INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 13, No. 6, p. 13-24, 2018

RESEARCH PAPER OPEN ACCESS

Qualitative analysis of yield attributes of sugarcane hybrid lines against red stripe disease in relation to epidemiological factors

M. Aslam Khan[1], Ajmal Nadeem[1], Yasir Ali[1*], Muhammad Atiq[1], Salman Ahmad[2], Shafqat Ali[1], Umar Farooq[3]

[1]*Department of Plant Pathology University of Agriculture Faisalabad-Pakistan*

[2]*Department of Plant Pathology, University College of Agriculture, University of Sargodha-Pakistan*

[3]*Department of Plant Protection, Jinnah Avenue, Milar Halt Karachi, Pakistan*

Key words: *Acidovoraxavenae,*Epidemiological factors,Resistance, Sugarcane, Yield.

http://dx.doi.org/10.12692/ijb/13.6.13-24 Article published on December 23, 2018

Abstract

Sugarcane is one of the most important major crops all over the world. Its productivity and quality decreased due to many biotic and abiotic factors among these red stripe disease caused by bacterium *Acidovoraxavenae* subsp.*avenae* is the most significant. The disease occurrence increased under favorable environmental conditions and caused significant yield losses. For this purpose, characterization of epidemiological factors and yield assessment, associated with red stripe disease of sugarcane was conducted in the Research Area of Sugarcane Research Institute, Ayub Agriculture Research Institute Faisalabad Pakistan under Augmented Design with single replication during crop season 2015.Among all fifteen sugarcane varieties 9 genotypes were resistant with 2.13-5.40 % infection whereas 1 genotype S-2003-US-107 demonstrated moderately resistant response with 9.76% infection. The minimum and maximum temperature, relative humidity exhibited significant while, wind speed and rainfall showed non-significant correlation with disease development. Maximum disease severity was recorded at maximum and minimum temperature ranging from 33-39 and 20-28 °C, respectively. Their disease severity increased with increase in relative humidity 55-70 %, rainfall 5-70 mm and wind speed 1.5-2.5 km/h.Qualitative analysis showed that the*Acidovoraxavenae*subsp. *avenae* significantly decreased the cane height, cane girth, percentage brix, polarity, purity, commercial cane sugar and sugar recovery in all inoculated sugarcane varieties.

* **Corresponding Author:** Yasir Ali ✉ yasirklasra.uca@gmail.com

Introduction

Sugarcane (*Saccharumofficinarum*L.) is an important cash crop cultivated from subtropical to tropical zones at the latitude 36°N and 31°S of the equator. It is cultivated on an area of 20.42 million hectares worldwide with annual production of 1333 million tons (Natrajin, 2005).

There are many factors that are affecting crop productivity of sugarcane including environmental, cultural, economic and diseases caused by viruses, bacteria and fungi. Bacteria associated with plants are diverse in their habitats and caused severe yield losses (Gwyn, 2006). Bacteria caused several diseases of sugarcane such as leaf scald (*Xanthomonasalbilineans*) and ratoon stunting (*Leifsoniaxyli*subsp. *Xyli*) but most significant is red stripe of sugarcane (*Acidovoraxavenae*subsp. *avenae*) (Shan *et al.,* 2017). Red stripe is a commonly distributed disease and has been reported from more than 50 sugarcane growing countries in the world. It is a disease of minor importance but when susceptible varieties are grown it resulted in the form of severe yield losses. The maximum yield losses up to 15% or more have been reported (Yonzone *et al.,*2018).

The disease generally appears in March-April when young tillers come out from the harvested clump to form a ratoon crop. At this period of time, due to the absence of sufficient moisture in the environment, the disease often restricted to the affected leaf and hardly causes any damage of economic importance. The bacterium can attack every part of the cane from crown to the roots but it generally remains restricted to the young foliage of the crown.

The infection occurs quickly through the stomatal opening and wounds. The pathogen also spreads through infected setts. However, the exact role played by diseased setts in spreading is not fully understood. The consensus is that transmission is possible, but apparently not common, because of the rotting of the buds or death of young sprouts (Rao*et al.,* 2004). Environmental factors i.e. temperature (minimum and maximum), relative humidity, rainfall and wind speed also played significant role in disease development (Tiwari*et al.,* 2017).

There fore, the main objective of present study was to evaluate sugarcane hybrid lines against red stripe diseaseand to characterize epidemiological factors (temperature, relative humidity, rainfall and wind speed) conducive for disease development and yield losses.

Materials and methods

Fifteen sugarcane hybrid lines viz. S-2008-AUS-135, S-2007-US-59, S-2008-AUS-87, S-2003-US-127, S-2003-AUS-107, S-2009-SA-169, S-2008-AUS-704, S-2008-AUS-576, S-2008-M-34, S-2008-AUS-130, S-2006-US-469, S-2006-US-658, S-2008-FD-19, S-2008-US-134 and S-2006-US-272 were sown in Sugarcane Research Institute Area during month of February, 2015 under Augmented Design with single replication. Forty eight double-budded sets of every variety were planted in a plot size of 3m × 2.4 m long with 60 cm row to row distance.

Collection of diseaseSample

The disease samples that showed clear red stripe disease symptoms were collected from the Sugarcane Research Area of Faisalabad.

Isolation and purification ofpathogen

The newly or fresh red stripe disease affected leaves of sugarcane were taken from Research Area of Sugarcane Research Institute Faisalabad. These diseased samples were taken to lab and cut into small pieces with a sterile blade and then these pieces were sterilized by dipping in 10% sodium hypochlorite solution and washed several times by distilled water to avoid any contamination. For isolation of the bacterium, infected leaves were plated on nutrient agar medium by following the procedure of Dye (1968). Plates were incubated for 72 h at 27°C in an incubator. After 3 days bacterial coloniesappeared on nutrient agar plates. Then the single colony was sub-cultured on nutrient agar medium by streaking method to attain pure culture.

Pathogenicity test

The pathogenicity test was performed on Tabaco plant. The bacterium *Acidovoraxavenae*subsp. *avenae* induced hypersensitive reactions on tobacco plants after 2 days of inoculum application. The pathogen produced narrow red stripes 0.5-4 mm in width and 205 mm in length within 12 days. Control remained free against red stripes disease symptoms. Pathogenicity results were similar to those of Akhtar (1986), Christopher and Edgerton (1930).

Inoculation

For inoculation bacterial suspension was made in distilled water through pure bacterial culture of *Acidovoraxavenae*sbsp. *avenae*. Ten plants in each row were tagged and inoculated with bacterial suspension. Inoculation was made by introducing the inoculum into the growing points with a suitable needle plastic sterile syringe of 16 guage. The suspension was also sprayed on leaves to increase disease in sugarcane field. The spreader BD-1283 was also used in sugarcane experimental field (Chinea*et al.,* 1978).

Data recording

After appearance of red stripe disease symptoms, data were recorded in each month from June to October on all the fifteen varieties. Data for disease severity were recorded following 0-5 rating scale as described by Akhtar*et al.,* (1986). Disease incidence was recorded using method given by Ashfaq*et al.,* (2008).

$$\text{Disease incidence} = \frac{\text{No. of infected plants}}{\text{Total number of plants}} \times 100$$

Relationship of environmental conditions with red stripedisease development

Epidemiological data consists of minimum and maximum temperatures, wind speed, relative humidity and rainfall were collected from Meteorological Department of Ayub Agricultural Research Institute, Faisalabad.

Assessment of yield losses caused by red stripe disease

Cane height

For the comparison of height losses due to red stripe, six sugarcane varieties i.e. S2008-AUS-135, S2005-US-59, S2003-US-134, S2003-US-107, S2008-AUS-576 and S-2008-AUS-87 were inoculated by top rot phase of red stripe. Height of healthy and diseased samples was measured with measuring tape.

Cane girth

Cane girth of six sugarcane varieties (inoculated) and healthy (uninoculated) were measured through Vernier caliper in millimeter and then converted it into centimeter (cm) by multiplying with hundred.

Sugarcanebrix

Brix of sugarcane indicates the percent of cane sugar (sucrose) by weight (grams per 100 milliliter of water) in a solution. Healthy and red stripe diseased samples of sugarcane varieties were taken and cane juice was extracted. The extracted juice was transferred to a 500 ml metallic cylinder for brix determination. Brix measurements were conducted using a hand held Brix meter. For obtaining a brix measurement of each sugar solution Brix was recorded through brix hydrometer calibrated at 24°C.

Polarity reading

To record polarity reading, 4-5 g of dry lead sub acetate was mixed into 100ml of extracted juice of each variety. The juice was filtered into a volumetric flask through a filter paper and injected into 200 mm polari-meter tube to record the polarity reading.

Measurement of sugarcane purity

Purity is the percentage of sucrose in the total solids in a sample. Purity of both healthy and diseased sample was calculated by the following formula:

$$\text{Apparent purity (\%)} = \text{Polarity} \times 100/\text{Brix}.$$

Commercial Cane Sugar (CCS)

It was calculated by the Australian formula which is also known as Queen Land Formula (King *et al.,* 1965)

$$\text{CCS (\%)} = \frac{P(1 - F + 3)}{B} - \left(\frac{B(1 - F + 3)}{B}\right)$$

*P = Pol. Percentage Reading, *B = Brix Percentage and *F = Fiber Percent.

Sugar recovery

Sugar recovery of both healthy and diseased samples was calculated by using following formula:

$$\text{Sugar recovery (\%)} = \text{C.C.S.} \times 0.94$$

0.94 = Constant factor

Statisticalanalysis

Statistical analysis was performed through statistical tests by using SAS/ STAT statistical software (SAS Institute, 1990). Data for disease prevalence and environmental parameters were analyzed through correlation and regression analysis to estimate the relationship with environmental factors and disease progress. Epidemiological factors having statistically significant impact on disease development were graphically plotted.

Whereas, yield losses as sugarcane brix, purity, polarity, commercial cane sugar and sugar recovery, sugarcane girth and height were determined by comparison test.

Results

Screening of sugarcane varieties against sugarcane red stripe

It was found that out of fifteen varieties, nine genotypes exhibited resistant (R) response against red stripe disease with 2.13-5.40% disease incidence.

One variety, S-2003-US-107 indicated moderately resistant (MR) response with 9.76% disease incidence whereas; two varieties S-2008-US-134 and S-2008-AUS-87 showed moderately susceptible (MS) response with 22.71 and 19.2% disease incidence.

Three varieties demonstrated susceptible and the remaining one genotype S2008-AUS-135 exhibited highly susceptible (HS) response against red stripe (Table 1).

Table 1. Response of different sugarcane varieties against red stripe disease.

Sr. No	Varieties	Disease incidence (%)	Response
1	S-2008-AUS-135	58.37 a	HS
2	S-2007-US-59	35.20 c	S
3	S-2008-AUS-87	19.20 e	MS
4	S-2003-US-127	3.20 ij	R
5	S-2003-AUS-107	9.76 f	MR
6	S-2009-SA-169	5.40 g	R
7	S-2008-AUS-704	4.87gh	R
8	S-2008-AUS-576	36.70 b	S
9	S-2008-M-34	4.17ghi	R
10	S-2008-AUS-130	2.13 j	R
11	S-2006-US-469	3.83 hi	R
12	S-2006-US-658	3.16 ij	R
13	S-2008-FD-19	2.73 ij	R
14	S-2008-US-134	22.5 d	MS
15	S-2006-US-272	3.43 hij	R

LSD = (1.4856).

Relationship of epidemiological factors with red stripe disease

Correlation of environmental factors with red stripe disease was observed at variety level. All epidemiological variables i.e. minimum and maximum temperatures and relative humidity showed statistically significant correlation with red stripe disease prevalence on all fifteen genotypes except rainfall and wind speed that showed non-significant correlation (Table 2).

Table 2. Relationship of different epidemiological factors with red stripe disease of sugarcane on different varieties.

Environmental Variables	Maxi. Temp. (°C)	Mini. Temp. (°C)	R.H. (%)	R.F. (%)	W.S. (km/h)
S-2008-AUS-135	0.59*	0.78*	0.76*	0.35	0.55
	0.04	0.03	0.03	0.05	0.05
S-2007-US-59	0.78*	0.85*	0.79*	0.87	0.27
	0.03	0.02	0.02	0.06	0.05
S-2008-AUS-87	0.98**	0.92**	0.97**	0.76	0.46
	0.01	0.01	0.01	0.07	0.05
S-2003-US-127	0.86*	0.95**	0.99**	0.47	0.27
	0.03	0.01	0.01	0.08	0.08
S-2003-AUS-107	0.86*	0.96**	0.89*	0.67	0.47
	0.02	0.01	0.02	0.06	0.05
S-2009-SA-169	0.59*	0.95*	0.82*	0.78	0.28
	0.04	0.04	0.03	0.05	0.06
S-2008-AUS-704	0.69*	0.95*	0.84*	0.87	0.57
	0.04	0.03	0.02	0.07	0.07
S-2008-AUS-576	0.99**	0.90*	0.95**	0.77	0.67
	0.01	0.01	0.01	0.08	0.05
S-2008-M-34	0.85*	0.96**	0.91**	0.37	0.38
	0.03	0.01	0.01	0.05	0.06
S-2008-AUS-130	0.84*	0.93**	0.81*	0.66	0.46
	0.02	0.01	0.02	0.07	0.05
S-2006-US-469	0.68*	0.87*	0.86*	0.35	0.37
	0.04	0.03	0.03	0.05	0.06
S-2006-US-658	0.98*	0.85*	0.69*	0.28	0.23
	0.01	0.03	0.02	0.05	0.06
S-2008-FD-19	0.98**	0.92**	0.87*	0.69	0.49
	0.01	0.01	0.01	0.06	0.07
S-2008-US-134	0.96*	0.96**	0.91*	0.47	0.37
	0.01	0.01	0.01	0.05	0.05
S-2006-US-272	0.86*	0.92**	0.84*	0.66	0.76
	0.02	0.01	0.02	0.06	0.05

Upper values indicated Pearson's correlation coefficient; Lower values indicated level of significance at 5% probability; * = Significant (P<0.05); ** = highly significant (P<0.01).

Characterization of environmental conditions conducive for red stripe disease development

Four varieties i.e. S2008AUS-135 (V_1), S2005-US-59 (V_2), S-2008-AUS- 576 (V_8), and S-2008-US-134 (V_{14}) were subjected to regression analysis to characterize the critical ranges of epidemiological conditions conducive for red stripe disease development. Results showed that maximum disease severity was recorded on S2008AUS-135 (V1) at maximum and minimum optimum temperature ranging from 33-39 °C and 20-28 °C, relative humidity 55-70 %, rainfall 5-70 mm and wind speed 1.5-2.5 km/h. Whereas, other three genotypes exhibited less disease severity at same environmental conditions as illustrated in Fig. 1, to 5.

Table 3. Comparison of cane height between un-inoculated and inoculated sugarcane varieties.

Varieties	Un-inoculated		Inoculated	
S2008-AUS-135	205(±1.1547)	a	143(±0.5774)	b
S2005-US-59	290(±0.5774)	b	103(±0.5774)	f
S2003-US-134	307(±1.1547)	a	168(±0.5774)	a
S2003-US-107	221(±0.5774)	c	111(±0.5774)	d
S2008-AUS-576	198(±0.5774)	f	108(±1.1547)	e
S-2008-AUS-87	203(±0.5774)	e	117(±0.5774)	b

(LSD: 0.765).

Assessment of yield losses caused by red stripe disease

Cane height and cane girth

A significant difference between cane heights and girth of un-inoculated) and inoculated sugarcane varieties is indicated in Table 3 and 4, respectively. Maximum plant highest (307 ± 1.1547) was recorded in un-inoculated genotype S2003-US-134 whereas; the lowest cane height (103 ±0.5774) was recorded in S2005-US-59 of inoculated genotype (Table 3).

Similarly, maximum cane girth (3.13 ± 0.577) was recorded in the un-inoculated variety S2003-US-107, and the minimum can girth (2.07 ± 0.0208) was recorded in inoculated genotype S2005-US-59 (Table 4).

Table 4. Comparison of cane girth between un-inoculated and inoculated sugarcane varieties.

Varieties	Un-inoculated	Inoculated
S2008-AUS-135	2.53(±0.577)c	2.34 (±0.0208)c
S2005-US-59	2.16 (±0.0115)e	2.07 (±0.0208)d
S2003-US-134	2.3 (±0.0115)d	2.13 (±0.0882)d
S2003-US-107	3.13 (±0.577)d	2.95 (±0.0173)a
S2008-AUS-576	2.68 (±0.577)b	2.53(±0.0176)b
S-2008-AUS-87	2.79 (±0.0115)b	2.66(±0.0173)b

(LSD: 0.1245).

Table 5. Comparison of brix between un-inoculated and inoculated sugarcane varieties.

Varieties	Un-inoculated	Inoculated
S2008-AUS-135	18.16 (±0.0115)e	14.2(±0.074)e
S2005-US-59	19.6(±0.0577)b	15.2(± 0.057)d
S2003-US-134	20.5(±0.0577)a	17.1(±0.088)b
S2003-US-107	19.28 (±0.011)c	18.4(±0.0115)a
S2008-AUS-576	19.13 (±0.057)d	16.2(±0.057)c
S-2008-AUS-87	19.3 (±0.017)c	16.7(±0.185)c

(LSD: 0.1924).

Sugarcane brix and polarity reading

A significant mean difference between cane brix and polarity reading of un-inoculated and inoculated sugarcane varieties are illustrated in Table 5 and 6, respectively.

It was found that the brix of un-inoculated varieties were considerably greater as compared to the inoculated. Maximum brix (%) and polarity mean values were recorded for S2003-US-134 and S2003-US-107 (un-inoculated varieties) and minimum mean

values recorded for S2008-AUS-135 and S-2008-AUS-87 (inoculated varieties).

Assessment of sugarcane purity, commercial cane sugar (CCS), and sugar recovery

A significant mean comparison of sugarcane purity, commercial cane sugar (CCS), and sugar recovery between un-inoculated and inoculated sugarcane varieties is illustrated in Table 7, 8 and 9, respectively.

Tab 6. Comparison of polarity reading between un-inoculated and inoculated sugarcane varieties.

Varieties	Un-inoculated	Inoculated
S2008-AUS-135	71.61(±0.0115) f	61.52 (±0.0115) d
S2005-US-59	73.42 (±0.0115) d	69.25 (±0.0115) b
S2003-US-134	75.62 (±0.0173) b	61.31 (±0.0115) e
S2003-US-107	78.72 (±0.0289) a	70.32 (±0.011) a
S2008-AUS-576	74.51 (±0.0115) c	65.33 (±0.066) c
S-2008-AUS-87	72.14 (±0.0173) e	60.41 (±0.011) f

(LSD: 0.0169).

Tab 7. Comparison of purity between un-inoculated and inoculated sugarcane varieties.

Varieties	Un-inoculated	Inoculated
S2008-AUS-135	87.45 (±0.0115) d	68.3 (±0.011)a
S2005-US-59	89.93 (±0.0115) b	72.29(±0.011) e
S2003-US-134	88.47 (±0.057)a	70.21(±0.011) b
S2003-US-107	86.1(±0.057)f	83.81(±0.011) c
S2008-AUS-576	90.34 (±0.057)e	69.45(±0.011) d
S-2008-AUS-87	85.69(±1.343) c	71.16(±0.011)f

(LSD: 1.1269).

Results indicated that maximum mean values for sugarcane purity (90.34 ± 0.057), commercial cane sugar (14.3 ± 0.015), and sugar recovery (13.44 ± 0.015) were recorded in S2008-AUS-576, S2008-AUS-576 and S2008-AUS-576 genotypes (un-inoculated). Whereas, minimum mean values were recoded for sugarcane purity (68.3 ± 0.011), commercial cane sugar (8.55 ± 0.057), and sugar recovery (8.1 ± 0.057) in S2008-AUS-135, S2008-AUS-135 and S2008-AUS-135 genotypes (inoculated).

Tab 8. Comparison of C.C.S between un-inoculated and inoculated sugarcane varieties.

Varieties	Un-inoculated	Inoculated
S2008-AUS-135	12.73 (± 0.0115) d	8.55 (± 0.057)f
S2005-US-59	13.48 (± 0.0577) b	11.32 (± 0.011) b
S2003-US-134	12.87 (± 0.0577) c	9.56 (± 0.011)e
S2003-US-107	12.47 (± 0.023)e	11.94 (± 0.011) a
S2008-AUS-576	14.3 (± 0.0115)a	10.25 (± 0.014) c
S-2008-AUS-87	13.55 (± 0.0577) b	9.93 (± 0.057)d

(LSD: 0.088).

Table 9. Comparison of Sugar recovery between un-inoculated and inoculated sugarcane varieties.

Varieties	Un-inoculated	Inoculated
S2008-AUS-135	11.95(0.057)d	8.1 (0.057)f
S2005-US-59	12.67(0.057)b	10.6(0.057)b
S2003-US-134	12.30(0.115)c	8.97(0.0577)e
S2003-US-107	11.73(0.0115)e	11.2(0.0574)a
S2008-AUS-576	13.44(0.0115)a	9.63(0.0115)c
S-2008-AUS-87	12.74(0.0115)b	9.34(0.0115)d

(LSD: 0.0964).

Discussion

The red stripe disease of sugarcane is a destructive disease causing severe yield losses worldwide. Fifteen varieties were evaluated against red stripe disease of sugarcane and it was found that nine genotypes were resistant one variety S-2003-US-107 exhibited moderately resistant response.

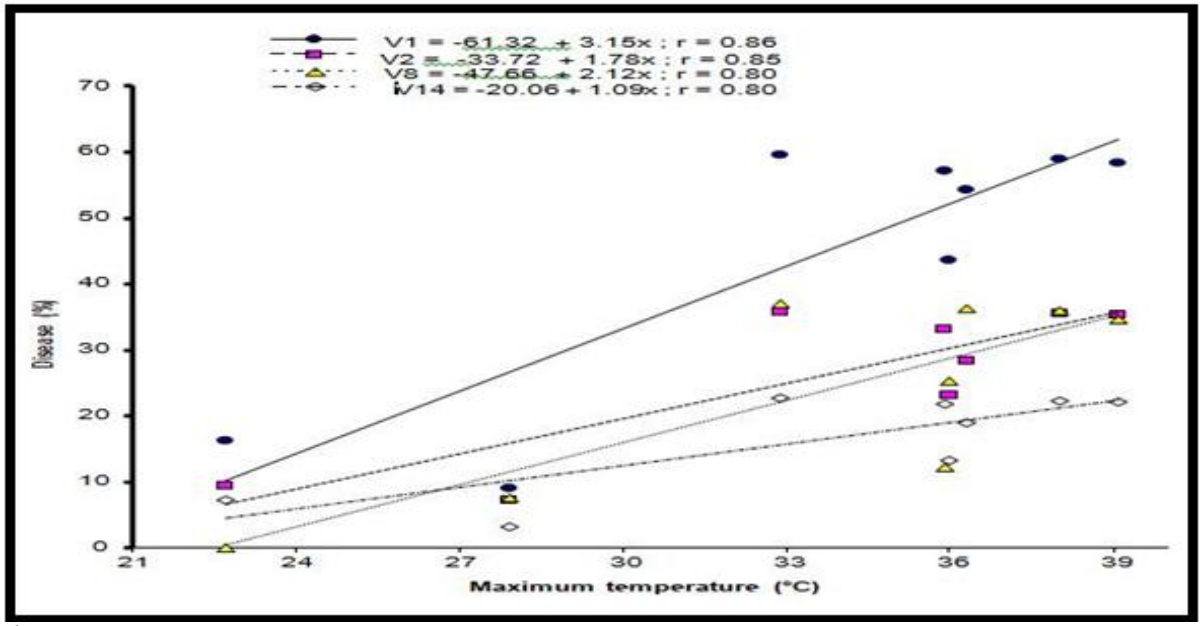

Fig. 1. Relationship of maximum temperature (°C) with red stripe disease on four sugarcane varieties S2008AUS-135 (V1), S2005-US-59 (V2), S-2008-AUS-576 (V8) and S-2008-US-134 (V14).

The results of present study are in line with the investigation of Christopher (1930) who studied the red-stripe disease and reported that P.O.J. varieties 826, 2725 and 2727 exhibited highly susceptible, while P.O.J. 36-M, 213, 234 and the D-74 demonstrated moderately resistant response against this disease. Red stripe disease was widely distributed over the sugar belt of Louisiana on P.O.J. varieties i.e. 2727, 2714, 826, 2725, 213,234, 36, 36-M, 979, and 228.

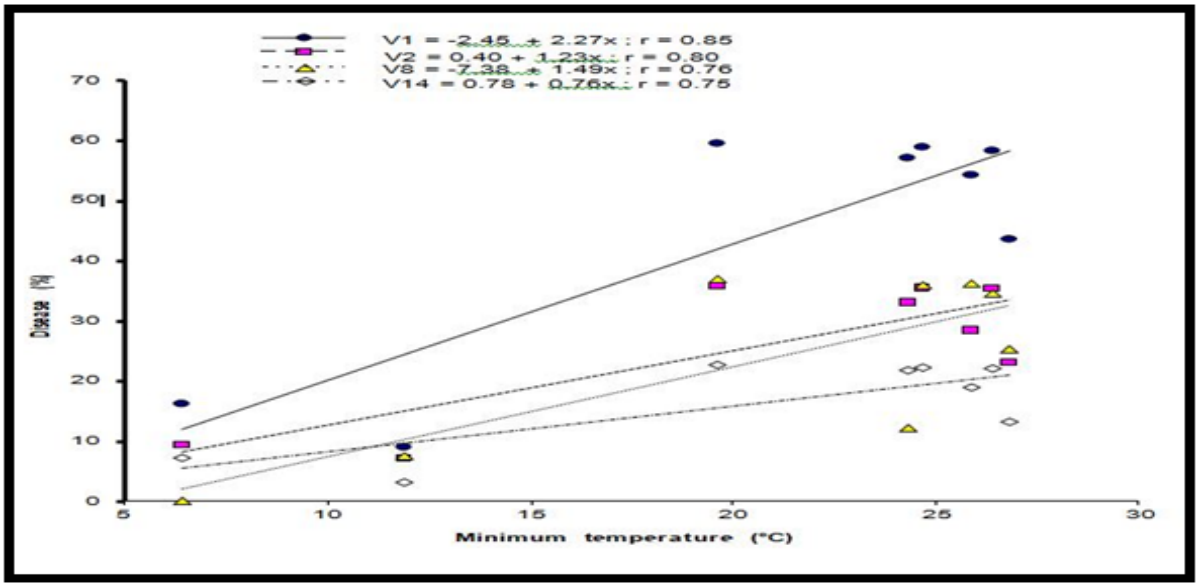

Fig. 2. Relationship of minimum temperature (°C) with red stripe disease on four sugarcane varieties S2008AUS-135 (V1), S2005-US-59 (V2), S-2008-AUS-576 (V8) and S-2008-US-134 (V14).

The most serious natural infection occurred at Youngsville in August indicating 10 % of top rot on POJ-2727 and 5% on POJ-2714. Akhtar*et al.,* (1986) evaluated nine commercial cultivars of sugarcane and showed that five genotypes IM-60, Katha, L-118, R-366 and BL-19 exhibited moderately resistant response, two Triton and NCO-310 moderately susceptible and twoL-116 and CP-48-103 showed susceptible response against disease development. Similarly, Zia-ul-Hussnain*et al.,* (2011) screened 27 sugarcane varieties against red stripe and showed that 16 genotypes i.e. NSG-555, SPSG- 79, CPF-237, HSF-240, CSSG-668, CSSG-676, NSG-311, CPSG-3481, NSG-59, CPSG-2923, CSSG-212, CPSG-104, HoSG-1257, CPSG25, CSSG-239, and CPSG-2713 were resistant and 4 genotypes viz. SPF-238, CP77-400, SPF-213, and GT-11were moderately resistant. Five genotypes such as HoSG-315, CPSG-437, NSG-49, CPSG-2453 and CP-NIA-82-223 demonstrated moderately susceptible whereas, remaining two varieties CSSG-2402 and US-114 exhibited susceptible response.

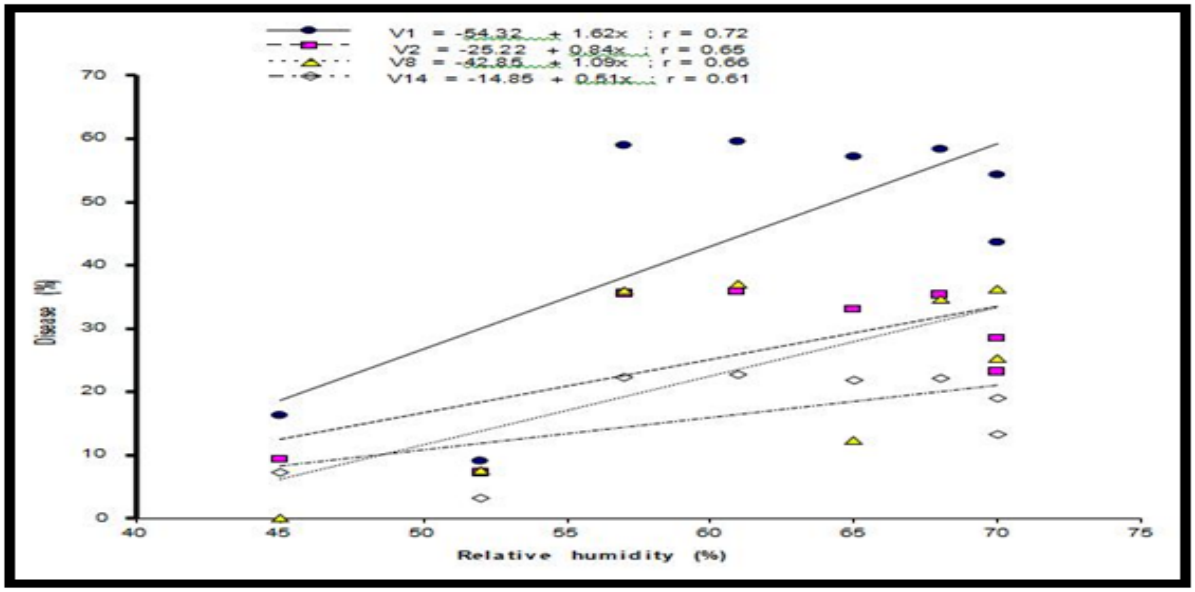

Fig. 3. Relationship of relative humidity (%) with red stripe disease on four sugarcane varieties S2008AUS-135 (V1), S2005-US-59 (V2), S-2008-AUS-576 (V8) and S-2008-US-134 (V14).

Epidemiological factors play important role in disease epidemics. All environmental conditions i.e. maximum and minimum temperature, rainfall, relative humidity and wind speed had significant correlation with red stripe disease.

The pathogen is spread by rain and wind in warm humid weather. Bell (1942) reported that, due to the failure of monsoon and late summer rains, red stripe and top rot disease not spread in severe epidemic form but the dry spring included some stem rot in over mature canes in a field at Maringa where patches of severe top rot were present. Akiba*et al.,* (1976) stated that red stripe of sugarcane is a wet weather disease. Martin and Wismer, (1989) studied and stated that the environmental conditions which favor disease development are an unusually dry spring and early summer before the wet season. In Hawaii, the disease is more severe at the higher than at the lower elevations due to higher rainfall. In an epidemiological study, carried out by Yonzone*et al.,* (2014) stated that the maximum lesion length of 32.28 cm on CoJ 85 and 27.72 cm on CoJ 88 was found 32 days after inoculation.

They further described the incubation period of 7 days and 9 days on ooze formation and development of disease symptom when inoculated with four isolates RS-2, RS-3, RS-6 and RS-8 on variety CoJ 85.

Considering the yield losses caused by sugarcane red stripe, the pathogen significantly reduced the

sugarcane quality by reducing its height, girth, brix, purity and polarity. Maximum yield losses were recorded in cane height and girth in the inoculated sugarcane varieties over to the uninoculated. Several studies confirmed that red stripe bacterium had potential to infect the height and thickness (girth) of the cane.

Though, it was concluded that there were 68% yield losses in terms of girth and height when contrasted to the uninoculated sugarcane genotypes (Kirtikar and Verma, 1962).

The present study also demonstrated the same results that red stripe of sugarcane reduced the cane girth and height in several genotypes significantly. Moreover, a clear difference was observed between inoculated and uninoculated sugarcane varieties with respect to sugar recovery, brix, purity, polarity and CCS.

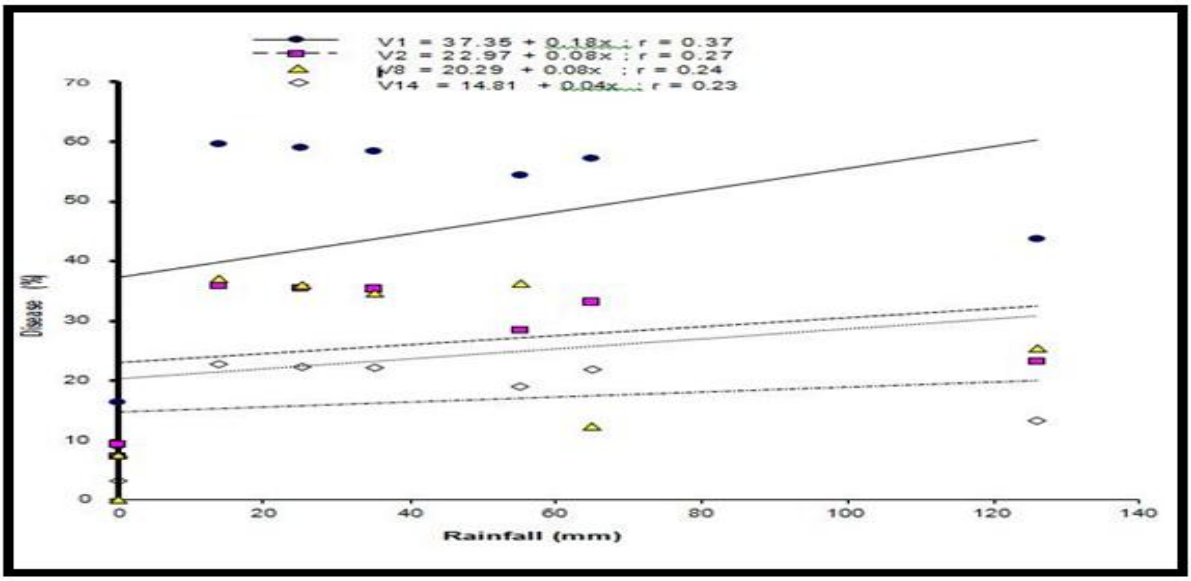

Fig. 4. Relationship of rainfall (mm) with red stripe disease on four sugarcane varieties S2008AUS-135 (V1), S2005-US-59 (V2), S-2008-AUS-576 (V8) and S-2008-US-134 (V14).

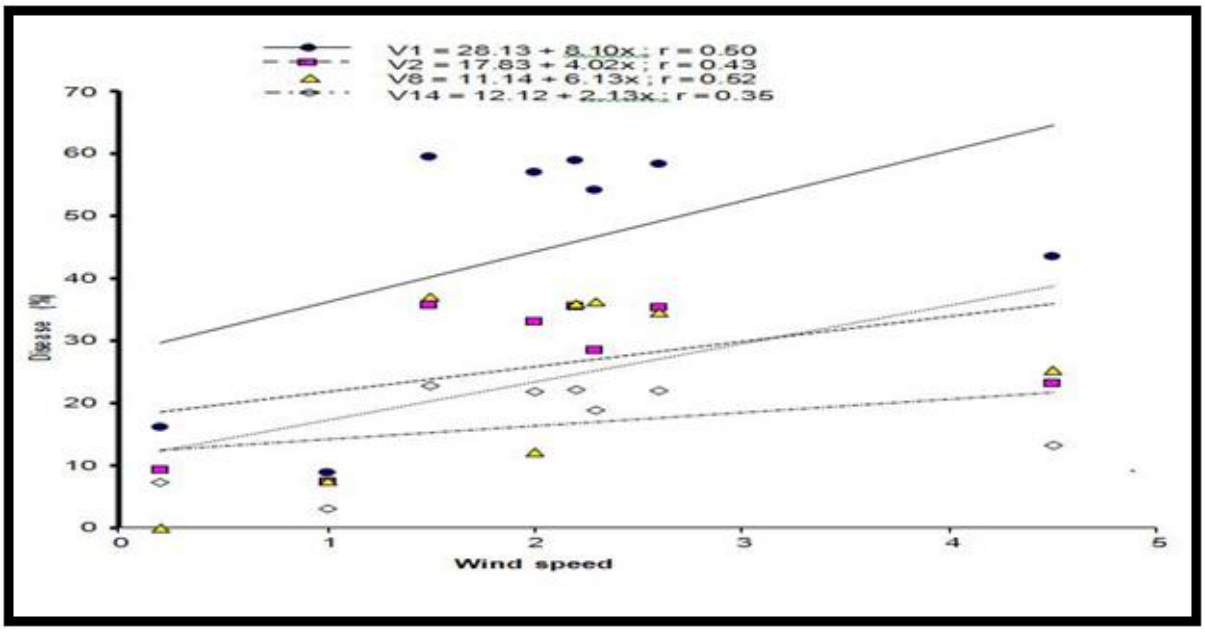

Fig. 5. Relationship of wind speed (km/ha) with red stripe disease on four sugarcane varieties S2008AUS-135 (V1), S2005-US-59 (V2), S-2008-AUS-576 (V8) and S-2008-US-134 (V14).

Brix and polarity of cane account the major role in juice quality. High amount of brix and polarity indicated good quality of cane juice. The standard values of brix is above 20 (Mao *et al.,* 2007) while polarity is between 10.49-17.86% (Blackburn, 1984). The average yield losses that were observed in case of brix and polarity were 11.36 and 14.74%, respectively. This reduction was due to infection by pathogen (Jaroenthai*et al.,* 2007). In case of purity and CSS, standard values of purity and CCS are 80 and 10-15% % respectively (Robertson*et al.,* 1996). Maximum losses were recorded in all inoculated sugarcane varieties. It indicated that pathogen while invading the sugarcane plant results in the reduction of purity and CSS percentage of the cane juice. The average yield losses of purity in all inoculated varieties were recorded 17% as compared to the uninoculated sugarcane varieties (Viswanathan and Rao, 2011). Similarly, Jaroenthai*et al.,* (2007) reported the losses in CCS up to 7-13 % which are less as compared to the genotypes we tested.

Conclusion

It was concluded that except rainfall and wind speed all environmental factors, shown significant correlation with sugarcane red stripe. Qualitative analysis of yield attributes indicated that *Acidovoraxavenae*subsp. *avenae* significantly decreases the cane height, percentage brix, cane girth, purity, polarity, CCS and sugar recovery in all fifteen varieties.

References

Akhtar MA, Aslam M. 1986.Resistance of sugarcane to bacterial red stripe, a new bacterial disease from Pakistan.Tropical Pest Management **32(2),** 188-119.

Akiba FA, Sanguino, Tokeshi H. 1976. Reacao de 18 variedades de Cana-de-agucar a Pseudomonas rubrilineans. Phytopathology, 2 (Oct-Dec 1976).

Bell AF. 1933. Thirty third Ann. Rept of Division of Plant Pathology Queensland Bureau of Sugar Expt St., 54-61 p.

Blackburn FHB. 1984. Sugarcane. Longman Inc. New York, USA, pp. 30-42.

Christopher WN, Edgerton CW. 1932. Bacterial stripe diseases of sugarcane in Louisiana. Journal of Agriculture Research **41,**259-267.

Gwyn AB. 2006. Plant-Associated Bacteria: survey, molecular phylogeny, genomics and recent advances, Samuel S. Gnanamanickameditor, Springer Netherlands. 1-56 p.

Jaroenthai KS, Dongchan S, Anusonpornpurm, Pliansinchai U. 2007. Occurrence of Sugarcane Diseases in the Germplasm Collection at MitrPhol Sugarcane Research Centre at Chaiyaphum, Thailand. Proceedings - International Society of Sugar Cane Technologists **26,** 1040-1045.

King NJ. 1965. Harvesting the crop and factors which affect it. Pages 164-179. In: Manual of Cane Growing. Second edition.N. J. King, R.W. Mungomery, and C. G. Hughes, eds. Angus and Robertson Ltd., Sydney.

Kirtikar HS. 1962. A review on effect of sugarcane diseases on yield and juice qualities in Uttar Pradesh. Indian Sugar **12,** 103-108.

Mao LC, Xu YQ, Que F. 2007. Maintaining the quality of sugarcane juice with blanching and ascorbic acid. Food Chemistry **104(2),** 740-745.

Martin JP, Wismer CA. 1989. Diseases of sugarcane major diseases.Elsevier, NY, Tokyo. 81-95 p.

Natrajin B. 2005. Sugar and sugarcane international and national scenario and the role of sugarcane breeding 77-93 p.

Robertson MJ, Muchow RC, Wood AW, Campbell JA. 1996. Accumulation of reducing sugars by sugarcane: Effects of crop age, nitrogen and cultivar. Field Crops Research **49(1),** 39-50.

Shan H, Li W, Huang Y, Wang X, Zhang R, Luo Z, Yin J. 2017. First detection of sugarcane red stripe caused by Acidovoraxavenae subsp. avenaeinYuanjiang, Yunnan, China. Tropical Plant Pathology **42(2),** 137-41.

Tiwari AK, Singh A, Singh SP, Dagar A, Kumari K, Kumar D, Pandey N, Kumar P. 2017. An Overview of Major Fungal Diseases of Sugarcane in India: Detection and Management Strategies. In Mole.MarkersMycol.Springer, Cham. 275-304 p.

Viswanathan R, Rao GP. 2011. Disease scenario and management of major sugarcane diseases in India. Sugarcane Technology **13(4),** 336-53.

Yonzone RB, Kumar J, Devi MS. 2014. Pathogenic Variability among Different Isolates of the Red Stripe/Top Rot Causing Pathogen in Punjab State. Environment & Ecology **32(3),** 873-877.

Yonzone R, Devi MS. 2018.Red Stripe/Top Rot Disease of Sugarcane: A Review. International Journal of Current Microbiologyand Applied Sciences **7(1),** 1469-78.

Zia-ul-Hussnain S, Haque MI, Mughal SM, Shah KN, Irfan A, Afghan S, Nawaz K. 2011. Isolation and biochemical characterizations of the bacteria (Acidovoraxavenae subsp. avenae) associated with red stripe disease of sugarcane. African Journal of Biotechnology **10(37),** 7191-7197.