



Research Article

EPIDEMIOLOGY OF BANANA FUSARIUM FRUIT ROT UNDER SOUTH GUJARAT CONDITION

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Abstract- Banana fusarium fruit rot is an important post-harvest disease. Environmental factor plays important role to disease development. The initiation of the disease was noted in the month of July and continuously progressed upto the harvest of the fruits. The disease was more progressive during 36th to 39th MSW which considered as the window period. Correlation coefficient study between weather parameters and disease incidence indicated that all the parameters jointly played an important role in the development of fusarium fruit rot. Moreover, maximum temperature, minimum temperature, average temperature and relative humidity were found to play important role in the disease development. The stepwise regression, it has been also observed that R²-value (0.67) indicating association between per cent disease index to average temperature and maximum temperature. The stepwise regression equation [$\hat{Y} = -586.270 + 18.613 (X_4) + (-38.456) (X_2)$ whereas, Y= Predicted Disease Index, X₂= Maximum Temperature and X₄= Average temperature]. Thus, maximum temperature and average temperature found to play dominant role in the disease development.

Keywords- Banana, Fusarium fruit rot, Fusarium musae, Epidemiology, Correlation, Regression

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Introduction

Banana (*Musa paradisiaca* L.) is one of the most important commercial fruit crop grown all over the world in the tropical and subtropical areas. It is the second largest fruit crop, belongs to family Musaceae in order Zingiberales. It is the most important fruit crop of south Gujarat region. Banana fruit majorly infected by *Alternaria alternate* (Fr.) Keissler, *Colletotrichum musae*, *Fusarium moniliforme* (Cooke) Sacc and *F. oxysporum* (Schlecht. Emend. Snyder and Hansen) pathogens. *Aspergillus flavus* Link., *A. fumigatus* Fresenius., *A. niger* Van. Teigh., *A. terreus* Thom., *Penicillium* spp. Link were dominant pathogens, same as *Curvularia lunata* (Wakker) Boedijn, *Cochliobolus lunatus* (Nelson and Haasis) and *Colletotrichum musae*. *Nigrospora oryzae* (Berk and Ba.) Petch. and *Khushkia oryzae* Hudson were active during the winter while, *Botryodiplodia theobromae* were sporadic whereas, *Deightonella torulosa* and *Cunninghamella echinulata* (Thaxter) were detected occasionally. *Rhizoctonia solani* (Kuhn) and *Macrophomina phaseolina* (Tassi) Goid. also caused considerable damage to fruits [1]. Fusarium fruit rot caused by *Fusarium musae* Van Hove and epidemically it was reported in Latin America (Mexico, Panama, Ecuador), the Canary Islands and the Philippines. In recent years, fusarium fruit rot has become a serious problem in many parts of the world due to climate-change and growing high yielding banana varieties, which were more susceptible to diseases. *Fusarium musae* over summering by producing fungal structures called perithecia, which contain pseudochlamydospores (resting spores) and compact masses of mycelia. The fungus forms pseudochlamydospores and perithecia late in the season which fall in the soil and to survive under field conditions. Pseudochlamydospores germinate to produce ascocarp containing ascospores, which are the act as a primary source of infection to banana plant, whereas a secondary source of infection may come from airborne. During *Fusarium musae* life cycle, produces sexual stage known as a pseudochlamydospores, and asexual stage known as a microconidia, both stages play a very important role to initiated *Fusarium musae* infection process. Fusarium fruit rot have been reported to emerge after the bunch formation.

Infection results in one or more unripe banana fruits replaced by only near the stylar end as few dark brown to black small spots and later dark brown to black pulp rot initiation. The fusarium fruit rot favouring the climatic factor is cloudy weather, relative humidity, temperature, rainfall and application of higher nitrogen doses favours the development of disease. Therefore, the present studies were done to know the effect of different weather parameter on the fusarium fruit rot disease of banana.

Materials and Methods

Epidemiological study of fusarium fruit rot of banana was carried out at weekly intervals at Horticulture and Organic Farm, NAU, Navsari, for starting from 2017-18 to 2018-19. At field level throughout the seasonal survey selected 10 bunches from randomly for the fixed plots survey.

Epidemiology of fusarium fruit rot of banana

To determine the influence of various environmental factors on the development of the fusarium fruit rot disease intensity data was correlated with different meteorological parameters viz., rainfall, maximum temperature, minimum temperature and relative humidity through analysis of correlation regression. The weekly observations of fusarium fruit rot disease intensity were recorded. The corresponding weather parameters were recorded throughout the season. Correlation and regression equation between disease severity dependent factors were worked out by using standard procedure given by Gomez and Gomez (1984) [2]. Percent disease index (PDI) was calculated using to the formula [3]. Percent disease index = Sum of all numerical ratings / Total number of fruit examined X Maximum rating X 100

Scale for Percent disease index (PDI)

The disease severity was recorded using 0-5 scales were selected for the study.

Scale Description**Scale Percent infection**

0 Fruit completely healthy

1 Disease presents only near the stylar end as few dark brown to black small spots and fruit completely healthy

2 < 10 percent area at stylar end coverage and dark brown to black pulp rot initiation

3 11- 25 percent area at stylar end coverage and dark brown to black pulp rot

4 26- 50 percent area at stylar end coverage and dark brown to black pulp rot

5 > 50 percent area at stylar end coverage and dark brown to black pulp rot

Experimental details

Seasonal survey was carried out at Horticulture Farm and Organic Farm, NAU, Navsari during 2017-18 and 2018-19 on banana variety Grande Naine

Epidemiology of fusarium fruit rot disease of banana

The epidemiological studies are generally divided into two groups (1) those established for studying the effect of as many variables as possible (Holistic approach) of host, pathogen and environment on disease development and (2) those in which only key variables are studied to explain most of the effect governing the epidemic (meristemic approach). The decision whether to employ a holistic or meristemic approach depends do not only the purpose of study or to the research facilities, but also on financial, instrumental and staff situation.

Progress of fusarium fruit rot disease of banana in natural condition during 2017 and 2018

The weekly survey carried out at field level throughout the seasonal survey at Horticulture Farm, NAU, Navsari and Organic Farm, NAU, Navsari were 10 bunches from randomly selected from cv. Grande Naine for the fixed plots survey during 2017-18 and 2018-19 revealed the presence of fusarium fruit rot at two location for assessing the percent disease index (PDI) of fusarium fruit rot disease of banana and correlated with different meteorological parameters viz., rainfall, maximum temperature (Max. T.), minimum temperature (Min. T.) and relative humidity (RH) through analysis of correlation regression.

Table-1 Effect of weather parameters on occurrence and development of banana fusarium fruit rot disease at Horticulture Farm, NAU, Navsari during 2017

MSW	Rainfall	Temperature (°C)			Relative Humidity (%)	PDI
	(mm)	Max.	Min.	Av.	Av.	
28	32	31.4	25.4	28.44	83.80	0.10
29	330	29.2	24.5	26.81	93.84	0.15
30	152	29.0	25.2	27.08	91.73	0.19
31	56.6	30.0	25.1	27.59	81.74	0.26
32	22	30.9	25.2	28.06	84.15	0.53
33	10	31.3	25.5	28.38	83.05	0.77
34	90	29.4	24.6	26.99	90.67	1.10
35	177	29.3	24.1	26.73	91.41	1.63
36	3	31.4	24.7	28.04	85.65	2.59
37	2	34.0	25.1	29.59	83.14	3.22
38	69	31.4	23.7	27.56	87.93	3.76
39	0	33.3	23.8	28.56	79.83	4.15

Table-2 Effect of weather parameters on occurrence and development of banana fusarium fruit rot disease at Organic Farm, NAU, Navsari during 2018

MSW	Rainfall	Temperature (°C)			Relative Humidity (%)	PDI
	(mm)	Max.	Min.	Av.	Av.	
28	619	28.1	23.1	25.64	98.42	0.11
29	314	26.8	23.3	25.07	97.87	0.17
30	9	29.1	25.0	27.07	87.56	0.21
31	4	30.3	25.0	27.66	80.74	0.30
32	11	30.0	24.7	27.35	86.44	0.64
33	53	29.7	23.8	26.77	88.20	0.84
34	127	29.0	22.8	25.88	92.02	1.00
35	27	29.9	23.5	26.71	85.26	1.24
36	35	29.7	22.2	25.99	81.69	2.65
37	1	30.8	21.8	26.31	79.81	3.29
38	15	32.7	21.8	27.27	75.34	3.89
39	0	33.8	21.5	27.65	70.50	4.33

The results of the surveys are presented in [Table-1] and [Table-2]. The data of field survey presented in [Table-1] revealed that maximum percent disease index (PDI) (4.15%) during 2017 at Horticulture Farm, NAU, Navsari was observed during 39th MSW during this week rainfall (0.0mm) maximum temperature (33.30°C) and minimum temperature (23.80°C), average temperature (28.56°C) and average relative humidity (79.83%) followed by 38th MSW (3.76%) and 37th MSW (3.22%). Minimum percent disease index (0.10%) observed in 28th MSW. During 2018 at Organic Farm, NAU, Navsari [Table-2] maximum percent disease index (4.33%) was observed during 39th MSW during this week rainfall (0.0mm) maximum temperature (33.80 °C) and minimum temperature (21.50°C), average temperature (27.65°C) and average relative humidity (70.50%) followed by 38th MSW percent disease index (3.89%) and 37th MSW (3.29%). Minimum percent disease index was observed in 28th MSW (0.11%).

Correlation for banana fusarium fruit rot on different weather parameters at Navsari

The data presented in [Table-3] revealed that the correlation of the individual parameters with disease development led to the percent disease index exhibited significant highly positive correlation ($r=0.70$) with maximum temperature in the year 2017 but in 2018 the correlation was highly positive significant ($r=0.84$) whereas significant negative and highly negative correlation ($r=-0.67$ and -0.84) with minimum temperature in the year 2017 and 2018 respectively. While average relative humidity showed significant negative correlation ($r=-0.83$) were found during 2018. In pooled 2017 and 2018 correlation of the individual parameters with disease development that percent disease index exhibited significant highly positive correlation with 0.75 and maximum temperature whereas rainfall, minimum temperature and average relative humidity highly negative correlation with $r=-0.41$, -0.58 and -0.63 , respectively.

From the results of the present investigation, it is very clear that fusarium fruit rot of banana is important disease in Navsari district. Hence, it causes heavy losses because, its infection at the post harvest stages directly effects on market value. Post harvest fusarium fruit rot disease infection starts on 28th to 39th MSW under favourable weather. The infection on fruit produced a huge quantity of inoculum in the presence of favourable climatic conditions. Due to the presence of a heavy load of inoculum, the pathogen attacked on the fruit part at maturity stage and results in loss of banana yield and quality.

Table-3 Correlation of percent disease index with weather parameters during experimentation

SN	Weather parameters	Correlation		
		2017	2018	Pooled
1	Rainfall (mm)	-0.41286	-0.44086	-0.41242**
2	Temperature Maximum (°C)	0.699412 **	0.839961**	0.747281**
3	Temperature Minimum (°C)	-0.66986*	-0.83649**	-0.58144**
4	Temperature (Average) (°C)	0.421591	0.307985	0.288752
5	Relative Humidity (Average) (%)	-0.32313	-0.82705**	-0.62725**

Note: Critical value (0.05) 2017= +/- 0.553* & 0.684**, 2018= +/- 0.553* & 0.684** and Pooled= +/- 0.396* & 0.505**

Stepwise regression equation for banana fusarium fruit rot on different weather parameters at Navsari

The regression coefficient based on stepwise regression analysis for PDI of banana fusarium fruit rot with respect to weather parameters have been worked out and presented in [Table-4, 5 and 6].

Stepwise regression equation for banana fusarium fruit rot on different weather parameters during 2017

The result presented in [Table-4] indicated, stepwise regression, it has been also observed that R-value was high (0.85%) indicating a strong association between percent disease index to average temperature. The co-efficient of determination value was found to be 0.72 percent.

This clearly indicates that at least 85 percent disease index of variation in banana fusarium fruit rot can be explained by the function of the weather parameter average temperature as evident from stepwise regression equation [$\hat{Y} = -1506.403 + 18.343 (X_4)$], whereas, Y = Predicted Disease Index, X_4 = Average temperature].

Table-4 Stepwise regression equation for banana fusarium fruit rot on different weather parameters during 2017

Multiple linear regression equation $\hat{Y} = a + b_1X_1 + b_2X_2 + \dots + b_nX_n$	Multiple R	Co-efficient of determination (R^2)
$\hat{Y} = -1506.403 + 18.343 (X_4)$	0.85	0.72

Whereas, Y= Predicted disease index, X_4 = Average temperature

Table-5 Stepwise regression equation for banana fusarium fruit rot on different weather parameters during 2018

Multiple linear regression equation $\hat{Y} = a + b_1X_1 + b_2X_2 + \dots + b_nX_n$	Multiple R	Co-efficient of determination (R^2)
$\hat{Y} = -1310.869 + 16.551 (X_4)$	0.75	0.56

Whereas, Y= Predicted disease index, X_4 = Average temperature

Table-6 Stepwise regression equation for banana fusarium fruit rot on different weather parameters in pooled

Multiple linear regression equation $\hat{Y} = a + b_1X_1 + b_2X_2 + \dots + b_nX_n$	Multiple R	Co-efficient of determination (R^2)
$\hat{Y} = -586.270 + 18.613 (X_4) + (-38.456) (X_2)$	0.82	0.67

Whereas, Y= Predicted disease index, X_4 = Average temperature, X_2 = Maximum temperature

Stepwise regression equation for banana fusarium fruit rot on different weather parameters during 2018

The result presented in [Table-5] indicated, stepwise regression, it has been also observed that R-value was high (0.75%) indicating a strong association between percent disease index and average temperature. The co-efficient of determination value was found to be 0.56 percent.

This clearly indicates that at least 75 percent disease index of the variation in banana fusarium fruit rot can be explained by the function of the weather parameter average temperature as evident from stepwise regression equation $\hat{Y} = -1310.869 + 16.551 (X_4)$, whereas, Y= Predicted Disease Index, X_4 = Average temperature].

Stepwise regression equation for banana fusarium fruit rot on different weather parameters in pooled

The result presented in [Table-6] indicated, stepwise regression, it has been also observed that degree of fitness model was found (0.67) indicating association between percent disease incidence to average temperature and maximum temperature. The multiple R- value was found to be 0.82 percent.

This clearly indicates that at least 82 percent of variation in banana fusarium fruit rot can be explained by the function of the weather parameter viz., average temperature and maximum temperature as evident from stepwise regression equation $\hat{Y} = -586.270 + 18.613 (X_4) + (-38.456) (X_2)$ whereas, Y= Predicted Disease Index, X_2 = Maximum Temperature and X_4 = average temperature].

Thus, observed banana fusarium fruit rot disease index and predicted banana fusarium fruit rot disease index found closely related and regression equation established may be most reliable and useful for forecasting of the banana fusarium fruit rot disease. The loss caused by the fusarium fruit rot can be saved by forewarning to the farmers and thereby controlling the same at the proper time. It is very clear from the present study that Navsari horticulture and organic farm for the banana fusarium fruit rot and variety Grande Naine is susceptible. The weather prevailing during kharif is the most congenial favouring the fusarium fruit rot and simultaneously make unprofitable cultivation. Thus, maximum temperature, and average temperature found to play a dominant role in the disease development. The results are very useful but to formulate weather-based forecasting model, 4 to 5 years further study is suggested. Moreover, the work to find out resistant variety, application of balanced fertilizers.

The result was support with Kedarnath (2011) [4] studied on correlation between *Lasiodiplodia theobromae* and weather parameters. In Navsari district during field survey, maximum percent disease index (PDI) was observed in October (2.87%), during this month maximum temperature (34.30°C) and minimum temperature (21.70°C), morning relative humidity (88.80 and 55.00%) and rainfall (0.20mm) while, minimum per cent disease index was observed in month of May (0.11%) during 2008. During 2009, maximum percent disease index was observed in October (2.43%), this month maximum temperature (33.90°C) and minimum temperature (21.50°C), morning relative humidity (85.10%) evening (47.00%), rain fall (2.70mm) while, minimum percent disease index was observed in month of

May (0.10%). In case of Surat district, maximum percent disease index was observed in November (3.03%), during this period maximum temperature (34.10°C) and minimum temperature (20.20°C), morning relative humidity (80.80%) and evening (52.30%) and rainfall (0.20mm). While, minimum percent disease index was observed in month of May (0.09%) during 2008. During 2009, maximum percent disease index was observed in November (3.03%), during this period maximum temperature (32.90°C) and minimum temperature (22.98°C), morning relative humidity (67.63%) and evening (45.55%) and rainfall (0.00mm) while, minimum percent disease index was observed in month of May (0.10%). Jagana *et al.* (2017) [5] was carried out post-harvest disease prevalence on banana in Dharwad and Hubballi markets of Karnataka were predominant diseases identified on banana fruits in Dharwad and Hubballi markets were anthracnose (*Colletotrichum musae*) and crown rot (*Fusarium semitectum*), Finger rot (*Lasiodiplodia theobromae*) and cigar end rot (*Verticillium theobromae*) observed in traces. Seasonal variation in disease incidence and disease severity were observed, the mean disease incidence of banana anthracnose was maximum (17.53%) during rainy season in Dharwad and (10.30%) in Hubballi in Cavendish, Ney poovan and Sughandi varieties when compared to winter (7.16 % in Dharwad and 6.56 % in Hubballi) and very low incidence was observed during summer (2.25 % in Dharwad and 2.22 % in Hubballi). Disease severity (percent disease index) of anthracnose was recorded maximum in rainy season which was more in Dharwad (20.56 %).

Conclusion

The present study clearly reveals that there is an increase in the incidence of fusarium fruit rot of banana in the variety Grande Naine grown in Navsari (indicating its susceptibility). The weather prevailing during the kharif season is the most congenial that favour the occurrence of fusarium fruit rot, therefore its cultivation of this variety becomes nonprofitable. Thus, average temperature and maximum temperature found to play an important role in the disease development. Moreover, the work to find out resistant variety, application of balanced fertilizers (especially nitrogen) because the heavy dose of nitrogen it favoured to fusarium fruit rot disease. So, management measures must be taken prior to infection get started to avoid huge losses.

Application of research: Results of the present study strongly reflected that the weather parameters play important role in disease development.

Research Category: Plant sciences

Abbreviation: PDI: Percent disease index, MSW: Meteorological standard week, mm: millimeter, °C: Degree centigrade, %: percent

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Cultivar / Variety name: Banana (*Musa paradisiaca* L.), Grande Naine

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

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