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Sugarcane diseases: Scenario, impact to cane cultivation, molecular diagnostics and management

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ABSTRACT

Vegetative propagation in sugarcane favours accumulation of pathogens inside the cane stalks and carryover of pathogenic inoculum through planting materials. Disease-infected setts serve as a primary source for disease spread for most of the diseases in the crop, except foliar diseases. In case of fungal diseases, planting infected setts leads to disease builds up in plant crop and probably death of the affected clumps. However, in case of non-fungal diseases continuous accumulation of pathogens systemically leads to loss of vigour in sugarcane varieties referred to as 'varietal degeneration' and this results in loss of yield potential in elite commercial varieties. Among the biotic constraints, different diseases caused fungi, bacteria, virus and phytoplasma impact sugarcane production and productivity in India. Several red rot epidemics have devastated elite varieties and were removed from cultivation in different decades. Variation in Colletotrichum falcatum, the red rot pathogen is being assessed continuously and recently two new pathotypes CF12 and CF13 were characterized and used for disease screening. Earlier there was a confusion on the identity of the etiological agents of different diseases. Application of precise molecular assays helped in resolving the issues. Recently cause of two Fusarium diseases viz. wilt and twisted top (pokkahboeng) in sugarcane by the same *Fusarium sp* has been established along with disease epidemiology. Under Indian conditions, it was found that combined or separate infections of viruses causing mosaic and yellow leaf disease (YLD), phytoplasmas causing grassy shoot and bacterium causing ratoon stunting disease (RSD) are associated with varietal degeneration. However, among all these diseases, YLD contributes more towards degeneration of sugarcane varieties. YLD occurrence to epidemic levels in different states is a serious concern for sugar industry and due to that longevity of the affected varieties in the field is threatened. Meristem-tip culture derived disease-free nurseries is imperative to sustain productivity of sugarcane and to realize yield potential of popular sugarcane varieties in India.

INTRODUCTION

Sugarcane is cultivated on about 5.8 M ha and produces approximately 494 MT sugarcane with average productivity of 84.01 tonne per ha during 2022-23 (sugarcane.dac.gov.in). The states of Uttar Pradesh, Maharashtra and Karnataka contributes about 75% of cane production in the country. Cane productivity has shown a positive increase during the last decade owing to the elite varieties and improved technologies. However, need for sugarcane increases every year since it serves as a raw material not only sugar but also for bioethanol. Blending of ethanol in petrol has reached nearly 12% target and we have to reach the target of 20% by 2025-26. Sugarcane diseases are constraints to crop production all over the world, and no country is protected to the

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destructive influences of plant pathogens and pests. More than 125 diseases of sugarcane caused by fungi, bacteria, viruses, phytoplasma and nematodes have been reported from all over the world (Rott *et al.*, 2000). In spite of all the efforts of breeding for disease resistant varieties, this crop is becoming more and more prone to many diseases and pests. The disease incidence is increasing at an alarming rate and the yield is falling down every year. About 10-15% of the nation's sugar produced are lost due to diseases. Among them red rot, smut, wilt and pineapple disease (sett rot) are the important fungal diseases. Bacterial diseases like leaf scald (LSD) and ratoon stunting (RSD) are found to cause considerable yield loss in some countries. Besides these, grassy shoot caused by phytoplasmas is also a potential disease, which can cause considerable damage to sugarcane production in all the states. In addition, newly recorded yellow leaf disease (YLD) has become a major constraint in many states. Foliar diseases such as brown spot and rust causes losses in the states of Karnataka and Maharashtra. Many promising cane varieties were removed from cultivation in the past since they succumbed to new pathogenic variants with more virulence. Also, slow build-up of many non-fungal diseases in sugarcane causes decline in varietal performance and results in "varietal degeneration". The review focuses on sugarcane disease scenario, red rot pathogen – variation, evolution of new variants and its interaction with sugarcane, molecular diagnostics, mechanized delivery of fungicides, healthy seed programmes to address varietal degeneration etc. I profusely thank the Deccan Sugar Technologists Association, Pune and other office bearers for inviting me to deliver the Late J.P. Mukherjee memorial lecture. I feel an update on current status of sugarcane diseases, their impact, diagnostics and management would be relevant to the Annual Convention.

Current sugarcane disease scenario in the country

Sugarcane is affected by many diseases such as red rot, smut, wilt, pokkahboeng GSD, YLD, mosaic, RSD etc in almost all the sugarcane growing states. The severity of the diseases varies depending on varieties under cultivation and agro climatic regions. Many popular sugarcane varieties including the popular variety Co 0238 exhibit varying severities of red rot in the recent years in the subtropical region. The variety Co 0238 which has occupied more than 70% area in the region is witnessing very severe red rot outbreaks and such severe red rot pandemic was witnessed during 1930s, which led to emergence of light races of the pathogen. Although red rot severity is not much in the tropical region, the disease is observed in few pockets in Tamil Nadu, AP, Odisha and Gujarat. Smut incidences have increased in the recent years in the subtropical region and this warrants attention of the breeders to introduce only smut resistant varieties. Wilt also affects many popular sugarcane varieties in both the tropical and subtropical regions. Combined incidences of red rot and wilt were reported more frequently from Bihar and South Gujarat. In the past 20 years, YLD severity increased with severe disease outbreaks in different states and the disease became a serious threat to sugarcane cultivation in the country (Viswanathan, 2018, 2021a). Recently, minor diseases such as rust, twisted top (pokkahboeng - PB) and brown spot assumed serious proportion in different parts of the country. The disease scenario suggests that the crop is impacted by different diseases across the sugarcane growing regions in the country. Growing disease resistant varieties is the mainstay in disease management in sugarcane and by that red rot and smut diseases are managed successfully. However, we will not be able to manage all the diseases through host resistance and we need to adopt novel strategies to manage them through an integrated approach.

Changing disease scenario of sugarcane in India

Red rot

It is one of the most widespread sugarcane diseases in the country and it has been a constraint for the past 100 years in India and other South Asian countries. First large-scale destruction of the cane in India by the disease was noticed in Godavari delta of then Madras Presidency on the cultivar Red Mauritius during 1895 to 1899. 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. It was involved in the 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 562, CoS 8436, CoSe 95422 etc in both tropical and subtropical regions. Currently the disease occurs in all the sugarcane growing states in India except Karnataka and Maharashtra states. The popular variety Co 0238 has succumbed to varietal breakdown caused by the newly emerged *Colletotrichum falcatum* pathotype CF13 (Viswanathan et al. 2022a). During the past four seasons the disease was confined to Uttar Pradesh and Bihar and now it has spread to Haryana and Punjab. Severe red rot epiphytotics have destroyed the crop of Co 0238 in thousands of hectares in UP and Bihar. In addition, the pathogen has gained very high levels of virulence and such aggressiveness of the new pathotype(s) may pose challenges to the new varieties introduced to replace Co 0238. The past disease scenario suggests occurrence of boom and bust cycle in case of red rot in the country especially in the subtropical region (Viswanathan, 2021b,c). We witness repeat of the same in the subtropical region particularly in UP and Bihar due to predomination of a single variety in the command areas and phenomenon is referred to as 'Vertifolia Effect' (Viswanathan et al. 2022a). Sett borne nature of the disease, secondary spread through irrigation/ flood water and survival of the pathogen inoculum in crop debris make the disease threatening under field conditions in the country.

Smut

The disease is caused by the fungus *Sporisoriumscitamineum* (Syd.) M. Piepenbr., M. Stoll &Oberw. 2002 (Syn: *Ustilagoscitaminea* H. & P. Sydow). It is cosmopolitan in distribution and at one time or another it has been important in all the sugarcane growing countries. The disease caused severe yield loss to sugarcane for long time in Maharashtra and Northern Karnataka regions till Co 740 was under cultivation. Replacement of Co 740 with Co 86032 and Co 94012 reduced the smut severity in these regions. Recently, widespread cultivation of CoA 92081 resulted in severe outbreak of smut in Andhra Pradesh and Telangana states and in Southern Karnataka due to introduction of new varieties. Similarly severe smut is noticed on in Gujarat in the tropical region. Although the disease was not severe in the subtropics, after 2010 the author witnessed severe smut on many varieties. Currently, severe occurrence of the disease is reported from sub-tropical region, especially in the ratoons of the popular cv Co 0238.

Wilt

Wilt has caused significant losses in India where several epidemics have occurred for more than 100 years. Like red rot, it is responsible for the elimination of many popular varieties from cultivation. Wilt is very common in certain locations where conducive environment and susceptible hosts are available (Viswanathan, 2013). In most of the delta regions and subtropical plains, endemic nature of the disease prevails. The disease adversely affects germination. Wilt incidence is always higher in ratoon crops compared with the plant crop. Besides yield reduction, wilt disease also causes 14.6-25.8% reduction in juice extraction and 3 to 20 percent in sugar recovery due to deterioration in juice quality. Combined infection of red rot and wilt causes more loss to the crop than their infection alone. *Fusarium sacchari* (E.J. Butler) W. Gams has been proved as the causative agent of the disease (Viswanathan et al., 2011). Abiotic factors like drought, water logging, drought followed by water logging weaken the root system and predisposes the plant for wilt infection. Subterranean soil pests such as white grub, root borer and nematode and insect pests like mealy bug, scale insect, fungal pathogen like red rot weakens the plant and root system paving the way for wilt infection. Earlier it was thought that the disease occurs during maturity stage and its severity can be seen during harvest. It is now established that the disease occurs during germination onwards and cause death of the germinated settlings or young plants. In many situations, the affected canes are lanky, stunted and die in course of time. Root growth in such plants is severely affected with no new roots. Wilt infection in young crops can also be seen as dried canes with de-topped crown. Similar to red rot, the subtropical region suffers from severe outbreak of wilt in large areas, especially those experience waterlogging.

Twisted top (Pokkahboeng) disease

Economic damages caused by twoFusarium diseases in sugarcane, wilt and twisted top in sugarcane have been documented in different decades in the past. twisted top disease manifests in two phases viz. pokkahboeng and top rot. The most common symptom is a malformed or twisted top, which gives this disease its name from the Javanese language. Most of the twisted top -affected canes generally recover from the symptoms but in top rot, recovery is not there. This disease is favoured by warm, moist growing conditions. Fusarium verticillioides and F. sacchari are the causative fungi (Teleomorph: *Gibberellafujikuroi* (K. Sawada) H.W. Wollenweber). Recently association of *F. proliferatum* with the disease has been found in India. Currently, evidences have been found on the same *F. sacchari* pathogen causing wilt in stalk and twisted top on the leaves of sugarcane. In the past, the twisted top disease was considered as a minor disease, however, recently it has gained national importance hence we have initiated research work across the country on epidemiology, management and screening sugarcane varieties. Earlier it was presumed that both the diseases occur in sugarcane during different growth phases in the past, however, detailed studies conducted at ICAR-SBI discovered that same plant exhibits both the diseases together, inflicted by the same pathogen Fusarium sacchari (Viswanathan et al., 2017a). The new findings on the role of *Fusarium* associated with twisted top in causing wilt have not been reported elsewhere. The recent widespread occurrences of these diseases in different states in the country may be due to the cause of these two diseases by the same fungal pathogen. Availability of the crop throughout the year may facilitate infection of the crop and cause of the disease depending on the crop phase and prevailing weather. Further studies are in progress on influence of host resistance and role of environmental conditions favouring stage shift from twisted top to wilt in sugarcane.

Yellow leaf disease (YLD)

The disease is characterized by a yellowing of the midrib and lamina occurred in most of the sugarcane growing regions of the country. Viswanathan (2002) reported spread of YLD in sugarcane in different regions and recorded disease intensity up to 100 per cent in certain susceptible varieties. In India, sugarcane yellow leaf virus (ScYLV) has been found to be the major causal agent in all the states. During 1999 when YLD was first noticed in the country it was thought to be a minor disease. However, in the past 25 years severe disease outbreaks were recorded in different states, which indicate that the disease has assumed a serious threat to sugarcane cultivation in the country. Although mild infections of the disease do not cause much crop loss, continuous use of seed from such fields leads to severe disease out breaks. In India, YLD symptoms occurred in most of the sugarcane growing regions of the country and the disease intensity was recorded up to 100 per cent in certain susceptible varieties (Viswanathan, 2012, 2021a). Further, the sugarcane varieties exhibited a seasonal variation for symptoms expression and sugarcane aphid *Melanaphissacchari* was found to transmit the virus in a non-persistent manner (Chinnaraja and Viswanathan, 2015a,b). Another interesting area of finding in this virus-vector-host varieties interaction revealed dynamic changes in aphid colonization under field conditions and impact of prevailing weather factors on aphid colonization (Viswanathan et al., 2022b). From India, four complete genomes of ScYLV from the cvs Co 86032 (IND2), CoV 92102 (IND3) and CoC 85061 (IND 4) and one foreign hybrid B 38192 (IND 1) were characterized (Chinnaraja *et al*. 2013). Recently, detailed studies on the associated pathogens causing YLD in sugarcane was found to be only by ScYLV not by phytoplasmas as reported earlier (Nithya et al. 2020a).

Grassy shoot disease (GSD)

The disease was first reported in Maharashtra during 1950s and later it spread throughout the country. Presently, it is recorded in all the sugarcane growing areas of India. This disease is characterized by the production of a large number of thin, slender, adventitious tillers from the base of the affected stools and this seriously affects millable cane production in the field. This particular disease causes substantial yield losses across the varieties and its impact is felt in ratoons (Nithya et al. 2020b).

Leaf fleck

This is virus a disease, lesser known to personnel in sugar industry and sugarcane scientists. The disease is caused by Sugarcane bacilliform virus (SCBV) and occurs throughout the country. Although prevalence of the disease was reported earlier in the germplasm (Viswanathan et al., 1996), recent studies convinced that it occurs rampantly in sugarcane fields (Viswanathan et al., 2019). It is going to be an emerging threat to cane cultivation in the country and its impact to sugarcane productivity needs to be assessed systematically. Major symptoms of the disease include appearance of flecks or specks throughout leaf lamina. However, the flecks are more prominently seen on leaf margins and distal end of the leaf. Gradually, the chlorotic flecks increase in size, turn yellow and reddish. In extremely severe cases entire leaf turns yellow or reddish and symptoms appear close to yellow spot symptoms. Severe disease expression leads to premature drying and death of the leaves. Such disease severity is noticed in east coast region in the popular varieties such as CoA 92081 (87A298), CoV 09356 (2003V46), CoV 92102 (83V15), VCF 517 (CoVc 14061) etc (Balan et al. 2020). SCBV from India was also characterized based on complete genomes and three new putative species were reported. The Indian SCBV isolates shared nucleotide identities of 69–85 % for the complete genomic sequence within themselves indicating wide genetic diversity among them. The SCBV population had >20% nucleotide variation in RT/RNase H-region along with a variation of more than 30% in other genomic region, which makes them all viz. SCBBBV, SCBBOV, SCBBRV, SCBIMV, and SCBMV to propose as new SCBV species from India. Around 13 SCBV phylogroups were designated based on analysis of partial RT/RNase H genomic region (SCBV-A to SCBV-M) (Muller et al. 2011; Karuppaiahet al. 2013; Rao et al. 2014) which represent a high diversity of global SCBV isolates. Recent studies with more than 100 isolates revealed a huge genomic variation among the SCBV isolates in the country (Janiga et al. 2022)

Varietal degeneration

Bacterial, viral and phytoplasma pathogens cause serious setback to cane cultivation in India and many elite varieties failed under field conditions due to their susceptibility to those pathogens, even though they possessed resistance to major diseases like red rot and smut. Furthermore, systemic accumulation of these pathogens in the stalks slowly reduces vigour of the plants referred as 'varietal degeneration' and this leads to reduced cane yield in plant as well as subsequent ratoons. The major diseases associated with varietal degeneration are YLD, mosaic (sugarcane mosaic virus [SCMV] and sugarcane streak mosaic virus [SCSMV]), RSD (*Leifsoniaxyli*subsp.*xyli*) and sugarcane grassy shoot (SCGS – Phytoplasma) (Viswanathan 2016). ScYLV alone causes a reduction of 40% in both cane and sugar yield in popular varieties Co 86032, CoC 671 and CoPant 84211. The virus significantly affects photosynthetic rate, stomatal conductance, transpiration rate, SPAD values and growth parameters in the affected canes. Hence, ScYLV-infected varieties exhibit a significant reduction in growth/yield parameters, viz. stalk height, stalk thickness and number of internodes. In qRT – PCR assays, the viruses associated with degeneration showed a titre threshold in causing degeneration (Bagyalakhsmiet al. 2019, Viswanathan et al. 2014).

The author has witnessed such degeneration in a popular cv Co 419 in Karnataka state due its high susceptibility to mosaic, YLD and RSD. Similarly, cv CoC 671 another popular variety of tropical region degenerated due its high susceptibility to mosaic and YLD in different parts of Karnataka and Maharashtra (Viswanathan and Balamuralikrishnan, 2005). The cv Co 86032 was able to replace popular variety CoC 671 in large areas in these states due to the degeneration. However, the cv Co 86032 also showed decline in performance due to very poor seed nursery programme in many sugar factories in the tropical region. Due to varietal degeneration caused by ratoon stunting, YLD and mosaic pathogens, the popular variety CoS 767 was withdrawn recently from cultivation in the subtropical region. This is one of the recent examples of impact varietal degeneration and varietal replacement. This is also for the first time that a popular variety is replaced without facing severe red rot epidemics. The cv Co 0238 released for cultivation in 2009 has occupied large areas due to its vigour and high quality. The new variety has largely benefited the farmers and sugar industry in the region. Recently, the author has reiterated the need for the sugar industry to understand on varietal degeneration, its impact and suggested measures to overcome the constraint through healthy seed programme (Viswanathan, 2024)

Foliar diseases

The foliar diseases such as rust, eye spot, yellow spot, brown stripe and ring spot are air borne and most of them survive on other collateral and weed hosts. None of the foliar pathogens are sett-borne. High moisture or relative humidity following rains accompanied by low or cool temperatures favours their incidence. During this period, excess irrigation and non-stripping off their lower leaves and dry leaves, leading to high relative humidity build up within the crop. Such microclimatic conditions help to build up of the disease to epidemic levels. Among the different foliar diseases, rust has become more severe and occurs in epidemic form in Maharashtra and Karnataka during post monsoon season. Almost all the varieties under cultivation such as CoM 0265, CoVSI 9805, Co 86032, Co 92005, CoC 671, Co 94012, etc were affected by rust. Large scale cultivation of the variety CoM 0265 led to epidemic occurrence of brown spot in Maharashtra and Karnataka, especially in the high rainfall areas. Severe crop losses were witnessed in the region especially in the variety due to brown spot (Viswanathan and Ashwin, 2020). Changes in climate and adoption of susceptible varieties contribute to the epidemics of rust and brown spot and this also made other varieties to suffer from the disease. For e.g. the popular variety Co 86032 was free or resistant to rust during 2009-10. However, adoption of susceptible varieties like CoVSI 9805 favoured perpetuation of the diseases in the same ecosystem.

Impact of diseases on sugarcane production

Red rot has been a major hurdle in sustaining elite sugarcane varieties due to frequent varietal breakdown events, especially in the subtropical region. Hence the variety with high yield and quality are being removed from cultivation. Also, we could not advance many promising clones with economic traits to coordinated trials due to their susceptibility to red rot. Due to the recent red rot epidemics on the popular cv Co 0238, the country has witnessed the losses of about Rs 10,000 crores per season in the recent years (Viswanathan 2023). In tropical region also, many newlyreleased varieties for cultivation like CoC 24, Co 06022, Co 06030, Co 11015 etc in Tamil Nadu succumbed to red rot. Even the unrecommended variety like CoM 0265 suffered severely in many pockets in Tamil Nadu. Severe smut infection severely affects the cane yield and sugar recovery. The yield loss due to the smut could be up to 50% in sugarcane. In addition to loss in cane tonnage due to reduced number of millable canes, the disease infection reduces sugar recovery. Ratoon crops experience more severe disease. Similarly, wilt epidemics severely affect crop productivity across the states. Severe wilt epidemics especially in the ratoons in the coastal Andhra Pradesh have affected performance of many varieties and it is also considered as a cause for shrinkage in cane area in the state. The disease still prevails in most of the states, more severely in the subtropical region. Even under upland conditions of tropical states, severe incidences of wilt noticed in certain varieties (Viswanathan 2020). Recent findings on Fusarium diseases revealed that the same pathogen *F. sacchari* causes both wilt and twisted top (pokkahboeng) in sugarcane. The severe occurrence of both the diseases in many states are due to this phenomenon (Viswanathan et al. 2017a, 2022). Another major setback to cane cultivation in Tamil Nadu and other parts is due to very severe occurrence of crown mealy bug *Phenacoccussaccharifoli.* The sucking pest not only causes crop failures but it also induced twisted top followed by wilt (Geetha et al. 2022, Viswanathan et al. 2023). Hundreds of hectares of the crop were destroyed in many parts in Tamil Nadu due to this mealy bug-twisted top complex. YLD has reached epidemic status in different states especially in the tropical region and most of the ruling varieties suffer from the disease. Detailed studies conducted at ICAR-SBI revealed that the associated virus infection reduces plant growth and juice yield by 39-43 % and 30-34 %, respectively, in susceptible varieties at harvest (Viswanathan et al. 2014).Under field conditions, we find a huge variation in crop performance between healthy and virus-infected fields. In ratoons also further severe losses are expected due to increase in virus titre. Unlike red rot or wilt where the cane dies, here the farmers harvest canes although they are degenerated. Hence the farmers and industry do not realize the impact caused by the disease and negligence of seed health is also another concern in many places for the poor cane yield (Viswanathan, 2024). In addition to the virus and bacterial pathogens, grassy shoot phytoplasma infection can cause 35% reduction in stalk height, 15% reduction in stalk girth, 50-60% reduction in length of the internodes. Above all, 50-75% plant crop infection resulted in 100% failure in millable cane production in the ratoon crop in different varieties in the field (Viswanathan and Rao 2011).

Disease Diagnostics

All the major pathogens infecting sugarcane viz. fungi, bacteria, virus and phytoplasma are transmitted through seed canes. On seed canes, very limited disease symptoms are expressed, hence the sett-borne diseases go unnoticed. This results in introduction of diseases to a new field or new location. Hence, there is a need to address production and supply of healthy planting materials. Tissue culture technique is expected to eliminate the viruses, however, there are chances for carry over of the viruses / phytoplasmas through planting materials. Hence tissue culture plants are to be indexed for the designated viruses and phytoplasma to produce and supply healthy planting materials. At ICAR-SBI, Coimbatore, detailed works were initiated to develop precise diagnostics against the sugarcane pathogens. In the past, ELISA has been extensively used for the diagnosis of RSD pathogen Lxx infection in sugarcane. Further, sensitivity of ELISA was compared with dot-blot and tissue blot assays and the results revealed that ELISA and TBIA were equally effective it detecting Lxx and were more efficient than DBIA. Several variations in serological techniques were developed and used in different countries to develop RSD-free planting materials. PCR assays were also developed for Lxx diagnosis in sugarcane. Although PCR technique is more sensitive, inhibitors found in the sap continue to limit its sensitivity (Grisham, 2004). Association of the virus with YLD was established through DAS-ELISA technique at ICAR-SBI, Coimbatore (Viswanathan, 2002; Viswanathan and Balamuralikrishnan, 2004). Later RT-PCR assays were found to be more sensitive to detect ScYLV before symptom expression and in tissue culture raised plants (Viswanathan et al. 2018a). Assays were also developed to detect more than one virus in a reaction through duplex and multiplex-RT-PCR assays (Viswanathan et al. 2010). In addition to the viruses, PCR assays were developed to detect phytoplasmas associated with grassy shoot. Recently RT-LAMP assays were developed to detect RNA viruses of sugarcane and these assays do not require PCR machine. These assays were found to be more sensitive than RT-PCR assays (Anandakumar et al. 2018, 2020) however, the test costs of these assays are high due to a greater number of primers and consumables. Recently, a nanocatalysis-based highly sensitive lateral flow immunochromatographic assay (LFIA) was developed to simultaneously detect SCMV and

SCSMV associated with mosaic disease in sugarcane. In the assay, gold nanoparticles were used as signal enhancement system. Such a method is developed for the first time for sugarcane viruses with the linear detection sensitivity range of 10-6 to 10-12, almost equivalent to PCR detection range (Thangavelu et al. 2022). These diagnostics will pave way to develop and popularize field diagnostic kits in healthy seed nursery programmes.

Integrated disease management in sugarcane

The diseases discussed above determine the quality, quality and stability of crop yield in sugarcane. The pathogens are not only reducing the yield but also cause the deterioration of the variety due to their accumulation in the stalk over the time. This phenomenon is referred to as varietal degeneration and this result in loss of full potential of a variety and subsequently such varieties are withdrawn from cultivation. In the past and even today many high yielding, high sugar and popular cane cultivar like Co 419, Co 740, CoC 671 etc are being withdrawn from cultivation only because of their high susceptibility to red rot, smut, grassy shoot and mosaic. No single method is efficient / available to control sugarcane diseases due to various reasons hence an integrated approach involving cultural, chemical/physical methods, host resistance and legislative measures is suggested for the sustainable management of sugarcane diseases (Viswanathan, 2012).

Easily available options

Infected planting materials are responsible for the primary spread of the disease in the field. Hence, going for the disease-free setts would reduce the risk of disease introduction to disease free areas. Lack of awareness on seed cane health and ignoring quarantine regulations resulted in introduction of diseases, their epidemics and varietal degeneration in the country. To increase sugarcane productivity, supply of healthy seed canes is to be ensured in the field. As vegetative propagation in sugarcane favoursharbouring of the pathogens causing red rot, smut, wilt, grassy shoot, leaf scald, yellow leaf and ratoon stunting in the setts, adequate care should be taken while selecting seed canes. Since it is difficult to detect incipient infections of C. falcatum in seed-pieces, it is recommended to take the planting material from a disease-free crop. Any crop with more than 5% smut or as high as 2% grassy shoot incidence is unsuitable for seed purpose. For red rot, if there is any infected clump in the field the plot is to be rejected for seed. It is advised to select always a disease-free area to raise the seed crop.

Next to healthy seed, sanitation is important in preventing healthy cane from becoming infected with pathogens. Left over sugarcane debris is the prime substrate for the survival and spread of pathogen inoculum especially in the case of red rot, wilt and ratoon stunting. Red rot-affected debris is found to favour infection in planted setts and cause death of settlings. Destruction of all plant debris such as cut canes, trash and stubble in situ is essential for the reduction of the pathogen inoculum. Further, complete removal of the disease-affected clumps in the field would also ensure disease free field.

Many of the diseases in sugarcane are aggravated by various biotic and abiotic factors. Negligent crop faces different biotic and abiotic factors like different borers, sucking pests, drought or water logging etc. Biotic factors such as infestation of internode borer or Strigafavours early expression of YLD. Hence, all these biotic stresses are needed to be minimized to reduce the severity of the disease. It is well known that root borer infestation favours wilt outbreaks in different regions. Hence, adequate care should be taken to minimize many of these biotic and abiotic factors which predispose the crop for the infection of different pathogens.

Disease surveillance

Disease surveillance has not been practiced effectively in the country due to difficult cropping system. Also, the field staffs are unable to identify the diseases correctly or they ignore the likely build-up of disease(s) during later stages of the crop or in the ensuing ratoon. When due attention is not paid during the first infection stage of the diseases it would lead to its eventual spread and thereafter attaining epidemic proportion. To overcome shortcomings in the conventional system, remote sensing tools are being explored to assess disease outbreaks over large geographical or command areas. Recently, at ICAR-SBI efforts were made to standardize use of remote sensing techniques to identify YLD-affected fields. The results revealed a clear-cut spectral difference between YLD-affected and healthy fields and demarcated YLD-affected fields (Palaniswami et al., 2014). Further studies are required to optimize the same technique to identify other diseases, other biotic and abiotic constraints affecting sugarcane in the field. Sugar industry associations should come forward to map sugarcane areas for different diseases, pests or other constraints using remote sensing approaches in association with IISR and SBI and other institutions. Such efforts are to be adopted in large scale to precisely estimate threats faced by the sugar industry and to take up timely management strategies. Further, application of artificial intelligence-based approaches is emerging to identify the disease using various AI tools. However, it is found that many reports are published in the recent years without proper basic studies. Also, the authors have wrongly selected images for the analysis and this creates a confusion among the readers. The scientists have to collaborate with the crop institutes or universities with expertise to create a new foolproof AI platform for surveillance that solves the farmers' problem and address the concerned disease.

Scientific introduction of varieties for cultivation

Major diseases like red rot, smut and wilt are managed through introduction of disease resistant varieties and simultaneous removal of disease susceptible varieties. Inspite of this, red rot occurs in different states in the country due to unscientific varietal introduction. Due to craze for new varieties unhealthy seed is taken to different places which results in unintended disease introduction in different regions. Unless the factories follow scientific varietal introduction, it is difficult to minimize red rot or other diseases occurrence in the country (Viswanathan, 2010, 2012). The new diseases may not be serious in their place of origin and it may become very serious in the new environment. Similarly, the new races of the viruses which were not expressed elsewhere may cause severe symptoms and pose new challenge to cane cultivation. The factories/farmers should avoid introducing unknown varieties to prevent disease outbreaks.

Chemical control

Sett treatment for a limited duration or stool spray with fungicides failed to control sugarcane diseases at earlier crop stages. Partial chemical control of the disease under field conditions is due to impervious nature of the rind, limited uptake of fungicide during short duration of treatment and inability of the fungicide to reach the site of infection in the tissue. Detailed studies taken up at ICAR-SBI improved delivery of fungicides in the setts through mechanized-vacuum infiltration and the treatment has resulted in more effective diffusion of the chemicals into sugarcane setts / buds. The mechanized device was developed in collaboration with ICAR-CIAE, Regional Station, Coimbatore. Field trials were conducted at disease endemic locations revealed that effective delivery of fungicides through the "Sett treatment Device" efficiently protected the crop from red rot, smut and wilt (Malathi et al. 2017, Viswanathan et al. 2016, 2017b). By effective sett treatment, both soil and sett borne inocula of the pathogens were killed or inactivated, thus resulted in a significant reduction in disease development. This new opportunity has created alternate strategy to effectively manage red rot and smut diseases in sugarcane. Apart from effective disease management through improved sett treatment, treating the planting material with different agro inputs like microbes, urea, micronutrients, insecticides etc good quality settlings with improved germination, growth promotion and tolerance to abiotic stresses are produced in the settling nurseries. Currently, more than 300 STD units were installed in different states for disease management and nurseries to produce healthy settlings.

Healthy seed nursery programme& management of varietal degeneration in sugarcane

The scientific principle involved in heat therapy is that the pathogens present in seed materials are inactivated or eliminated at set temperatures not deleterious for the host tissues. Aerated stream therapy (AST) or moist hot air treatment (MHAT) is advocated to eliminate sett borne infections of grassy shoot and ratoon stunting. Any fault in the AST or MHAT unit may adversely affect the sett germination. Hence functioning of the heating unit and temperature control systems, proper volume and circulation of the heating medium and proper loading of the cane within the treatment chamber are to be monitored time to time. Treated setts should always be treated with fungicides (Carbendazim 0.1%) to reduce the entry of soil pathogens through cut ends. Since operations in AST need critical care and handling this treatment is recommended only for raising primary seed in three tier seed nursery programme. The treated setts should always be planted in factory farm for better monitoring. However, heat treatment is not effective against viruses and partially effective against other pathogens, hence in place of the thermotherapy meristem-culture derived seedlings is recommended in three tier seed nursery programme to get disease-free seedlings.

In sugarcane, disease resistance has been successfully exploited to manage major fungal diseases such as red rot, smut and wilt in India and other South Asian countries. However, there is no systematic breeding or screening programme to develop resistance to grassy shoot, RSD, YLD and mosaic of sugarcane in these regions. Addition of new selection traits will complicate varietal selection process in the current varietal developmental programme and also the process will become more cumbersome. The diseases associated with varietal degeneration can be managed successfully through healthy seed nursery programme whereas this approach is not sufficient to manage fungal diseases in the crop. Hence three-tier seed nursery programme was advocated to manage non-fungal diseases of sugarcane such as grassy shoot and RSD during the last 3-4 decades in the country (Viswanathan and Rao, 2011). Heat therapy, either aerated steam or moist hot air was employed to inactivate grassy shoot phytoplasma / Lxx in seed canes in this programme. Partial or complete inactivation of these pathogens was adequate to manage these two important diseases contributing towards varietal degeneration in a five-year seed cycle.

Since heat therapy is ineffective against viral diseases, tissue culture methods were employed to eliminate systemic virus(es) infection in sugarcane in different countries.

Meristem culture has been exploited for the production of virus-free plants by meristem culture in many vegetatively propagated crops. By this approach, it has been possible to eliminate ScYLV and other viruses from many commercial varieties worldwide. Ever since YLD became a serious constraint to sugarcane production in different countries efforts were made to manage the disease through different strategies. Among the different approaches, going for meristem culture technique was found to be more effective in the elimination of the causative virus from the systemically infected plants (Ramgareeb et al. 2010, Snyman et al. 2011). At our conditions incorporation of nucleic acid analogues like ribavirin improved the efficiency of ScYLV elimination from the infected mother plants. Since these virus elimination techniques are not 100% efficient to eliminate the virus there is a need to index the sugarcane seedlings using precise techniques. At seedlings stage the disease symptoms are not expressed. Also, symptom expression in meristem derived plants in the field may be suppressed due to very low titre of the infective pathogens. Many improved diagnostic techniques based on serological and molecular techniques were developed to detect these pathogens. Meristem culture combined with molecular diagnosis was proved to be successful to effectively manage the disease. Detailed studies conducted at SBI proved that ScYLV elimination can be achieved through meristem culture combined with molecular diagnosis. The virus-free plants have maintained good crop stand under field conditions and recorded higher yield than the conventional seed planted fields (Viswanathan, 2018). Earlier Chatenet et al. (2001) and Parmessur et al. (2002) reported successful elimination of ScYLV by tissue culture from infected sugarcane plants from France and Mauritius, respectively.

The potential for eradicating pathogens via rapid regeneration of plants directly from leaf roll discs was explored in South Africa. The technique, NovaCane®, has been used successfully to remove SCYLV (Snyman et al. 2008). In addition, this process enabled elimination of bacterial pathogens from diseased sugarcane plants while simultaneously enabling large-scale micro propagation. Cheong et al. (2012) developed procedures for the in vitro elimination of SCMV, sorghum mosaic virus (SrMV), SCSMV, ScYLV and Fiji disease virus (FDV) from infected sugarcane and they standardized in vitro shoot regeneration, elongation and virus elimination through meristem tissue culture originating from both apical and axillary shoots and found 61–92% virus-freedom among elongated shoots. Overall, clean seed programme initiated through tissue culture benefit sugar industry in different sugarcane growing countries. Production of ScYLV-free seedlings has ensured supply of YLD-free planting materials to the growers' fields and such fields showed renewed vigour in the crop. Detailed studies conducted in the factory areas in Tamil Nadu revealed that adoption of tissue culture derived YLD-free nurseries resulted in a better crop stand with good vigour. Such fields recorded as high as 250 tonnes per hectare cane yield in Erode Dt in Tamil Nadu (Viswanathan et al. 2018b). Degeneration in the popular cv Co 86032 has been addressed through a systematic study and viable strategy has been developed to address varietal degeneration in the country (Viswanathan, 2021a, 2023). In addition, adoption of sett treatment device to deliver different agro inputs have improved settling vigour in settling nurseries has been demonstrated (Viswanathan et al. 2017b).

Healthy seed nursery chains to sustain cane productivity

Three-tier seed nursery programme has been in vogue for many decades in the country. Many sugar mills have installed/adopted heat treatment systems for sett treatment followed by raising Foundation nurseries and production of certified/ commercial seed. After initial years of implementation its adoption was very poor across the country. Heat treatment systems are not maintained or used in the nursery programmes. Since heat treatment is partially effective against phytoplasma and RSD bacterium, the heat treatment could not address the desired outcome. Further, heat treatment is ineffective against viruses hence it cannot be recommended against the viruses like ScYLV or mosaic causing viruses. Hence virus elimination through meristem culture combined with indexing for designated viruses / phytoplasma was suggested to ensure total freedom from the designated pathogens. Healthy planting materials derived from this approach exhibit high vigour and restore yield potential of a variety. Hence there is a need to create a chain of healthy seed nurseries across the country to address varietal regeneration and to achieve sustainable sugarcane production. Unless the industry takes such revolutionary approach, it is difficult to meet the growing demand of sugarcane for sugar and ethanol.

CONCLUSION

In sugarcane, major fungal diseases like red rot and smut are managed through varietal development by releasing new disease resistant varieties and other diseases are to be managed through other management strategies. Minor diseases like twisted top, rust and brown spot have emerged as major diseases in certain regions, probably due to changes in climate, deployment of susceptible varieties and development new pathogenic variants. To address soil and sett borne inoculum of fungal diseases, we have demonstrated effectiveness of mechanized sett treatment with fungicides. Additionally, the same system was useful to deliver various agro inputs through setts and to raise vigorous settlings. To manage fungal diseases during grand growth phases, delivery through drones is being standardized. Here caution is to be given on indiscriminate sprays through drones as there is a need to fix ideal spray timing and spray volume. In addition, there is a need to continuously monitor the diseases, changes in the disease spectrum/severity, emerging new pathogenic strains and standardizing AI tools to monitor the diseases in sugarcane ecosystem.

Although newly introduced varieties were superior in yield and quality, under field conditions we could not harness the improved potential of yield and quality. The major reason for this situation is attributed to slow degeneration of the new varieties due to systemic accumulation of non-fungal pathogens in the canes. By the time the new variety becomes popular, it succumbs to different stages of degeneration depending on seed replacement programmes. The varietal degeneration was not recognized in the country till YLD reached an epidemic level across the states. The crop loses about 2 to 3 months of its active growth depending on the pathogen load and plant or ratoon crop. The overall loss caused by YLD and other non-fungal pathogens associated with varietal degeneration could be several billion rupees in India, hence a clean seed programme is recommended to tackle this constraint. Adoption of disease-free nurseries raised from tissue (meristem) culture combined with molecular diagnosis resulted in a significant improvement in cane yield. In the long run, adopting disease-free nurseries will lead to enhanced cane productivity in the country and the elite commercial varieties will have an extended life with vigour. Further, by adopting the clean seed programme, the country will be able to realize additional cane production of 55 to 100 mt within the same cropped area. As the demand for sugarcane for sugar, ethanol, power and other downstream processes increases every year, additional cane production can be met by managing non-fungal diseases through varietal rejuvenation programmes.

REFERENCES

1. Anandakumar, L., K. Bagyalakshmi, K. Nithya, B. Parameswari and R. Viswanathan (2018). Reverse transcription loop-mediated isothermal amplification (RT-LAMP) assay for rapid diagnosis of *Sugarcane yellow leaf virus in sugarcane. Sugar Tech*20:708-716 DOI: 10.1007/s12355-018-0606-2

2. Anandakumar, L., K. Bagyalakshmi, T. Raja Muthuramalingam, K. Nithya, B. Parameswari and R. Viswanathan (2020). Reverse transcription loop-mediated isothermal amplification based rapid detection of *Sugarcane mosaic virus and Sugarcane streak mosaic virus* associated with mosaic disease of sugarcane. *Indian Phytopathology*73:349-358 DOI: 10.1007/s42360-020-00219-w

3. Bagyalakshmi, K., R. Viswanathan and V. Ravichandran (2019). Impact of the viruses associated with mosaic and yellow leaf disease on varietal degeneration in sugarcane. *Phytoparasitica*47: 591–604 DOI: 10.1007/s12600-019-00747-w

4. Balan S, R. Viswanathan and K. Anita Cherian (2020) Status of leaf fleck caused by Sugarcane bacilliform virus incidence and severity in different sugarcane growing areas of Kerala and Tamil Nadu. *Journal of Sugarcane Research* 10: 74-86 https://doi.org/10.37580/JSR.2020.1.10.74-86

5. Chatenet, M., C. Delage, M. Ripolles, M. Irey, B.E.L. Lockhart and P. Rott (2001). Detection of Sugarcane *yellow leaf virus* in quarantine and production of virus-free sugarcane by apical meristem culture. *Plant Disease* 85: 1177-1180.

6. Cheong, E.L., R. Mock and R. Li (2012). Elimination of five viruses from sugarcane using in vitro culture of axillary buds and apical meristems. Plant *Cell Tissue and Organ Culture* 109: 439–445.

7. Chinnaraja C, Viswanathan R, Karuppaiah R, Bagyalakshmi K, Malathi P et al. (2013) Complete genome characterization of Sugarcane yellow leaf virus from India: evidence for RNA recombination. *European Journal of Plant Pathology* 135: 335–349.

8. Chinnaraja, C. and R. Viswanathan(2015a) Variability in yellow leaf symptom expression caused by the Sugarcane yellow leaf virus and its seasonal influence in sugarcane. *Phytoparasitica*43:339-353DOI: 10.1007/s12600-015-0468-z

9. Chinnaraja, C. and R. Viswanathan (2015b) Quantification of sugarcane yellow leaf virus in sugarcane following transmission through aphid vector, *Melanaphissacchari. Virus Disease* 26 (4): 237-242

10. Geetha N., R. Viswanathan, T. Ramasubramanian, K.P. Salin, C. Yogamba, P. Nirmala Devi, S. Karthigeyan and N. Chitra (2022) *Phenacoccussaccharifolii* (Green) (Pseudococcidae: Hemiptera) on sugarcane in Tamil Nadu, India. *Current Science* 123(9): 1142-1151.

11. Grisham, M.P. (2004). Ratoon stunting disease. In: *Sugarcane Pathology,* Volume III: Bacterial and Nematode Diseases. Rao G. P., Saumtally A. S., and Rott P., (eds) pp 77-96, Science Publishers, Inc., Enfield, NH, USA.

12. Janiga, P.K., K. Nithya and R. Viswanathan (2023). Dynamics of genetic diversity among Indian sugarcane bacilliform virus species and implications of associated recombination events in the virus. *Sugar Tech*25: 705–716

13. Karuppaiah, R., R. Viswanathan and V.G. Kumar (2013). Genetic diversity of *Sugarcane bacilliform virus* isolates infecting Saccharum spp. in India. Virus Genes 46: 505-516

14. Malathi, P, R. Viswanathan and A.R. Sundar (2017). Mechanized means of sett treatment: An effective way of delivering fungicides for the management of red rot in sugarcane. *Sugar Tech* 19:176-182

15. Muller, E., V. Dupuy, L. Blondin, F. Bauffe, J.-H. Daugrois et al (2011) High molecular variability of sugarcane bacilliform viruses in Guadeloupe implying existence of at least three new species. *Virus Research* 160: 414-419

16. Nithya, K., B. Parameswari, A. Bertaccini, G. P. Rao and R. Viswanathan (2020b). Grassy shoot: the destructive disease of sugarcane. *Phytopathogenic Mollicutes* 10(1): 10-24 doi: 10.5958/2249-4677.2020.00002.X

17. Nithya, K., B. Parameswari, and R. Viswanathan (2020a). Mixed infection of sugarcane yellow leaf virus and grassy shoot phytoplasma in yellow leaf affected Indian sugarcane cultivars. *Plant Pathology Journa*l 36(4): 364-377 https://doi.org/10.5423/PPJ.OA.06.2020.0092

18. Palaniswami, C., R. Viswanathan, A. Bhaskaran, P. Rakkiyappan and P. Gopalasundaram (2014). Mapping sugarcane yellow leaf disease affected area using remote sensing technique. Journal of *Sugarcane Research* 4 (1) 55-61

19. Parmessur, Y., S. Aljanabi, S. Saumtally and A. Dookun-Saumtally (2002). Sugarcane yellow leaf virus and sugarcane yellows phytoplasma: elimination by tissue culture. *Plant Pathology* 51: 561–566.

20. Ramgareeb, S., S.J. Snyman, T. Van Antwerpen and R. S. Rutherford (2010). Elimination of virus and rapid propagation of disease-free sugarcane (Saccharum spp. cultivar NCo 376) using apical meristem culture. *Plant Cell Tissue Organ Culture* 100: 175–181.

21. Rao, G.P., S.K. Sharma, D. Singh, M. Arya, P. Singh and V.K. Baranwal (2014) Genetically diverse variants of Sugarcane bacilliform virus infecting sugarcane in India and evidence of a novel recombinant *Badnavirus variant. Journal of Phytopathology* 162: 779-787

22. Rott, P., R.A. Bailey, J.C. Comstock, B.J. Croft, S. Saumtally (2000). *A Guide to Sugarcane Diseases*. Montepellier: CIRAD-ISSCT, CIRAD Publication Services

23. Snyman, S.J., G.M. Meyer, A.C. Koch, M. Banasiak and M.P. Watt (2011). Applications of in vitro culture systems for commercial sugarcane production and improvement. *In Vitro Cellular and Developmental Biology-Plant* 47:234–249

24. Snyman, S.J., G.M. Meyer, M. Banasiak, T.L. Nicholson, T. Van Antwerpen, P. Naidoo and J.D. Erasmus. (2008). Micropropagation of sugarcane via Novacane®: Preliminary steps in

commercial application. *Proceedings of South African Sugar Technologists Association* 81: 513 - 516

25. Thangavelu RM, K. Nithya, B. Parameswari, R. Viswanathan 2022. Ultrasensitive nano-gold labelled, duplex lateral flow immunochromatographic assay for early detection of sugarcane mosaic viruses. *Scientific Reports* 12: 4144 https://doi.org/10.1038/s41598-022-07950-6
26. Viswanathan, R. (2002). Sugarcane yellow leaf syndrome in India: Incidence and effect on yield parameters. *Sugar Cane International* 20(5): 17-23.
27. Viswanathan, R. (2012). *Sugarcane Diseases and Their Management*, Sugarcane Breeding Institute, Coimbatore, p140.
28. Viswanathan, R (2013). Status of sugarcane wilt: one hundred years after its occurrence in India. *Journal of Sugarcane Research*3 (2): 86-106.
29. Viswanathan, R. (2016). Varietal degeneration in sugarcane and its management in India. Sugar Tech 18: 1–7.
30. Viswanathan, R. (2018). Changing scenario of sugarcane diseases in India since introduction of hybrid cane varieties: path travelled for a century. *Journal of Sugarcane Research* 8 (1): 1 – 35.
31. Viswanathan R. (2020). Fusarium diseases affecting sugarcane production in India. *Indian Phytopathology* 73:415–424
32. Viswanathan, R. (2021a). Impact of yellow leaf disease in sugarcane and its successful disease management to sustain crop production. *Indian Phytopathology* 74: 573–586 DOI:10.1007/s42360-021-00391-7
33. Viswanathan, R (2021b). Red rot of sugarcane (*Colletotrichum falcatum* Went). CAB Reviews 16, No. 023, doi: 10.1079/PAVSNNR202116023
34. Viswanathan, R. (2021c). Sustainable sugarcane cultivation in India through threats of red rot by varietal management. *Sugar Tech* 23(2):239–253 https://doi.org/10.1007/s12355-020-00882-3
35. Viswanathan,R.(2023) Management of sugarcane diseases in India: the role of disease resistance and healthy seed cane. *Proceedings of the International Society of Sugar Cane Technologists*31: 884–892
36. Viswanathan, R. (2024) Degeneration in Sugarcane Varieties: Does the Sugar Industry Realize it? *Sugar Tech* DOI: 10.1007/s12355-024-01439-4
37. Viswanathan, R., K. C. Alexander and I.D. Garg (1996). Detection of sugarcane bacilliform virus in sugarcane germplasm. Acta Virologica 40: 5-8
38. Viswanathan, R. and N.M.R. Ashwin (2020) Brown spot of sugarcane: an emerging disease in South Western region in India. *Journal of Sugarcane Research* 10: 79-85
39. Viswanathan, R. and M. Balamuralikrishnan (2004). Detection of sugarcane yellow leaf virus, the causal agent of yellow leaf syndrome in sugarcane by DAS-ELISA. *Archives of Phytopathology and Plant Protection* 37: 169-176

40. Viswanathan, R. and M. Balamuralikrishnan (2005). Impact of mosaic infection on growth and yield of sugarcane. *Sugar Tech* 7(1): 61-65.

41. Viswanathan, R., M. Poongothai, and P. Malathi (2011) Pathogenic and molecular confirmation of Fusarium sacchari causing wilt in sugarcane. Sugar Tech13:68-76.

42. Viswanathan, R. and G. P. Rao (2011). Disease scenario and management of major sugarcane diseases in India. Sugar Tech 13: 336–353.

43. Viswanathan, R.,C. Chinnaraja, P. Malathi, R. Gomathi, P. Rakkiyappan, D. Neelamathi and V. Ravichandran (2014). Impact of Sugarcane yellow leaf virus (ScYLV) infection on physiological efficiency and growth parameters of sugarcane under tropical climatic conditions in India. Acta Physiologiae Plantarum36: 1805–1822

44. Viswanathan, R., R. Karuppaiah, K. Bagyalakshmi, S. Balan, K. Kaverinathan (2019). Emergence of leaf fleck caused by Sugarcane bacilliform virus in sugarcane as a serious disease under field conditions in India. International *Sugar Journal* 121:146-153.

45. Viswanathan, R., R. Karuppaiah and M. Balamuralikrishnan (2010). Detection of three major RNA viruses infecting sugarcane by multiplex reverse transcription polymerase chain reaction multiplex-RT-PCR. *Australasian Plant Pathology* 39: 79-84.

46. Viswanathan, R, Malathi P, Naik R (2016) A sett treatment device for fungal disease management and healthy nursery programme in sugarcane. *Proceedings Annual Convention of Sugar Technologists of India* 77: 236-253.

47. Viswanathan, R., C.G. Balaji, R. Selvakumar, P. Malathi, A.R. Sundar et al. (2017a) Epidemiology of Fusarium diseases in sugarcane: a new discovery of same Fusarium sacchari causing two distinct diseases, wilt and pokkahboeng. *Sugar Tech*19: 638-646

48. Viswanathan, R., P. Malathi, C.N. Prasanth, R. Naik and S.J.K. Annamalai (2017b). Sett way of growing sugarcane for fungal treatment. *ICAR NEWS* 23 (2) 1-3

49. Viswanathan, R., B. Parameswari and K. Nithya (2018a) Molecular characterization of sugarcane viruses and their diagnostics. In: Crop Improvement through Microbial Biotechnology (Eds R. Prasad, S. S. Gill and N. Tuteja), Elsevier, Amsterdam, pp 175-193.

50. Viswanathan, R., P. Malathi and D. Neelamathi (2018b). Enhancing sugarcane yield per hectare through improved virus-free seed nursery programme. *ICAR NEWS* 24(4): 4-5.

51. Viswanathan, R., S.P. Singh, R. Selvakumar, D. Singh, Y.P. Bharti, M. L. Chhabra, B. Parameswari, A. Sharma and Md. Minnatullah (2022a). Varietal break down to red rot in the sugarcane variety Co 0238 mimics Vertifolia effect: characterizing new *Colletotrichum falcatum* pathotype CF13. Sugar Tech 24: 1479–1496https://doi.org/10.1007/s12355-021-01070-7

52. Viswanathan, R, T. Ramasubramanian, C. Chinnaraja, R. Selvakumar, T. Lakshmi Pathy, K. Manivannan, and R. Nithyanantham (2022b). Population dynamics of *Melanaphissacchari* (Zehntner), the aphid vector of sugarcane yellow leaf virus under tropical conditions in India. *Tropical Plant Pathology* 47: 260–277 DOI 10.1007/s40858-021-00483-9

53. Viswanathan R., N. Geetha, K.P. Salin, R. Selvakumar, P. Malathi, A. R. Sundar, R. Nithyanantham and K. Manivannan (2023) Twisted top disease a destructive disease of sugarcane in India. Indian Phytopathology76:625-630

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Digital Era in Sugar Industry
Multipronged approach towards AI/ML Adoption

Alok Pandit [1], Dr Sanjiv Bachal [2], Dr Shilpa Kodolikar [3]

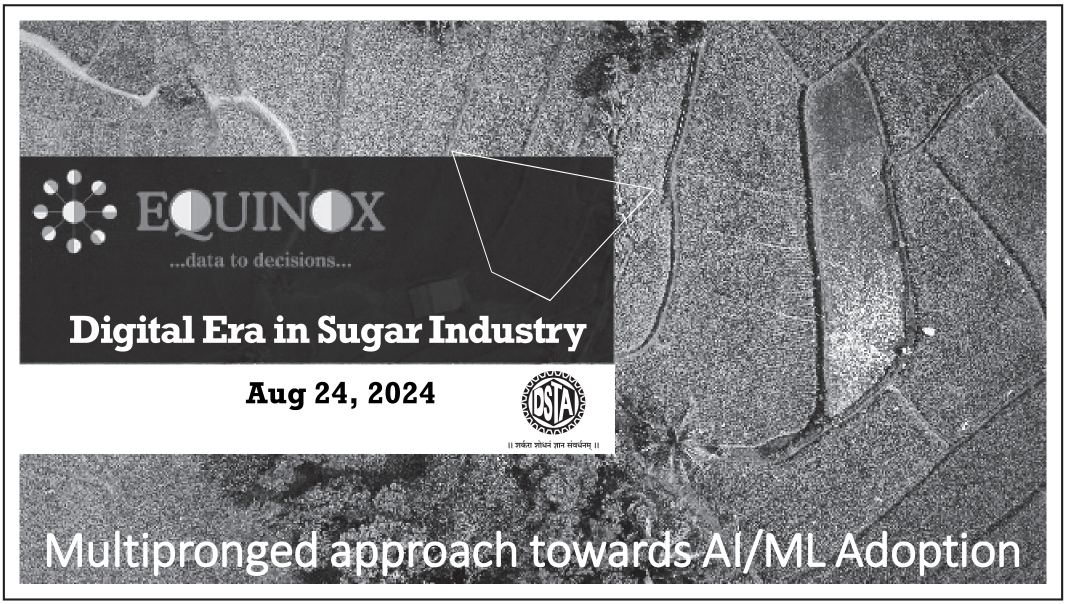
ABSTRACT

We are lucky to live in a Digital Era!!

The pace at which digital transformation is taking place, across the industries and across the globe, has ensured that we cannot remain untouched with this transformation. In fact, leading technologists have gone to the extent of saying that digital transformation is crucial for our survival!!

AI/ML, in some form or the other, is at the back of this digital transformation. This transformation spans across data, images, sound, video, 3D models, virtual reality, code, music, sound generation – The technology is indeed pushing the horizons.

This presentation aims to introduce the audience to a few generic concepts in AI/ML space, in non-technical language, to set the stage. It will then, take a look at the industrial adoption of AI/ML technology, specifically citing examples from its adoption in the sugar industry world-wide.



[1] Alok Pandit - CEO, [2] Dr Sanjiv Bachal - Vice President - A & D2, [3] Dr Shilpa Kodolikar - Senior Manager, Technical., Equinox Software and Services Pvt. Ltd.

Agenda

In today's attention economy, capturing the focus of individuals has become increasingly challenging, as attention itself is a scarce and valuable resource.

|| शर्करा शोधनं ज्ञान संवर्धनम् ||

- The digital era
- Focus on AI
- Variants of AI
- Applications of AI
- AI in Sugar worldwide
- Discussion

EQUINOX ...data to decisions... 2

Let us begin on a bright note

Coming together…is beginning

Working together … is progress

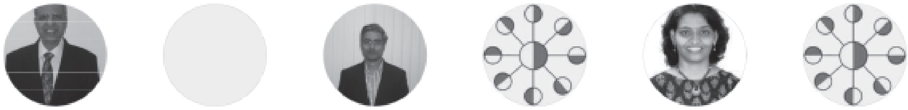
Building together …. Is success

|| शर्करा शोधनं ज्ञान संवर्धनम् ||

- No prior acquaintance with AI or machine learning is required; your curiosity is the sole ticket to this expedition

EQUINOX ...data to decisions... 3

EQNX Team



Alok Pandit
CEO

Dr. Sanjiv Bachal
Vice President

Dr Shilpa Kodolikar
Senior Manager

We are thrilled and humbled to be your guide
on this thrilling expedition into this exciting technology

EQUINOX
4

Objective

- To equip you to navigate the complex, yet exhilarating landscape of AI
- Our goal is to make you AI aware so that you start thinking of embedding AI in everything you do

EQUINOX
5

Profile

॥ शर्करा शोधनं ज्ञान संवर्धनम् ॥

Founded	Strength	Projects	Global	Aim
2005 Started active business in 2007	Over 60 People More than 25% with Masters Degree	1.5 Million Person Hours Delivered	Projects in 15 countries over 3 continents	"...Gain better "process" understanding to "process" better Gains..."

EQUINOX ...data to decisions...

6

॥ शर्करा शोधनं ज्ञान संवर्धनम् ॥

- What is AI
- What is driving so much interest in AI
- Is Sugar Industry ready for AI Adoption

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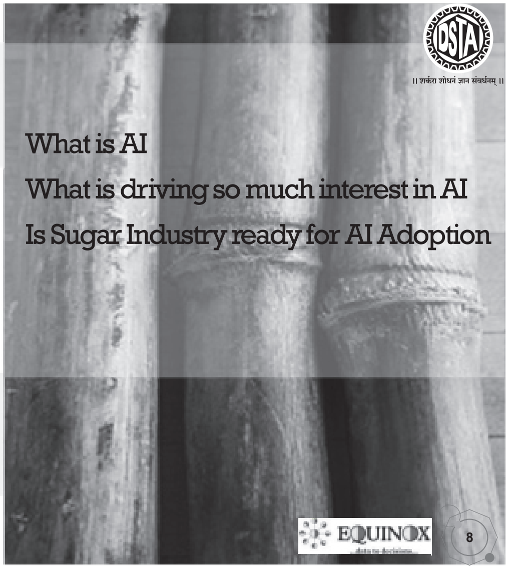
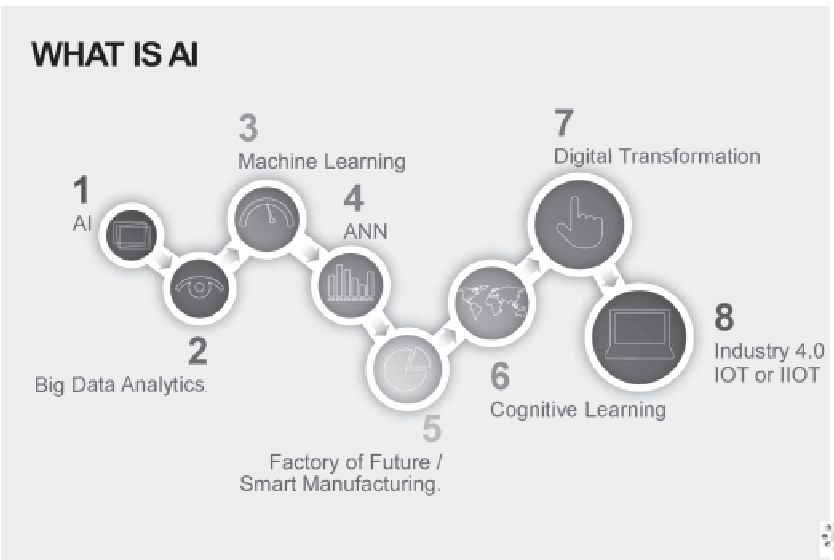
7

"Artificial Intelligence is the study of how to make computers do things at which, at the moment, people are better.

that if a machine can trick humans into thinking it is human, then it has intelligence—the so-called Turing test.

AI can best be described as collection of different technologies brought together to enable a system — a process, asset or machine — to act with intelligence.



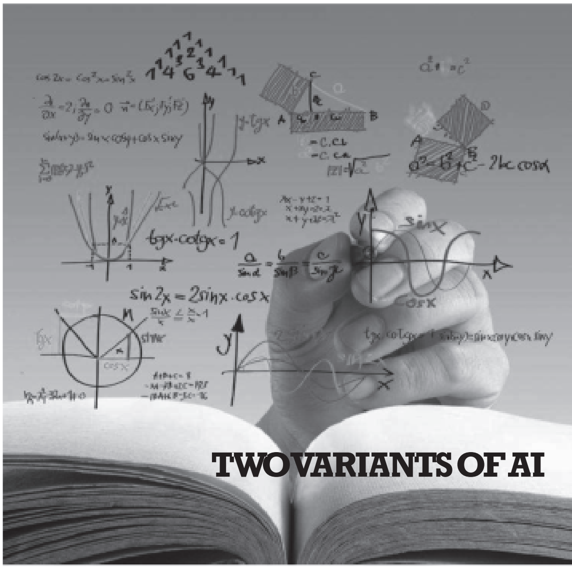


DSTA

Many different terms are in vogue

EQUINOX

9



1. Discriminative
2. Generative

॥ शर्करा शोधनं ज्ञान संवर्धनम् ॥

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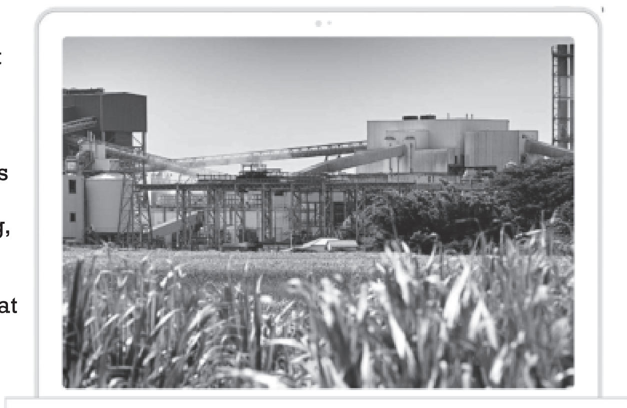
10

Discriminative AI

- Learns to tell apart different data classes.
- Put simply, in one way or another, this part of AI is deciding, selecting, distinguishing, or differentiating on data or a problem at hand.



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11

Discriminative AI

॥ शर्करा शोधनं ज्ञान संवर्धनम् ॥

Example

Molasses Grade - Classification

Collect Data

Grade Features

Prediction

Input a set of features

AI will predict its grade

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12



॥ शर्करा शोधनं ज्ञान संवर्धनम् ॥

Sample Data – Molasses Classification

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13

Generative AI

- Generative AI, is fundamentally different.
- It has the ability to generate all kinds of data and content.
- By learning the patterns and characteristics of given datasets, generative AI models can create new data samples that are similar to the original data.

|| शर्करा शोधनं ज्ञान संवर्धनम् ||

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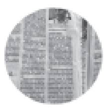
Generative AI

|| शर्करा शोधनं ज्ञान संवर्धनम् ||

Data

Generation



Data

Transformation

Data

Enrichment

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Data

॥ शर्करा शोधनं ज्ञान संवर्धनम् ॥

Requirement for timely collection / provision and electronic storage

Remote

Share / send data manually

Real time Collection

Auto scheduled

Consistency is the key

Eliminate data gaps and data errors

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Case Studies

॥ शर्करा शोधनं ज्ञान संवर्धनम् ॥

1 **Brazil**

2-3 **Germany**

4-5 **India**

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Process Optimization and Energy Management

|| शर्करा शोधनं ज्ञान संवर्धनम् ||

- **Sugarcane Crushing and Juice Extraction:** AI can optimize the crushing process by monitoring the condition of machinery, adjusting operational parameters in real-time to maximize juice extraction, and minimizing sugar loss.
- **Juice Clarification and Filtration:** AI models can optimize the clarification process, predicting the best conditions for removing impurities, thus improving the quality of the extracted juice.
- **Energy Management:** AI helps in optimizing the energy usage in sugar mills by predicting energy demand, managing the use of by-products like bagasse (sugarcane residue) for cogeneration, and improving overall energy efficiency.
- **Case Study: Raízen, Brazil**
  Integrated AI into its operations to optimize sugarcane crushing and energy generation. Using AI algorithms, Raízen monitors the performance of its mills in real-time, adjusting parameters such as the speed of crushing and the use of steam in turbines. This optimization has led to significant increases in sugar extraction rates and a reduction in energy consumption. Additionally, AI helps in the optimal use of bagasse (a by-product of sugarcane) for co-generation, which not only meets the energy needs of the mills but also allows surplus energy to be sold back to the grid.

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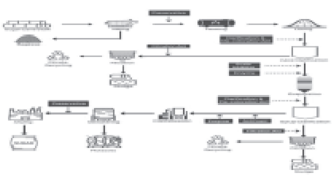
Quality Control and Product Consistency

|| शर्करा शोधनं ज्ञान संवर्धनम् ||

- **Real-Time Monitoring:** AI systems can monitor sugar quality during production, ensuring that the product meets the required specifications for color, purity, and granulation size.
- **Defect Detection:** AI-driven image recognition systems can detect impurities or inconsistencies in the sugar crystals, ensuring that only high-quality sugar is packaged and shipped.
- **Case Study: Südzucker, Germany:** Südzucker, one of Europe's largest sugar producers, has implemented AI-driven quality control systems in its production lines. These systems use machine learning algorithms to analyze data from various sensors and cameras, detecting impurities or inconsistencies in sugar crystals. This real-time monitoring ensures that only high-quality sugar reaches the market, reducing waste and enhancing customer satisfaction. The AI system has also helped Südzucker reduce the time required for quality checks, leading to faster production cycles.



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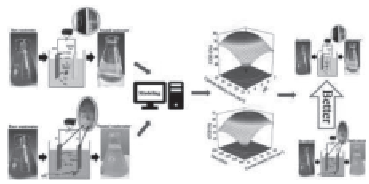
Environmental Management and Sustainability

॥ शर्करा शोधनं ज्ञान संवर्धनम् ॥

- **Effluent Treatment Optimization:** AI can optimize the treatment of wastewater generated during sugar processing, ensuring that effluents meet environmental standards before being discharged, thus reducing the environmental impact.
- **By-Product Utilization:** AI can assist in optimizing the use of by-products like molasses and bagasse, turning them into valuable products such as bioethanol, animal feed, or paper, contributing to a circular economy within the sugar industry.
- **Case Study: DCM Shriram, India:** DCM Shriram, a prominent sugar producer in India, has adopted AI technologies to manage its effluent treatment processes. AI models optimize the treatment of wastewater generated during sugar production, ensuring that effluents meet environmental standards before being discharged. This not only helps the company comply with stringent environmental regulations but also reduces the environmental impact of its operations. Additionally, DCM Shriram uses AI to optimize the use of by-products like molasses, converting them into value-added products such as bioethanol.



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Summary

Digital Era in Sugar Industry

॥ शर्करा शोधनं ज्ञान संवर्धनम् ॥

- A mere glimpse into the recent past reveals the embryonic stages of generative AI, yet, within a fleeting span, advancements like ChatGPT have marked a point of no return.
- This crescendo of innovation is not confined to textual realms alone but spans across images, videos, 3D objects, datasets, virtual realities, code, music, and sound generation, each stride accelerating our pace toward the enigmatic horizon of AGI.
- The rapid maturation and adoption of generative AI outshine the evolutionary arcs of many preceding technologies.

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Alternative Fuels in India: Technology and Regulatory Landscape

Dr. S. S. Thipse

India's energy landscape is undergoing a significant transformation as the nation seeks to reduce its reliance on conventional fossil fuels and address pressing environmental concerns. The push for alternative fuels is driven by the need to enhance energy security, combat air pollution, and meet global climate commitments. This write-up delves into the various alternative fuel technologies being adopted in India, along with the regulatory framework supporting their implementation.

1. COMPRESSED NATURAL GAS (CNG)

A. Overview:

Compressed Natural Gas (CNG) is primarily used as a cleaner alternative to petrol and diesel in vehicles. CNG is a fossil fuel that produces fewer emissions of harmful pollutants, making it an attractive option for urban transport.

B. Key Features

i. Environmental Benefits: CNG vehicles emit significantly lower levels of carbon monoxide (CO), nitrogen oxides (NOx), and particulate matter compared to diesel and petrol vehicles.

ii. Cost-Effectiveness: The cost of CNG is generally lower than that of petrol and diesel, leading to reduced operating costs for vehicle owners.

iii. Infrastructure Development: India has established a robust network of CNG stations, particularly in metropolitan areas like Delhi, Mumbai, and Kolkata, with over 3,000 stations operational.

C. Challenges

i. Limited Range: CNG vehicles typically have a shorter driving range compared to their petrol or diesel counterparts, which can be a concern for long-distance travel.

ii. Infrastructure Gaps: While urban areas have a good network of CNG stations, rural regions still lack adequate refuelling infrastructure.

2. LIQUEFIED NATURAL GAS (LNG)

A. Overview

Liquefied Natural Gas (LNG) is increasingly being recognized as a viable alternative fuel for heavy-duty vehicles, including trucks and buses. LNG is natural gas that has been cooled to a liquid state, allowing for more efficient storage and transportation.

Dr. S. S. Thipse, Sr. Deputy Director, Power Train Engingering, ARAI

B. Key Features

i. Longer Range: LNG vehicles can travel longer distances without refuelling, making them suitable for freight transport.

ii. Lower Emissions: LNG combustion results in lower greenhouse gas emissions compared to diesel, contributing to cleaner air quality.

iii. Infrastructure Initiatives: The Indian government is planning to establish around 1,000 LNG refuelling stations along major highways to facilitate the adoption of LNG vehicles.

C. Challenges

I. High Initial Investment: The cost of LNG vehicles and the required infrastructure can be high, posing a barrier to widespread adoption.

ii. Public Awareness: There is limited awareness among fleet operators and consumers about the benefits and availability of LNG as a fuel option.

3. BIOFUELS

A. Overview

Biofuels, including ethanol and biodiesel, are derived from renewable biological materials. India is focusing on biofuels to enhance energy security and reduce greenhouse gas emissions.

B. Key Features

i. Ethanol Production: India has mandated a 10% ethanol blending in petrol, with a target of 20% blending by 2025. Ethanol is primarily produced from sugarcane and other agricultural residues.

ii. Biodiesel Initiatives: Biodiesel can be produced from various feedstocks, including used cooking oil, non-edible oils, and animal fats. The government has set a voluntary target of 5% biodiesel blending in diesel.

iii. Rural Development: The biofuel sector can provide additional income to farmers and create rural employment opportunities.

C. Challenges

i. Feedstock Availability: The availability of feedstocks for biofuel production can be inconsistent, impacting supply chains.

ii. Competition with Food Production: The use of food crops for biofuel production raises concerns about food security and pricing.

4. HYDROGEN AND FUEL CELL VEHICLES

A. Overview

Hydrogen is emerging as a promising alternative fuel, particularly in the form of Fuel Cell Electric Vehicles (FCEVs). The Indian government has launched the National Hydrogen Mission to promote hydrogen production and utilization.

B. Key Features

i. Diverse Production Methods: Hydrogen can be produced through various methods, including electrolysis, steam methane reforming, and biomass gasification.

ii. Zero Emissions: FCEVs emit only water vapor, making them an environmentally friendly option.

iii. Infrastructure Development: Plans are underway to establish hydrogen refuelling stations in urban areas and along major highways.

C. Challenges

i. Production Costs: The cost of hydrogen production remains high, particularly for green hydrogen produced from renewable energy sources.

ii. Limited Awareness: There is a lack of consumer awareness and understanding of hydrogen technologies and their benefits.

5. BIO-CNG

A. Overview

Bio-CNG, also known as Compressed Biogas, is a renewable and clean-burning transportation fuel produced by upgrading biogas to natural gas quality. It is made from organic waste materials like agricultural waste, food waste, sewage sludge, and industrial effluents.

B. Key Features

i. Renewable and Sustainable: Bio-CNG is a renewable fuel derived from organic waste, making it a sustainable alternative to traditional natural gas produced from fossil fuels.

ii. Environmental Benefits: The production and use of Bio-CNG can reduce greenhouse gas emissions, improve air quality, and contribute to a circular economy.

iii. Economic Advantages: Bio-CNG production aligns with market demand, making it economically viable. It also has the potential to generate renewable fuel credits to offset production costs.

C. Challenges

i. Insufficient Feedstock Availability: One of the primary challenges in Bio-CNG production is the inconsistent supply of suitable organic waste. Many municipalities do not effectively segregate waste, leading to contamination with non-biodegradable materials. This not only affects the quality of the feedstock but can also damage anaerobic digesters, reducing their efficiency and output.

ii. High Capital Investment: Setting up a Bio-CNG plant requires a substantial capital investment of ₹20 to ₹40 crores (approximately $2.5 to $5 million) for a facility capable of processing 100 tonnes of waste per day, which may deter small-scale investors and farmers from participating in Bio-CNG production.

iii. Use of Conventional Technology: Existing Bio-CNG plants often use outdated technology, limiting efficiency and scalability. The lack of advanced purification and upgrading technologies can impede the production of high-quality Bio-CNG meeting market standards.

iv. Lack of Infrastructure: The distribution network for Bio-CNG is still underdeveloped. There is a need for robust infrastructure for storage, transportation, and refuelling stations to make Bio-CNG widely accessible to consumers and industries

6. REGULATORY FRAMEWORK

India's regulatory environment plays a crucial role in promoting alternative fuels. The government has implemented several policies and initiatives to support the transition to cleaner fuels:

A. Automotive Industry Standards (AIS)

The AIS outlines technical specifications and safety requirements for alternative fuel vehicles, ensuring that they meet safety and performance standards.

B. Bureau of Indian Standards (BIS)

The BIS sets quality standards for alternative fuels, including specifications for biofuels, CNG, and LNG, ensuring that they meet safety and environmental requirements.

SUMMARY : Alternative fuels are important from Indian perspective to abate pollution and promote energy security

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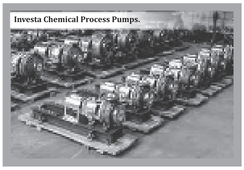


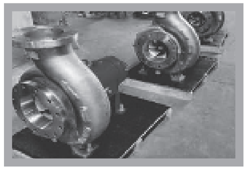
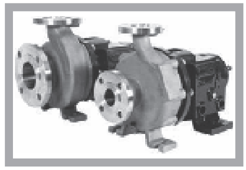
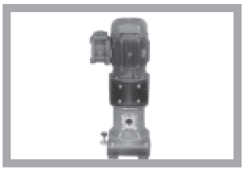


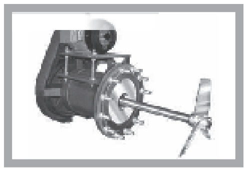
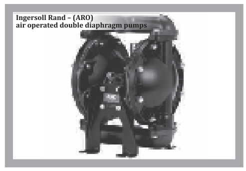

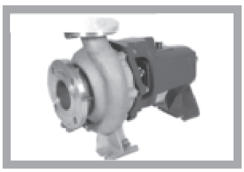
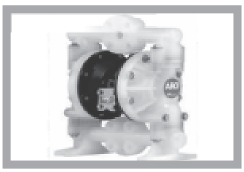


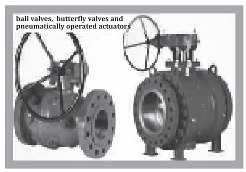


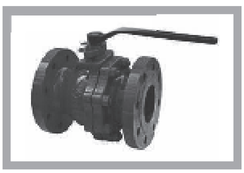




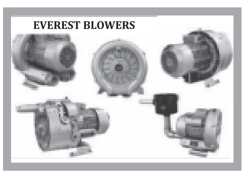

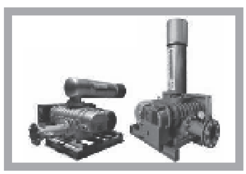

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