

Original Research Article

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Effect of Weather Parameters on the Development of Post Harvest Rots of Papaya

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ABSTRACT

Postharvest rots of papaya reduce quality as well as quantity of papaya (*Carica papaya* L.). Due to firm texture, various microorganisms attack the fruit during ripening stages and cause losses. During the present investigation, effect of various weather factors on the progress of different rots was studied during the year 2019-20. However, storage conditions could not be recorded but, data in terms of normal weather conditions such as monthly average minimum temperature, average maximum temperature and average relative humidity of district Hamirpur were recorded and correlated with disease abundance of different rots viz., anthracnose (*Colletotrichum fructicola* and *C. truncatum*), *Rhizopus stolonifer*, *Aspergillus flavus*, *Fusarium pallidoroseum* and *Alternaria* sp. under study during different months to calculate simple as well as partial correlation coefficients and multiple regression equation. Weather parameters like temperature and relative humidity were found to influence the abundance of these rots to a significant level. *Rhizopus* rot was positively and significantly correlated with average minimum temperature, *Aspergillus* rot was positively and significantly correlated while, *Fusarium* rot was negatively and significantly correlated with average maximum as well as average minimum temperature. Regression equation with weather parameters revealed that these factors could influence the outbreak of rots up to 69.50, 13.00, 45.40, 55.70, 59.20 and 62.30 per cent in case of *C. fructicola*, *C. truncatum*, *R. stolonifer*, *A. flavus*, *F. pallidoroseum* and *Alternaria* sp., respectively.

Keywords

Post harvest rots, Papaya, *Carica papaya*, Weather parameters, Temperature, Relative Humidity, Correlation, Regression

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Introduction

Papaya (*Carica papaya* L.) also called common man's fruit, is a native of tropical America (Singh, 1990) and is grown throughout the tropics and subtropics for its melon like fruit and ranks third in importance among fruits (Alvarez and Nishijima, 1987).

The leading global producers of papaya are Brazil, Colombia, Democratic Republic of Congo, Ethiopia, Guatemala, India, Indonesia, Mexico, Nigeria and Phillipines (Lustria *et al.*, 2009). Papaya fruits are highly susceptible to diseases caused by microorganisms mainly fungi, as papaya fruits contain high moisture and nutrients (Sankat and Maharaj, 1997).

Post-harvest losses due to fungal infections are significantly more in papaya fruits. The susceptibility of papaya fruit to several diseases is a major reason for extensive postharvest losses during handling and storage (Zhu et al., 2013). Storage conditions of papaya like temperature and relative humidity play an important role in the development of different post harvest rots in papaya. Maximum fungal rot in papaya, caused by fungi such as *Rhizopus* sp., *Aspergillus* sp., *Fusarium* sp., and *Colletotrichum* sp. occurs between at a temperature range of 30-35°C and relative humidity (RH) between 60-80 per cent (Baiyewu and Amusa, 2005). According to Pooja et al., (2012) optimum temperature for post harvest rots in papaya ranges between 17-30°C with RH of 80 per cent. Keeping in view the importance of post harvest rots of papaya, present studies were conducted with an objective to find correlation of temperature

and relative humidity with the abundance of the post harvest rots associated with papaya fruits.

Materials and Methods

A routine survey and surveillance was conducted during the year starting from May, 2019 to April, 2020 in the local fruit markets i.e. Hamirpur, Nadaun, Sujampur, Sulagwan and Barsar of district Hamirpur (Himachal Pradesh) to record the abundance (%) of different post harvest rots of papaya. From each market, 15 diseased fruits were collected and brought to laboratory for identification of a particular rot and pathogen associated with it. The rot was identified on the bases of symptoms produced and associated pathogen was identified on the bases of microscopic and cultural characters. Disease abundance of each rot was then calculated as per the following formulae:

$$\text{Disease abundance (\%)} = \frac{\text{Number of fruits affected by a particular rot}}{\text{Total number of diseased fruits}} \times 100$$

Final identification of these pathogens was confirmed from ITCC, New Delhi National Centre of Fungal Taxonomy. However, one pathogen associated with the rot exhibiting very low abundance was identified on the basis of its microscopic characters up to genus level only. Simultaneously, data in terms of average minimum temperature, average maximum temperature and average relative humidity pertaining to district Hamirpur were recorded daily from website <https://www.accuweather.com> w.e.f. May, 2019 to April, 2020 and averaged for each month, in order to correlate the disease abundance of each rot with these weather parameters. Simple and partial correlation coefficients between abundance of different rots and three weather parameters under study were calculated and multiple regression equations were devised by taking disease

abundance of individual rot as dependent variable and all three weather parameters as independent variables.

Results and Discussion

Identification of different post harvest rots and symptomatology

Six fungal species viz., *Rhizopus stolonifer*, *Aspergillus flavus*, *Fusarium pallidoroseum* (identified from ITCC, New Delhi under Accession No. 11309.20, 11310.20 and 11308.20, respectively), *Colletotrichum fructicola*, *C. truncatum* (identified from National Centre of Fungal Taxonomy as under Id No. 9013.20 and 9014.20, respectively) and *Alternaria* sp. (identified in the laboratory itself on the basis of mycelial and spore characters) were found to be

associated with different types of post harvest rots in papaya. Symptoms of anthracnose caused by *C. fructicola* were recorded as dark brown to black coloured sunken water soaked spots with orange coloured acervuli in the form of concentric rings (Figure 1), while that of *C. truncatum* were recorded as dark brown to black sunken lesions with black coloured acervuli in concentric rings (Figure 2). *R. stolonifer* produced a soft rot which developed white to grayish black fluffy mycelium bearing sporangia in the rotten portion (Figure 3). *A. flavus* produced soft rot bearing white mycelium with suppressed growth and green coloured conidial mass (Figure 4). In case of Fusarium rot, symptoms developed as sunken watery spots with white to yellowish or pinkish mycelial growth which later became soft with time (Figure 5) while, in case of Alternaria rot, symptoms were recorded as brown semi circular to circular spots covered with dark brown mycelium (Figure 6).

Abundance of different post harvest rots in relation to weather parameters

Averages of monthly weather parameters and abundance of various rots associated with papaya have been presented in Table 1. It is clear from the table that average maximum temperature ranged from 18.19°C in January 2020 to 43.97°C in June 2019, average minimum temperature ranged from 9.09°C in January, 2020 to 31.20°C in June, 2019 and average relative humidity ranged from 18.29 per cent in May, 2019 to 71.83 per cent in September, 2019. Individually, maximum abundance (86.11%) of *C. fructicola* was recorded in the month July, 2019 when the average maximum temperature was 37.87°C and minimum temperature was 28.03°C with 55.29 per cent average RH and minimum abundance (11.00%) was recorded in May, 2019, with significantly maximum temperature and minimum temperature of

41.26°C and 28.97°C, respectively with 18.29 per cent average RH. Maximum abundance (83.31%) of *C. truncatum* was recorded in the month September, 2019 with maximum average temperature of 33.90°C and minimum average temperature of 25.27°C with average 71.83 per cent RH while, minimum abundance (66.10%) was recorded in December, 2019, when maximum and minimum average temperature was recorded to be 20.77°C and 11.71°C, respectively with average RH of 50.75 per cent. As far as abundance of *R. stolonifer* was concerned, it was recorded to be maximum (85.50%) in the month June, 2019 when maximum and minimum temperature were recorded to be 43.97 and 31.20°C, respectively with average RH of 21.36 per cent. However, minimum abundance of *R. stolonifer* (72.43%) was recorded in August, 2019 having maximum and minimum temperature of 35.13 and 26.74°C, respectively with average RH of 68.60 per cent.

Maximum abundance (100%) of *A. flavus* was recorded in the month July, 2019 when maximum temperature was 37.87°C while, minimum temperature was 28.03°C with average RH of 55.29 per cent. Minimum abundance of *A. flavus* (10.50%) was recorded in May, 2019 when maximum and minimum temperatures were recorded to be 41.26 and 28.97°C, respectively with average RH of 18.29 per cent. Maximum abundance (86.44%) of *F. pallidoroseum* was recorded in the month March, 2020 with maximum temperature of 27.13°C and minimum temperature of 15.19°C with average RH of 58.40 per cent while, its minimum abundance (17.20%) was recorded in July, 2019, when maximum and minimum temperatures were recorded to be 37.87 and 28.03°C, respectively with an average RH of 55.29 per cent. Maximum abundance (12.06%) of *Alternaria* sp. was recorded in the month of August, 2019 with average maximum

temperature of 35.13°C, average minimum temperature of 26.74°C and average RH of 68.60 per cent while, minimum mean abundance (2.50%) was recorded in September, 2019, with average maximum and minimum temperature of 33.90 and 25.27°C, respectively and average RH of 71.83 per cent.

Simple correlation between different post harvest rots and weather parameters

Simple correlation analysis between abundance of different rots and weather parameters has been presented in Table 2. It is clear from the table that anthracnose caused by *C. fructicola* was positively and non-significantly correlated with mean monthly maximum temperature (0.022), mean monthly minimum temperature (0.201) and mean relative humidity (0.526) while, that caused by *C. truncatum* was negatively and non-significantly correlated with mean monthly maximum as well as minimum temperature (-3.555 and -0.340, respectively) and positively and non-significantly correlated with mean RH (0.250).

The simple correlation analysis between abundance of rot caused by *R. stolonifer* and weather factors revealed its positive and non-significant correlation with mean monthly maximum temperature (0.574), positive and significant correlation with mean monthly minimum temperature (0.633) while, negative and non-significant correlation with mean monthly RH (-0.101). The mean abundance of *A. flavus* was positively and significantly correlated with mean monthly maximum (0.620) as well as minimum temperature (0.690) while, negatively and non-significantly correlated with mean monthly RH (-0.080). However, abundance of rot caused by *F. pallidoroseum* was negatively and significantly correlated with mean monthly maximum (-0.651) as well as

minimum temperature (-0.725) and positively and non-significantly correlated with mean RH (0.160). Abundance of rot caused by *Alternaria* sp. was positively and non-significantly correlated with all three weather parameter under study (0.249, 0.390 and 0.408, respectively).

Partial correlation between different post harvest rots and weather parameters

A perusal of the data presented in Table 3 reveal that partial correlation between abundance of *C. fructicola* and weather factors was negative and significant (-0.811) with mean monthly maximum temperature, while, positive and significant (0.82) with mean monthly minimum temperature as well as with RH (0.718). Abundance of rot caused by *C. truncatum* was negatively and non-significantly correlated (-0.130) with mean monthly maximum temperature while, positively and non-significantly correlated with mean monthly minimum temperature (0.072) as well as mean RH (0.122). However, partial correlation analysis between abundance of rot caused by *R. stolonifer* and weather factors depicted a non-significant correlation (0.289, 0.408 and -0.259) with all the three weather factors under study.

Abundance of rot caused by *A. flavus* and weather factors was also non significantly correlated with all the three factors being negatively correlated (-0.340) with mean monthly maximum temperature while, positively correlated with mean monthly minimum temperature (0.498) and mean RH (0.385). Abundance of rot caused by *F. pallidoroseum* was positively and non significantly correlated (0.372) with mean monthly maximum temperature, negatively and non significantly correlated with mean monthly minimum temperature (-0.539) as well as mean RH (-0.299).

Table.1 Prevalence of various post harvest rots of papaya in relation to weather parameters during 2019-20

Month	Average Maximum temperature (°C)	Average Minimum temperature (°C)	Average Relative Humidity (%)	Average abundance of pathogen (%)					
				<i>C. fruticola</i>	<i>C. truncatum</i>	<i>R. stolonifer</i>	<i>A. flavus</i>	<i>F. pallidoroseum</i>	<i>Alternaria sp.</i>
May, 2019	41.26	28.97	18.29	11.00	0.00	0.00	10.50	76.50	0.00
June, 2019	43.97	31.20	21.36	0.00	0.00	85.50	54.10	0.00	0.00
July, 2019	37.87	28.03	55.29	86.11	0.00	77.79	100	17.20	4.72
August, 2019	35.13	26.74	68.60	78.70	0.00	72.43	40.74	40.33	12.06
September, 2019	33.90	25.27	71.83	70.79	83.31	0.00	23.05	50.89	2.50
October, 2019	31.87	21.16	53.17	57.26	74.78	0.00	22.33	53.47	0.00
November, 2019	28.27	17.90	44.08	56.36	74.17	0.00	19.11	66.33	0.00
December, 2019	20.77	11.71	50.75	51.01	66.10	0.00	0.00	70.62	0.00
January, 2020	18.19	9.09	69.77	16.72	0.00	0.00	0.00	83.47	0.00
February, 2020	23.21	10.97	62.07	15.88	0.00	0.00	0.00	84.85	0.00
March, 2020	27.13	15.19	58.40	15.09	0.00	0.00	0.00	86.44	0.00
April, 2020	36.33	22.57	28.59	14.87	0.00	0.00	13.67	79.97	0.00

Table.2 Simple correlation between abundance of different post harvest rots in papaya and weather parameters

Post harvest rot caused by pathogen	Simple Correlation Coefficients		
	Disease abundance with maximum Temperature	Disease abundance with minimum Temperature	Disease abundance with Relative humidity
<i>C. fruticicola</i>	0.022	0.201	0.526
<i>C. truncatum</i>	-3.555	-0.340	0.250
<i>R. stolonifer</i>	0.574	0.633**	-0.101
<i>A. flavus</i>	0.620**	0.690**	-0.080
<i>F. pallidoroseum</i>	-0.651**	-0.725*	0.160
<i>Alternaria sp.</i>	0.249	0.390	0.408

T_{min.} – Minimum temperature; T_{max.} – Maximum temperature; RH - Relative Humidity

*Significant at 1% level of significance

** Significant at 5% level of significance

Table.3 Partial correlation between abundance of different post harvest rots in papaya and weather parameters

Post harvest rot caused by pathogen	Partial correlation coefficients		
	Disease abundance with maximum Temperature. r _{DITmax.RH&Tmin.}	Disease abundance with minimum Temperature. r _{DITmin.RH&Tmax.}	Disease abundance with Relative humidity r _{DIRH, Tmax.&Tmin.}
<i>C. fruticicola</i>	-0.811*	0.820*	0.718*
<i>C. truncatum</i>	-0.130	0.072	0.122
<i>R. stolonifer</i>	0.289	0.408	-0.259
<i>A. flavus</i>	-0.340	0.498	0.385
<i>F. pallidoroseum</i>	0.372	-0.539	-0.299
<i>Alternaria sp.</i>	-0.653**	0.694*	0.729*

DI=Disease incidence; T_{max.}= Maximum Temperature; T_{min.}= Minimum temperature; RH= Relative humidity

*Significant at 1 % level of significance

** Significant at 5% level of significance

Table.4 Regression equation revealing relationship between abundance of different post harvest rots in papaya and weather parameters

Post harvest rot caused by pathogen	Regression equation (s)	R ²	Coefficient of multiple determination (%)
<i>C. fructicola</i>	Y= 94.83 - 10.43X ₁ + 12.10X ₂ + 0.44X ₃ (87.86) (5.09) (4.87) (0.55)	0.695	69.50
<i>C. truncatum</i>	Y= 95.35 - 3.24X ₁ + 1.87X ₂ + 1.87X ₃ (423.44) (31.20) (31.86) (2.41)	0.130	13.00
<i>R. stolonifer</i>	Y= -54.62 - 1.43X ₁ + 4.86X ₂ + 0.37X ₃ (138.471) (8.02) (7.68) (0.87)	0.454	45.40
<i>A. flavus</i>	Y= -47.02 - 1.35X ₁ + 4.51X ₂ + 0.39X ₃ (103.242) (5.98) (5.73) (0.65)	0.557	55.70
<i>F. pallidorozeum</i>	Y= 80.51 + 3.71X ₁ - 6.56X ₂ - 0.05X ₃ (94.05) (5.45) (5.22) (0.54)	0.592	59.20
<i>Alternaria sp.</i>	Y= -6.01 + 0.44X ₁ + 0.77X ₂ + 0.11X ₃ (11.64) (0.67) (0.65) (0.07)	0.623	62.30

X₁= Maximum. Temperature; X₂= Minimum Temperature; X₃= RH; Y= Pathogen
 Figures in parentheses represent respective standard errors

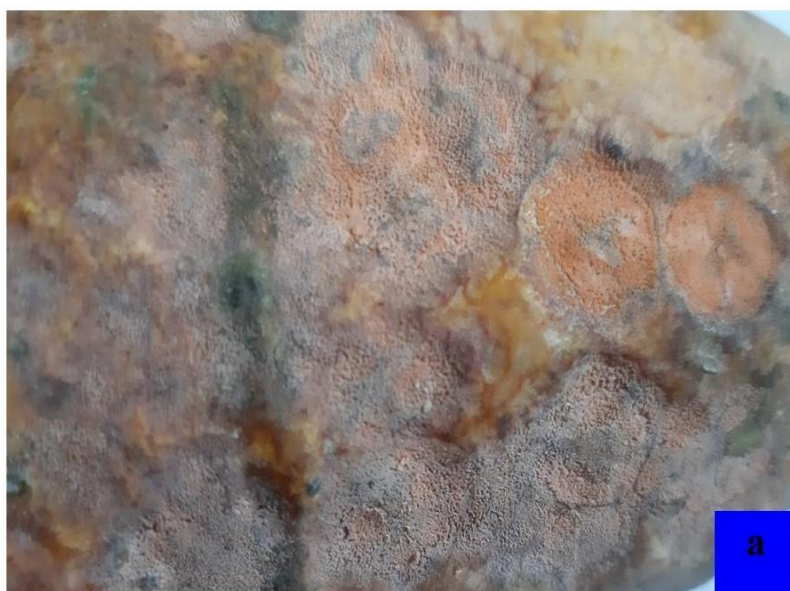


Figure1. Symptoms of *C. fructicola*



Figure 2. Symptoms of *C. truncatum*



Figure 3. Symptoms of *R. stolonifer*

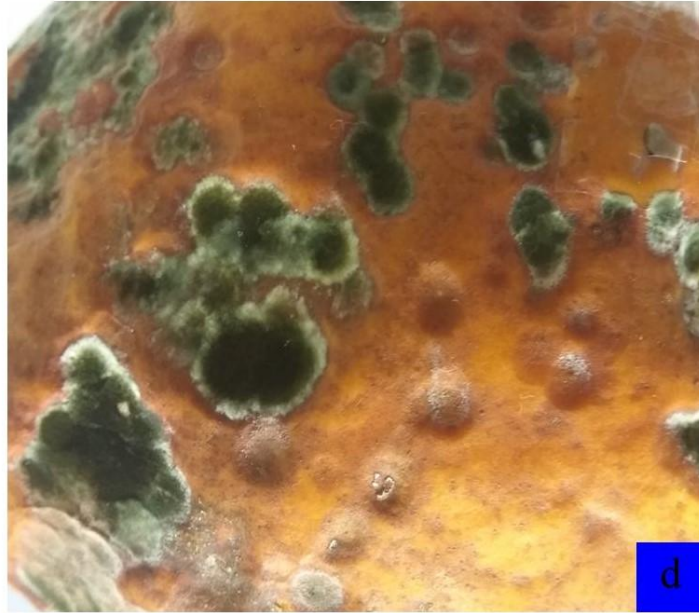


Figure 4. Symptoms of *A. flavus*

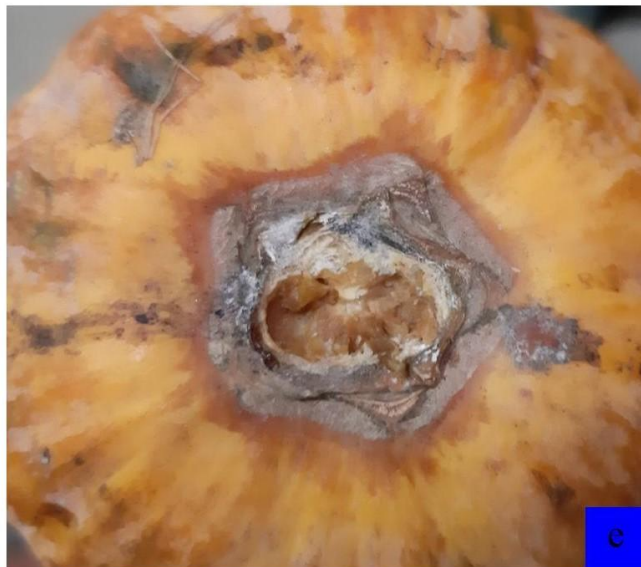


Figure 5. Symptoms of *F. pallidoroseum*



Figure 6. Symptoms of *Alternaria* sp.

Partial correlation analysis between abundance of rot caused by *Alternaria* sp. and weather factors indicated that mean pathogen abundance was negatively and significantly correlated (-0.653) with mean monthly maximum temperature while, positively and significantly correlated with mean monthly minimum temperature (0.694) as well as mean RH (0.729).

Multiple regression between different post harvest rots and weather parameters

Data presented in Table 4 reveal the multiple regression equation devised between different pathogens and group of independent variables which indicated that a unit change in mean maximum temperature, mean minimum temperature and mean RH could influence the disease abundance of rot caused by *C. fructicola* up to -10.43, 12.10 and 0.44 units, respectively; *C. truncatum* up to -3.24, 1.87

and 1.87 units, respectively; *R. stolonifer* up to -1.43, 4.86 and 0.37 units, respectively; *A. flavus* up to -1.35, 4.51 and 0.39 units, respectively; *F. pallidoroseum* up to 3.71, -6.56 and -0.05 and *Alternaria* sp. up to 0.44, 0.77 and 0.11 units, respectively.

The multiple coefficient of determination between disease abundance of rot caused by particular pathogen and group of independent variables were found to be 0.695, 0.130, 0.454, 0.557, 0.592 and 0.623 for *C. fructicola*, *C. truncatum*, *R. stolonifer*, *A. flavus*, *F. pallidoroseum* and *Alternaria* sp., respectively thereby indicating that 69.50, 13.00, 45.40, 55.70, 59.20 and 62.30 per cent change in the disease abundance of different rots caused by respective pathogens was attributed to all weather factors included in the studies collectively whereas, rest of the variation was due to unexplained factors not included in the investigations

Five fungal species viz., *Colletotrichum fructicola*, *C. truncatum*, *Rhizopus stolonifer*, *Aspergillus flavus*, *Fusarium pallidroseum* and *Alternaria* sp. were found to be associated with different post harvest rots in papaya during present studies. These findings are in conformity with various workers who have also reported the association of these pathogens with post harvest rots in papaya (Pooja *et al.*, 2012; Aktaruzzaman *et al.*, 2018 and dos Santos Viera *et al.*, 2019; Phoulivong *et al.*, 2012 and Marquez-Zequera *et al.*, 2018).

The symptoms of various rots observed are the same as described by Sharma and Kulshrestha (2015), Aktaruzzaman *et al.*, (2018), Popat (2013), Pooja *et al.*, (2012), Singh *et al.*, (2012) and Patel (2013).

Abundance of various rots varied in different months under study according to varying temperature and RH conditions. Earlier, Baiyewu and Amusa (2005) and Gore *et al.*, (2016) have reported that fungal rot caused by *Colletotrichum* sp. could develop well at temperature range 27 to 35°C with relative humidity between 60-80 per cent. Sommer (1982) reported *R. stolonifer* to grow on tomato fruits at 27°C and high relative humidity. Therefore, the disease usually increased during rainy season. However, as per Schipper (1984) and Liou *et al.*, (2007), 24°C is optimum temperature for the growth of *R. stolonifer* and it can grow on strawberry fruits at a temperature range of 8 to 33°C. But, the fungus has been reported to thrive well even up to 60°C which is the thermal death point of this fungus (Langeron and Vanbresueghem, 1965). Holmquist *et al.*, (1983) recorded best growth of *A. flavus* at 33°C. However, Belli *et al.*, (2004) reported 30 and 37°C to be optimum temperature for the growth of *Aspergillus* sp. on grapes. Mitchell (2004) reported 30–35°C to be the optimum temperature for most of the *Aspergillus* sp. strains on grapes. Gore *et al.*,

(2016) has also reported that *Fusarium* sp. could grow at temperature range 20-35°C with an optimum at 27°C. Also, our findings are supported by Nagaraja *et al.*, (2011) who reported a temperature range 25 to 27°C to be optimum for growth of *Fusarium* sp. Our findings pertaining to *Alternaria* rot are in conformity with Smilanick and Mansour (2007) and Hudge and Datar (2009) who reported that *A. alternata* could grow well at a temperature range 20-35°C with sporulation at 25 to 27°C.

Correlation and regression analyses between any post harvest rot of papaya and weather parameters have never been conducted by any researcher, so these results cannot be compared with available literature. However, it is a well known fact that temperature and relative humidity are two major factors influencing the outbreak of any disease (Agrios, 2005). Whereas, other than these two factors, many other factors are also responsible for the disease development. From the coefficients of multiple determinations between different rots and weather parameters under study, it was concluded that these factors could influence the outbreak of different rots only below 70 per cent. This can be attributed to the fact that the post harvest rots generally develop during transportation and storage and actual temperature and relative humidity prevailing under these conditions might be somewhat different from outside weather conditions.

From this study it was concluded that different post harvest rots of papaya were prevalent throughout the year and were influenced by weather parameters like temperature and relative humidity. These results do give us an idea about the role of these three factors under investigation in the development of different post harvest rots and open avenues for further studies on this aspect.

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