against the disease pathogen and even helps in improving the yield status. Besides, application of bavistin had also caused complete inhibition of growth of mycelia of fungus (Bharadwaj and Sahu, 2014).

(5) Growth of resistant varieties: The most effective way to manage this infection in canes is the use of resistant varieties. In India, efforts are being made in developing canes resistant to this infection through breeding but even success attained in doing so could not make varieties resistant to this diseases for more than 8-10 years as the virulent nature of this pathogen varies and new races are developed as climate changes (Chona and Hingorani 1950; Yadav, 2006).

CONCLUSION

Red rot infection of sugarcane is a common and life threatening disease of sugarcane and still an important disease infecting sugarcane throughout the world. This infection had causes demise of various good varieties of sugarcane. The best and effective way of management of this disease is the integrated management strategy wherein combinations of various management measures are involved instead of one single management strategy. Before adapting any management measures for infection, there is a need of better understanding of the disease that had infected the canes. This could be accomplished by the advance molecular diagnostic tools for red rot infection. Identification of molecular markers for the disease resistance is another good approach for developing varieties resistant to this disease through breeding programs. Furthermore mixture of biotechnological, biological, chemical application and agricultural practices is the best way to eliminate red rot and prevent the stalks from infection. There is need to identify candidate genes against this disease, development of transgenic sugarcane with resistant potential against red rot. Besides, there is a need to investigate such method for inducing systemic resistance against the pathogen of this disease.

ACKNOWLEDGEMENTS

Authors are grateful to ICAR-Indian Institute of Sugarcane Research, Lucknow 226 002, U.P., India, for providing Laboratory facilities.

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