Int.J.Curr.Microbiol.App.Sci (2018) Special Issue-6: 418-430

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 Special Issue-6 pp. 418-430
Journal homepage: http://www.ijcmas.com

Original Research Article

Epidemiological Relations to *Phytophthora* Spp. Causing Citrus Gummosis in Nagpur Mandarin

R. J. Choudhari, R. M. Gade, R. S. Lad[*] and S. S. Bangar

Department of Plant Pathology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M. S.) 444104, India
**Corresponding author*

A B S T R A C T

Epidemics caused by *Phytophthora* spp. were monitored in four commercial citrus orchards to plot correlation between environmental and soil factors with gummosis disease caused by *Phytophthora* spp. in citrus. Agro-meteorological data was recorded by using wireless sensors (for air temperature 107 Temperature probe, for relative humidity HC2S3 with 30 minutes time interval for both the sensors and for rainfall measurement Texas Electronic rain gauge) in selected plots. The soil moisture, soil pH and soil EC was recorded at fortnightly interval. The observations recorded in order to characterise the progression of the symptoms expression over the time and to provide evidence for the possible correlation of inoculum dynamics with root rot and environmental factors. The relationship of rainfall, temperature, relative humidity, soil moisture, soil pH and soil EC on disease development was investigated. Sensor based data was recorded for rainfall, temperature, relative humidity and converted to forth nightly interval. The disease incidence vis-a-vis inoculum potential recorded at forth nightly interval from June 2016 to May 2017. There was significant progression in the disease development with the increasing rainfall and soil moisture. After high soil moisture and relative humidity condition intensity and incidence of gummosis was increased in the second forth night of December (44.90%) and first forth night of December (87.50%) respectively. Progress in disease was attributed to increase in soil moisture, relative humidity and decrease in the air temperature. A tendency of spreading the disease at adjoining trees was observed. Drainage of water, possibly containing propagules of the pathogen may have been responsible for disease progression. The disease initially low but gradually increases with time. There was positive correlation between soil moisture, relative humidity, soil EC with disease progression and inverse correlation with temperature.

Keywords

Nagpur mandarin, gummosis, intensity, incidence, *Phytophthora* spp.

Introduction

Phytophthora gummosis is one of the most important soil –borne disease of citrus. It causes mortality of newly planted trees and slow decline and yield loss of mature trees. The disease caused by several *Phytophthora* species (Verniere *et al.*, 2004) but the most widespread and important are *P. citrophthora* and *P. nicotianae* (var. *parasitica*) (Erwin and Ribeiro, 1996). Gummosis has a worldwide distribution and is responsible for 10 to 30% of losses in citrus culture around the world (Timmer *et al.*, 2000). Foot rot, root rot, Collar rot, crown rot, gummosis caused by *Phytophthora* spp. (Naqvi, 1999; Gade and Armarkar, 2011).

More than 20 per cent seedling mortality has been reported in central India due to *Phytophthora* spp. in Madhya Pradesh adjoining to Vidarbha region of Maharashtra, 20-50% Nagpur mandarin plants were found to be affected resulting in severe decline due to *P. parasitica, P. citrophthora* along with *P. palmivora*. In Andhra Pradesh also, 20-100% acid lime plantation was severely affected with *P. parasitica* along with *P. citropthora* and *P. palmivora*. In kinnow growing areas of Punjab state,10-80% plants of *C. sinensis* and 10-100% plants of kinnow mandarin (12-25 years old) showed symptoms of diseases caused by *P. parasitica, P. citrophthora* and *P. palmivora* due to excessive flood irrigation (Savita *et al.*, 2012).

Correlation of environmental factor *viz*., relative humidity, temperature and rainfall with Phytophthora gummosis epidemic in citrus has the potential to provide important information for management of the disease. Since high soil moisture is correlated with increase in incidence and severity of gummosis caused by *Phytophthora* spp. in many crops. Thus, correlation of environmental factors with the disease will be valuable tool for epidemiological studies of this pathogen and may be important for the development of suitable management strategies (Benson *et al.,* 2006). High temperature combined with high soil and air humidity provides favourable condition for infection and disease development (Matheron and matejka, 1997; Timmer *et al.,* 2000).

The amount of rainfall and frequency of irrigation can have large effect on the rate of development of phytophthora, amount of pathogen spread. The dispersal of inoculums down row in surface rain of irrigation the rate of disease development (Shew, 1987). *Phytophthora nicotianae* was present consistently while incidence of *Phytophthora citrophthora* was greatest in the soil during low temperature and then decreased with increased temperature. This behaviour confirmed hypothesis that *P. citrophthora* could attack citrus root during cool period (Goldschmidt and Golomb 1982). Showed that peak period of disease expression was November-January after high rainfall in August because many studies have demonstrated importance of water in the development and spread of disease (Cafe-Filho *et al.,* 1995) The peak period of disease expression was August-September which was concomitant with heavy rainfall, high humidity percentage and optimum temperature range 18 -35^{o}C (Singh, 2002).

In relation of H- ion concentration it was found in avocado that there was no significant difference in the disease progression in range of 3.5 and 8.0 (Bingham and Zentmyer, 1958). However salinity in soil favours in increasing the population of *Phytophthora parasitica* in citrus. When rootstocks are exposed to high levels of salinity (EC = 22 dS/m) before inoculation, those of in sweet orange cultivar pineapple were predisposed to severe root rot, whereas, Troyer citrange was unaffected. However, Troyer seedlings grown for 9 week in soil salinized to an EC of 3-4 dS/m and infested with *P. parasitica* had 30% of their total root length decayed by Phytophthora, whereas plants in infested non-saline soil had only 10% decay. Similar results were obtained with pineapple, sweet orange seedlings at even lower levels of soil salinity (Blanker and Donald, 1986).

The purpose of disease study was to describe epidemiology of Phytophthora gummosis in citrus field in relationship to dispersal of *Phytophthora* spp. from disease foci and importance of inoculum sources.

We correlated field parameters such as rainfall, temperature, relative humidity, soil moisture, soil pH and soil EC with Phytophthora gummosis. Result analysis may provide insight into management consideration for growers. Epidemiological study of the pathogen will be helpful to estimate Phytophthora severity and also it is useful for getting advanced information that how many sprays are needed during a growing season as a function of the weather and to prevent occurrence of Phytophthora diseases.

Materials and Methods

Experimental plots

The experiment was conducted at six fixed locations (villages) viz. plot A and plot –B (Nagziri), plot C (Goregaon), plot D (Bargaon) and plot E and F (Benoda) in Warud tahsil of Amravati district.

Collection of weather and soil factors data

The data on relative humidity and temperature was recorded with 30 minutes interval and received rainfall measured without any interval by the wireless sensors installed in each location (selected experimental plots) with the collaboration of IIT, Bombay and IIT, Hyderabad. The sensors viz. Model 107 Temperature probe based on Thermistor principle; HC2S3 used to measure relative humidity on principle of ratio of actual vapour pressure to saturation vapour pressure and Texas Electronic rain gauge 0.01 inch (0.254 mm) were used. The HC2S3 sensors used for measuring relative humidity in the range of 0 to 100% RH, Temperature probe used for measuring air temperature in the range of -40°C to 60oC, and Texas Electronic rain gauge used for measurement of rainfall. Air temperature, relative humidity and rainfall probes typically consist of three separate sensors packaged in the same farm tower in all selected plots.

The soil moisture measured within 24 hours of soil sample collection by using electronic soil moisture meter at department of Horticulture, Dr. P.D.K.V., Akola, while soil pH meter and soil EC meter were used for measurement of soil pH and EC at Department of Soil science and Agricultural Chemistry, Dr. P.D.K.V., Akola. Soil factors (soil moisture, pH and EC) were analysed at 15 days regular interval from collected soil samples.

Development of disease rating scale for disease intensity

The intensity of gummosis of citrus was recorded on the basis of levels of visible symptoms that showed the trees showing oozing of gum at bud joint and one meter above the ground level on the trunk where observed for calculating disease intensity of citrus gummosis. The modified disease rating scale (Gade and Koche, 2012) was adopted for recording the data of disease intensity.

Environmental and soil factors *viz*., relative humidity, temperature, rainfall, soil moisture, soil pH, soil EC were correlated with population of Phytophthora and intensity and incidence of gummosis of citrus. Statistical analysis was performed by using analysis of variance. Means were tested by significance and critical differences were used for comparison (Gomez and Gomez, 1984).

Disease intensity and incidence of gummosis in Nagpur mandarin

Data on gummosis incidence and intensity in Nagpur mandarin orchards at 15 days regular interval was carried out in Warud tahsil of Amravati district during the period of June 2016 to May 2017. Six different experimental fields Viz. Plot A, B, C, D, E and F were selected for forth nightly observations on incidence and intensity of gummosis and soil samples were collected from these Nagpur mandarin orchards.

Results and Discussion

Six different plots were selected to study the correlation of environmental and soil factors with gummosis intensity and incidence of Nagpur mandarin in selected plots. The correlations were worked out at fifteen days intervals in selected plots. Three species of Phytophthora *i.e. Phytophthora palmivora*, *P. nicotianae*, and *P. citrophthora* were associated with gummosis in selected plots.

Present results of relative humidity, soil moisture, soil pH, soil EC, rainfall and temperature were correlated with disease intensity and incidence of gummosis in Nagpur mandarin. The results presented in the Table 1 revealed that maximum intensity of disease was recorded in plot D (44.90%) in the second forth night of December at relative humidity (69.51%), rainfall (00.00 mm), temperature (34.65ºC), soil moisture (21.11%), pH (7.30) and EC (0.29 dS/m), which was followed by 43.05%, 42.59 % and 42.59% in plot B during same period and in plot A and D (in first forth night of January) respectively. The lowest disease intensity was recorded in plot E (10.18%) during first forth night of June.

Similarly the correlations of environmental and soil factors *viz*., relative humidity, rainfall, temperature, soil moisture, soil p^H and soil EC with incidence of Nagpur mandarin gummosis were worked out at 15 days intervals in selected plots. The results presented in Table 2 indicated that, the highest disease incidence was observed in plot E (87.50%) at relative humidity (68.81%), rainfall (00.00 mm), temperature (33.61ºC), soil moisture (22.71%), p^H (7.36) and EC (0.30 dS/m) in first forth night of December, followed by in the plot F (85.58%) during same time period. The lowest disease incidence was recorded in plot E (18.05 %); plot A (19.25 %) and plot-F (19.25%) in the second forth night of May.

Environmental and soil parameters *viz.*, mean relative humidity, rainfall, temperature, soil moisture, soil pH and soil EC were correlated with incidence of Nagpur mandarin gummosis in selected Nagpur mandarin orchards. It is seen from results depicted in Table 3 (Figure C and D) that positively significant correlations existed between mean relative humidity, soil EC, and with soil moisture in plot F with incidence of gummosis in Nagpur mandarin but positively non-significant correlations existed between gummosis incidence and mean p^H, soil moisture were existed in all plots except (plot F). Temperature correlated with gummosis incidence of Nagpur mandarin in orchards was negatively non-significant.

The positively significant correlations were existed between mean relative humidity, soil EC, with disease intensity in all plots. Positively significant correlations were existed between soil pH and soil moisture with gummosis intensity in plot A and F.

Temperature correlated with gummosis incidence of Nagpur mandarin in orchards was negatively non-significant and also rainfall was negatively non-significant (Table 3, Figure A and B). The peak period of disease expression was starting August-September and increase in December that was concomitant with after heavy rainfall, high humidity percentage and optimum temperature range 18^{o}C -35^{o}C. Similar, result was obtained by Das (2009) and Sing (2002). These results confirm other previous studies which indicated that low temperature, combined with high soil and air humidity, provide favourable conditions for the infection and development of disease (Matheron and Matejka, 1997; Timmer *et al.*, 2000). Timmer and Menge (1988) found that gummosis prefers low temperature area of at least 24ºC. The present results confirm the findings of Jonsson (2006) reported that Phytophthora disease considered to be more severe at higher pH values. These results are supported by the study of Graciela *et al.*, (2016) in which he reported the occurrence of plant pathogens and levels of disease are modified by variations in the abiotic and biotic environment. However, there is little information on the effects of environmental changes at a local scale on incidence and severity of foliar disease in seasonal tropical natural systems.

It is agreed that the environment is the driving force in the development of epidemics (Hardwick, 1998). This includes major climatic variables, such as rains, temperature and humidity. Wind and rain are essential for pathogen dispersal; rain provides free water on host surfaces for most pathogen to infect and sporulate and sun provides favourable temperature for disease development (Vallvieille-Pope *et al.*, 2000). The results showed that, peak period of disease expression were November-January after high rainfall in August because many studies have demonstrated importance of water in the development and spread of disease (Cafe-Filho *et al.*, 1995; Ristaino *et al.*, 1994). Similarly peak period of gummosis was recorded from October to January (Wagh, 2016). The work carried out by Mounde *et al.*, (2009) in Kenya who reported that there was positive and significant correlation between citrus gummosis and temperature but in present work the results was not correlated with this results due the variation in climatic conditions of different continents. Citrus gummosis positively significant correlation with humidity, rainfall, negatively significant correlation with temperature also recorded in past (Wagh, 2016).

Acknowledgments

The authors grate fully acknowledge the Information Technology Research Academy (ITRA), Ministry of Information Technology, GOI, New Delhi for providing fellowship and funding to conduct this research work. We are also thankful to Indian Institute of Technology (IIT), Bombay and Indian Institute of Technology (IIT), Hyderabad for providing sensor based data on environmental factors of all four experimental plots.

Development of disease rating scale for disease intensity

Scale	Remark
0	Healthy
1	Oozing and lesion developed up to 1 cm^2 area
3	Oozing lesion developed above 1 to 2.5 cm^2 area
5	Oozing lesion developed above 2.5 to 5 cm^2 area
7	Oozing lesion developed above 5 cm^2
9	Splitting of bark

Table.1 Effect of environmental and soil factors on intensity of gummosis in Nagpur mandarin

Tr. No.	Month	Rainfall (mm)	Humidity (%)	Temp. (ºC)	Soil moisture (%)	pH	EC (dS/m)	Intensity of gummosis (%)						Mean
								Plot A (Nagziri)	Plot B (Nagziri)	Plot C (Goregaon)	Plot D (Bargaon)	Plot E (Benoda)	Plot F (Benoda)	
T_1	June-1	109.50	65.32	23.22	22.44	7.30	0.25	17.73* (24.90)**	17.59 (24.80)	15.81 (23.43)	14.34 (22.25)	10.18 (18.61)	14.34 (22.25)	15.00
T_2	June-2	108.70	65.71	23.87	24.51	7.34	0.26	20.73 (27.08)	19.44 (26.16)	19.96 (26.540	17.27 (24.54)	15.81 (23.43)	17.27 (24.56)	18.41
T_3	July-1	108.50	65.80	24.56	25.14	7.41	0.28	26.85 (31.21)	20.84 (27.16)	19.44 (26.16)	20.84 (27.16)	19.44 (26.16)	20.73 (27.08)	21.36
T_4	July-2	90.70	72.45	22.51	27.38	7.44	0.31	31.61 (34.21)	23.89 (29.26)	22.22 (28.12)	26.74 (31.14)	23.92 (29.28)	25.66 (30.43)	25.67
T_5	August-1	186.00	80.51	20.56	29.41	7.51	0.33	34.72 (36.10)	25.00 (30.00)	25.00 (30.00)	27.35 (31.53)	25.00 (30.00)	26.74 (31.14)	27.30
T_6	August-2	181.50	83.80	21.54	29.33	7.60	0.32	35.22 (36.40)	31.27 (34.00)	27.35 (31.53)	31.27 (34.00)	26.38 (30.90)	31.85 (34.36)	30.56
T_7	September-1	123.00	82.65	22.64	30.27	7.74	0.34	40.36 (39.44)	37.03 (37.48)	31.94 (34.41)	39.87 (39.16)	35.85 (36.78)	37.03 (37.48)	37.01
T_8	September-2	111.80	81.03	28.49	24.27	7.76	0.35	41.66 (40.20)	38.72 (38.48)	35.24 (36.42)	40.36 (39.44)	39.87 (39.16)	40.36 (39.44)	39.37
T_9	October-1	4.87	76.50	29.84	26.51	7.40	0.34	39.87 (39.16)	36.65 (37.26)	37.03 (37.48)	41.66 (40.20)	40.36 (39.44)	39.87 (39.16)	39.24
T_{10}	October-2	1.23	78.94	30.84	25.03	7.30	0.32	37.02 (37.48)	37.05 (37.49)	39.87 (39.16)	39.87 (39.16)	39.87 (39.16)	38.65 (38.44)	38.72
T_{11}	November-1	0.60	65.12	32.85	24.54	7.34	0.33	36.72 (37.30)	35.77 (36.73)	36.98 (37.45)	38.57 (38.39)	38.65 (38.44)	37.03 (37.48)	37.29
T_{12}	November-2	0.20	66.84	31.54	23.8	7.28	0.31	35.22 (36.40)	36.15 (36.96)	34.79 (36.14)	37.03 (37.48)	35.65 (36.66)	35.65 (36.66)	35.75
T_{13}	December-1	00.00	68.81	33.61	22.71	7.36	0.30	37.19 (37.58)	41.20 (39.93)	36.72 (37.30)	40.27 (39.39)	37.02 (37.48)	36.15 (36.96)	38.09
T_{14}	December-2	00.00	69.51	34.65	21.11	7.30	0.29	38.57 (38.39)	43.05 (41.01)	38.57 (38.39)	44.90 (42.07)	36.72 (37.30)	35.36 (36.49)	39.53
T_{15}	January-1	00.00	55.31	34.70	21.05	7.29	0.29	42.59 (40.74)	41.20 (39.93)	40.27 (39.39)	42.59 (40.74)	35.36 (36.49)	35.36 (36.49)	39.56
T_{16}	January-2	00.00	53.10	34.10	20.80	7.30	0.28	37.19 (37.58)	36.55 (37.20)	30.09 (33.27)	31.18 (33.94)	30.09 (33.27)	31.01 (33.84)	32.69
T_{17}	February-1	00.00	48.60	35.80	20.45	7.28	0.30	35.65 (36.66)	30.09 (33.27)	29.62 (32.97)	29.62 (32.97)	29.62 (32.97)	30.09 (33.27)	30.78
T_{18}	February-2	00.00	42.75	35.40	20.10	7.26	0.29	33.33 (35.26)	28.70 (32.39)	27.31 (31.51)	28.54 (32.29)	27.31 (31.51)	28.70 (32.39)	28.98
T_{19}	March-1	00.00	35.23	35.38	19.86	7.25	0.27	30.09 (33.27)	26.39 (30.91)	25.00 (30.00)	27.77 (31.80)	25.00 (30.00)	26.39 (30.91)	26.77
T_{20}	March-2	00.00	29.66	35.50	19.77	7.25	0.28	27.31 (31.51)	25.00 (30.00)	20.84 (27.16)	27.54 (31.65)	20.84 (27.16)	25.00 (30.00)	24.42
T_{21}	April-1	00.00	25.30	36.20	19.65	7.24	0.27	25.00 (23.00)	26.92 (31.25)	20.10 (26.64)	26.39 (30.91)	19.44 (26.16)	20.84 (27.16)	23.12
T_{22}	April-2	00.00	23.11	38.65	18.62	7.25	0.26	19.96 (26.54)	20.80 (27.13)	19.96 (26.54)	20.80 (27.13)	15.81 (23.43)	18.05 (25.14)	19.23
T_{23}	May-1	00.00	20.71	42.12	18.50	7.22	0.25	17.59 (24.80)	19.96 (26.54)	18.05 (25.14)	17.59 (24.80)	16.54 (24.00)	17.59 (24.80)	17.89
T_{24}	May -2	00.00	19.30	43.22	18.21	7.21	0.26	17.27 (24.56)	18.05 (25.14)	15.81 (23.43)	15.81 (23.43)	14.34 (22.25)	15.27 (23.00)	16.09
	F Test							Sig	Sig	Sig	Sig	Sig	Sig	
	GM							31.64	29.89	27.83	30.34	27.46	28.54	
	SE(m)±							0.64	0.54	0.51	0.55	0.49	0.53	
	CD@5 %							1.84	1.54	1.44	1.56	1.39	1.52	

*Average of three replications ** Values in parenthesis are arc sine transformed

Table.2 Effect of environmental and soil factors on incidence of gummosis in Nagpur mandarin

Tr. No.	Month	Rainfall (mm)	Humidity (%)	Temp. (^oC)	Soil moisture (%)	p^H	EC (dS/m)	Incidence of gummosis (%)						Mean
								Plot A (Nagziri)	Plot B (Nagziri)	Plot C (Goregaon)	Plot D (Bargaon)	Plot E (Benoda)	Plot F (Benoda)	
T_{1}	June-1	109.50	65.32	23.22	22.44	7.30	0.25	33.33* (35.26)**	25.00 (30.00)	25.00 (30.00)	33.33 (35.26)	31.64 (34.23)	26.39 (30.91)	29.12
T_{2}	June-2	108.70	65.71	23.87	24.51	7.34	0.26	37.50 (37.76)	33.33 (35.26)	41.67 (40.20)	37.50 (37.76)	37.50 (37.76)	31.94 (34.41)	36.57
T_{3}	July-1	108.50	65.80	24.56	25.14	7.41	0.28	41.67 (40.20)	37.50 (37.76)	45.83 (42.61)	45.83 (42.61)	41.67 (40.200	38.19 (38.17)	41.78
T_{4}	July-2	90.70	72.75	22.51	27.38	7.44	0.31	37.50 (37.76)	45.83 (42.61)	54.56 (47.62)	50.00 (45.00)	45.83 (42.61)	51.17 (45.67)	47.48
T_{5}	August-1	186.00	80.51	20.56	29.41	7.51	0.33	50.00 (45.00)	41.67 (40.20)	58.33 (49.80)	54.33 (47.48)	54.17 (47.39)	52.08 (46.19)	51.76
T_{6}	August-2	181.50	83.80	21.54	29.33	7.60	0.32	58.33 (49.80)	54.17 (47.39)	50.00 (45.00)	58.33 (49.80)	50.00 (45.00)	54.86 (47.79)	54.28
T_{7}	September-1	123.00	82.65	22.64	30.27	7.74	0.34	58.33 (49.80)	58.33 (49.80)	62.50 (52.24)	66.67 (54.74)	58.33 (49.80)	61.81 (51.83)	61.00
T_{8}	September-2	111.80	81.03	28.49	24.27	7.76	0.35	66.67 (54.74)	66.67 (54.74)	57.17 (49.12)	50.00 (45.00)	62.50 (52.24)	59.53 (50.49)	60.42
T_{9}	October-1	4.87	76.50	29.84	26.51	7.40	0.34	62.50 (52.24)	66.67 (54.74)	75.00 (60.00)	72.22 (58.19)	66.67 (54.74)	68.98 (56.15)	68.67
T_{10}	October-2	1.23	78.94	30.84	25.03	7.30	0.32	66.67 (54.74)	79.17 (62.85)	70.83 (57.31)	79.17 (62.85)	70.83 (57.31)	74.31 (59.55)	73.50
T_{11}	November-1	0.60	65.12	32.85	24.54	7.34	0.33	70.83 (57.31)	80.55 (63.83)	75.00 (60.00)	75.00 (60.00)	75.00 (60.00)	75.93 (60.62)	75.39
T_{12}	November-2	0.20	66.84	31.54	23.8	7.28	0.31	84.03 (66.45)	84.03 (66.45)	83.33 (65.90)	83.33 (65.90)	85.55 (67.66)	83.93 (66.37)	84.03
T_{13}	December-1	00.00	68.81	33.61	22.71	7.36	0.30	83.33 (65.90)	85.55 (67.66)	84.03 (66.45)	85.55 (67.66)	87.50 (69.30)	85.58 (66.37)	85.26
T_{14}	December-2	00.00	69.51	34.65	21.11	7.30	0.29	78.94 (62.68)	79.33 (62.96)	78.94 (62.68)	79.15 (62.83)	83.33 (65.90)	76.10 (60.73)	79.30
T_{15}	January-1	00.00	55.31	34.70	21.05	7.29	0.29	75.00 (60.00)	76.54 (61.03)	75.00 (60.00)	78.86 (62.63)	77.15 (61.44)	71.83 (57.94)	75.73
T_{16}	January-2	00.00	53.10	34.10	20.80	7.30	0.28	66.67 (54.74)	62.56 (52.27)	70.83 (57.31)	66.67 (54.74)	70.83 (57.31)	70.83 (57.31)	68.07
T_{17}	February-1	00.00	48.60	35.80	20.45	7.28	0.30	50.00 (45.00)	54.64 (47.66)	58.83 (50.09)	58.33 (49.80)	58.33 (49.80)	45.54 (42.44)	54.28
T_{18}	February-2	00.00	42.75	35.40	20.10	7.26	0.29	41.67 (40.20)	50.00 (45.00)	54.56 (47.62)	50.00 (45.00)	54.64 (47.66)	41.83 (40.30)	48.78
T_{19}	March-1	00.00	35.23	35.38	19.86	7.25	0.27	37.50 (37.76)	45.33 (42.32)	45.33 (42.32)	45.83 (42.61)	45.54 (42.44)	36.65 (37.26)	42.70
T_{20}	March-2	00.00	29.66	35.50	19.77	7.25	0.28	33.33 (35.26)	38.19 (38.17)	41.83 (40.30)	41.67 (40.20)	38.19 (38.17)	33.33 (35.26)	37.76
T_{21}	April-1	00.00	25.30	36.20	19.65	7.24	0.27	31.28 (34.01)	35.33 (36.47)	37.50 (37.76)	35.33 (36.47)	36.65 (37.26)	31.18 (33.94)	34.55
T_{22}	April-2	00.00	23.11	38.65	18.62	7.25	0.26	25.00 (30.00)	28.18 (32.06)	33.33 (35.26)	29.17 (32.69)	33.33 (35.26)	30.56 (33.56)	29.93
T_{23}	May-1	00.00	20.71	42.12	18.50	7.22	0.25	21.28 (27.47)	25.00 (30.00)	29.17 (32.69)	25.00 (30.00)	25.00 (30.00)	26.29 (30.85)	25.29
T_{24}	May -2	00.00	19.30	43.22	18.21	7.21	0.26	19.25 (26.02)	21.28 (27.47)	26.29 (30.85)	21.28 (27.47)	18.05 (25.14)	19.25 (26.02)	20.90
	F Test							Sig	Sig	Sig	Sig	Sig	Sig	
	GM							51.28	53.12	55.62	55.11	54.51	52.00	
	SE(m)±							0.94	0.96	1.08	1.08	1.03	0.98	
	CD@5 %							2.68	2.73	3.08	3.07	2.93	2.80	

*Average of three replications

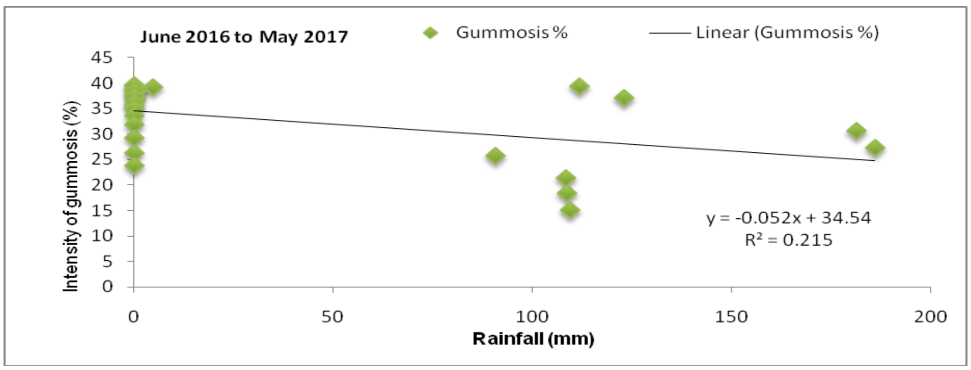
** Values in parenthesis are arc sine transformed

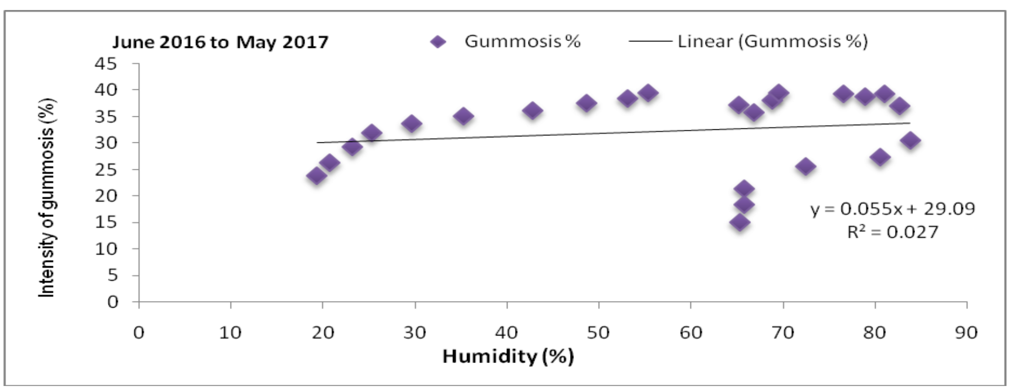
Table.3 Correlation coefficients of environmental and soil factors of incidence and intensity in Nagpur mandarin gummosis

Sr. No.	Meteorological Parameter and soil factors	Experimental fields											
		A	B	C	D	E	F	A	B	C	D	E	F
		Incidence (%)						Intensity (%)					
1	Humidity	0.595*	0.566*	0.596*	0.590*	0.577*	0.667*	0.644*	0.501*	0.553*	0.541*	0.580*	0.620*
2	Rainfall	-0.133	-0.237	-0.186	-0.186	-0.198	-0.100	0.019	-0.227	-0.232	-0.184	-0.180	-0.095
3	Temperature	-0.108	-0.062	-0.133	-0.128	-0.103	-0.200	-0.248	-0.006	-0.030	-0.063	-0.074	-0.148
4	Soil moisture	0.324	0.276	0.358	0.355	0.298	0.437*	0.458*	0.226	0.272	0.318	0.356	0.416*
5	p^H	0.292	0.209	0.209	0.194	0.207	0.304	0.490*	0.301	0.253	0.353	0.374	0.447*
6	EC	0.669*	0.646*	0.664*	0.664*	0.643*	0.714*	0.819*	0.644*	0.687*	0.741*	0.801*	0.838*

R value 0.404* Significant at 5% level.

Fig. A Correlation between environmental factors and gummosis intensity (%)





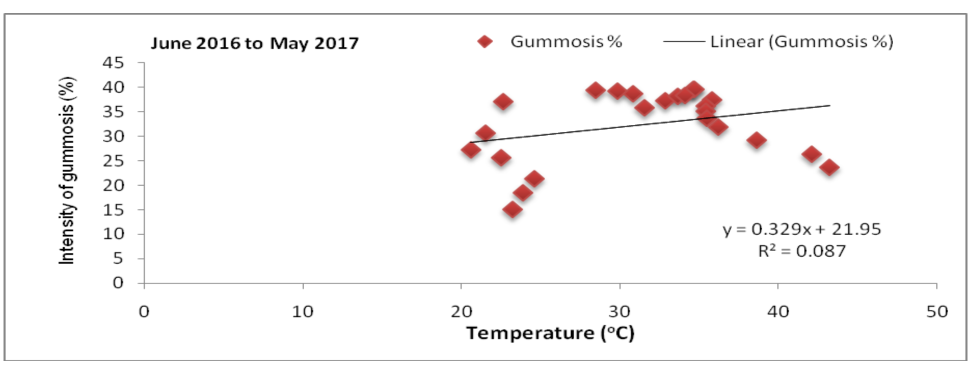


Fig. B Correlation between soil factors and gummosis intensity (%)

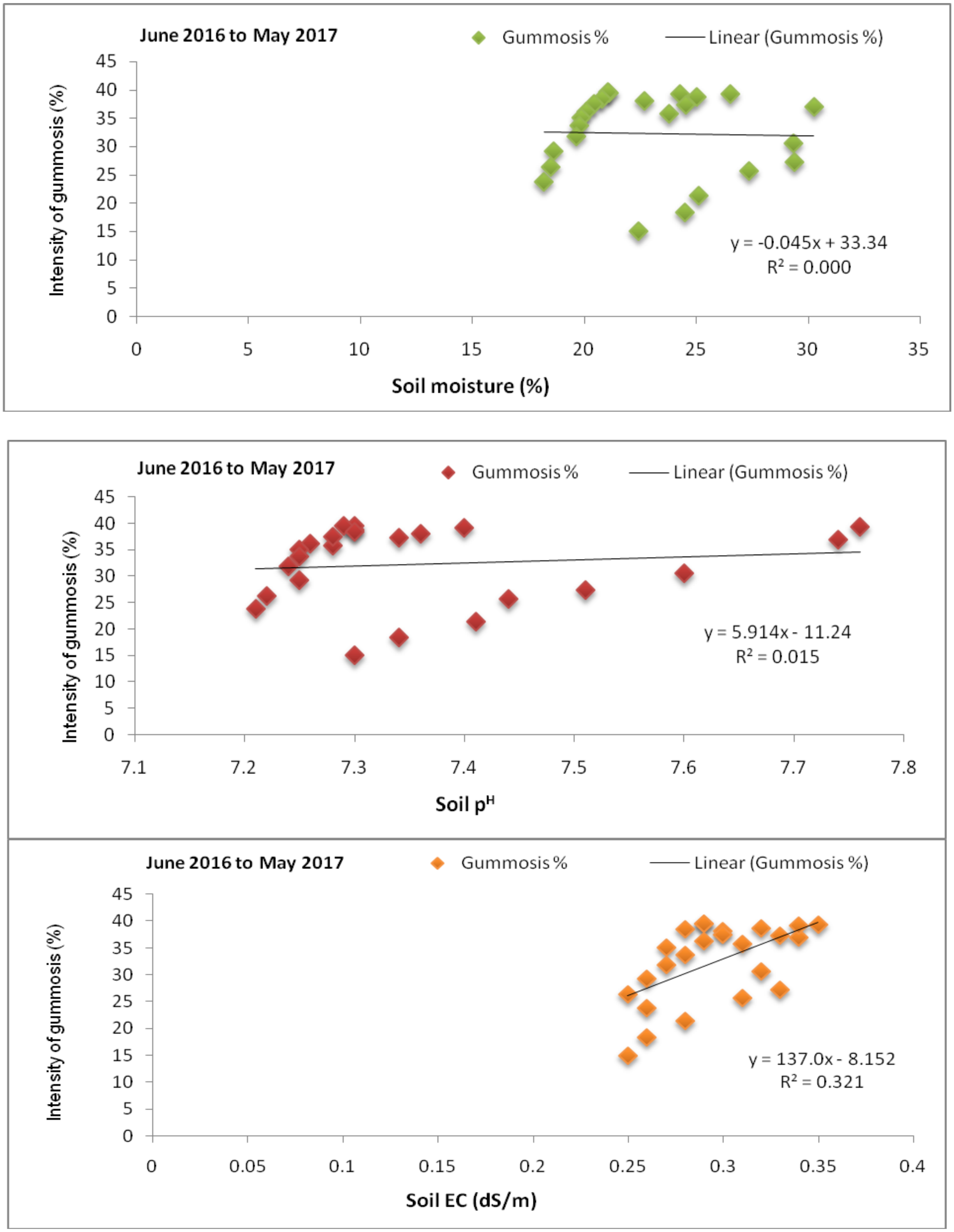


Fig. C Correlation between environmental factors and gummosis incidence (%)

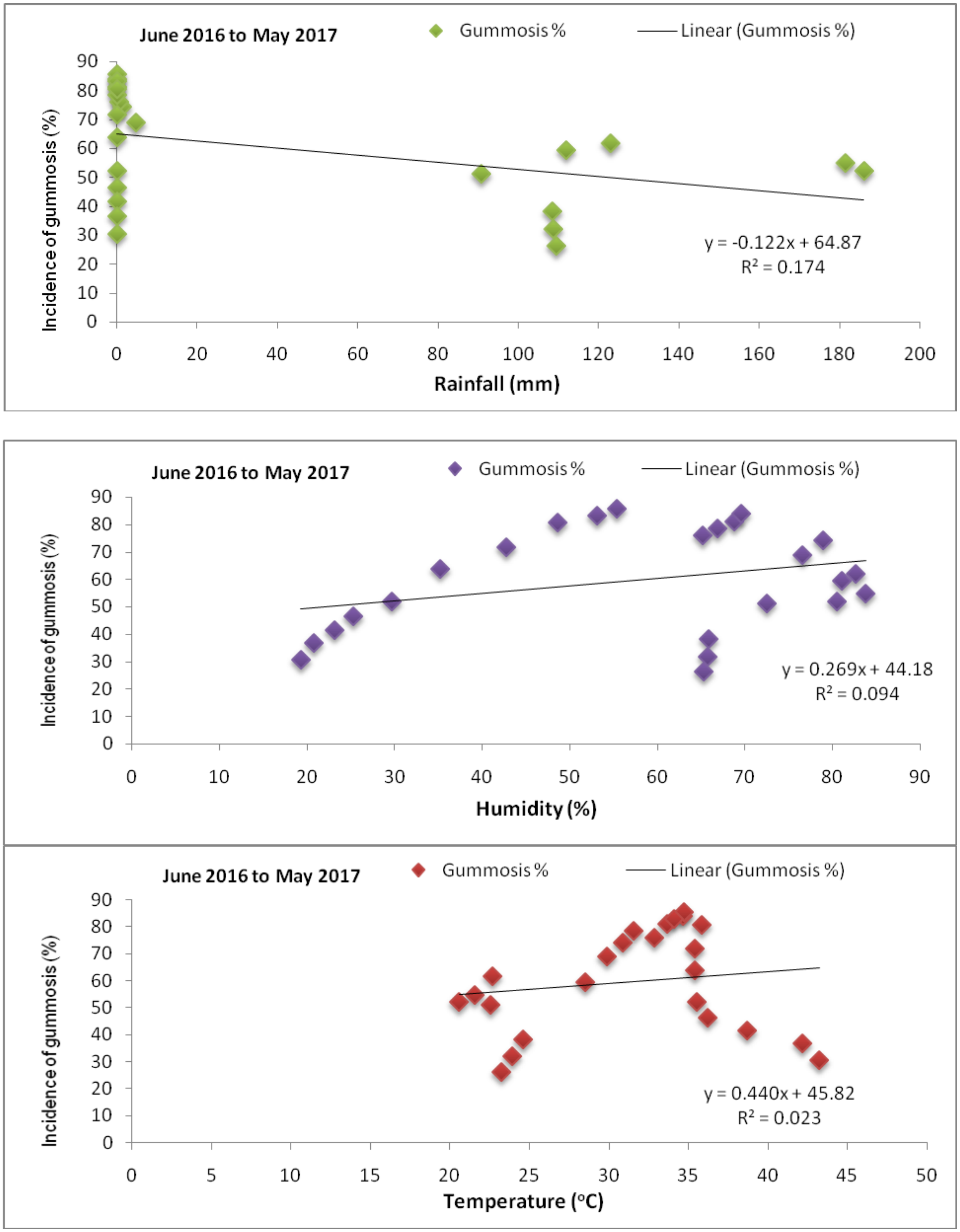
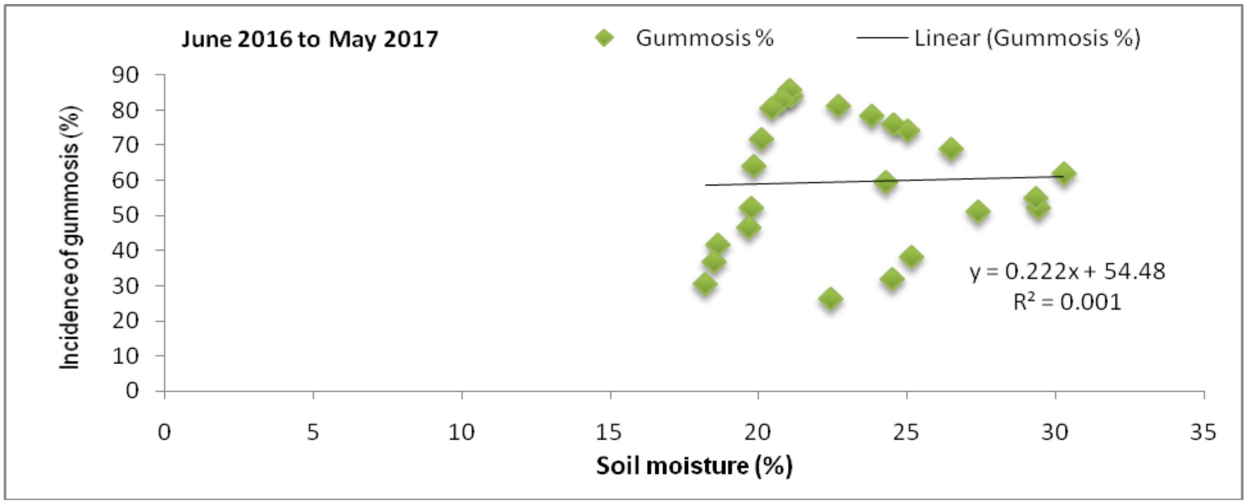
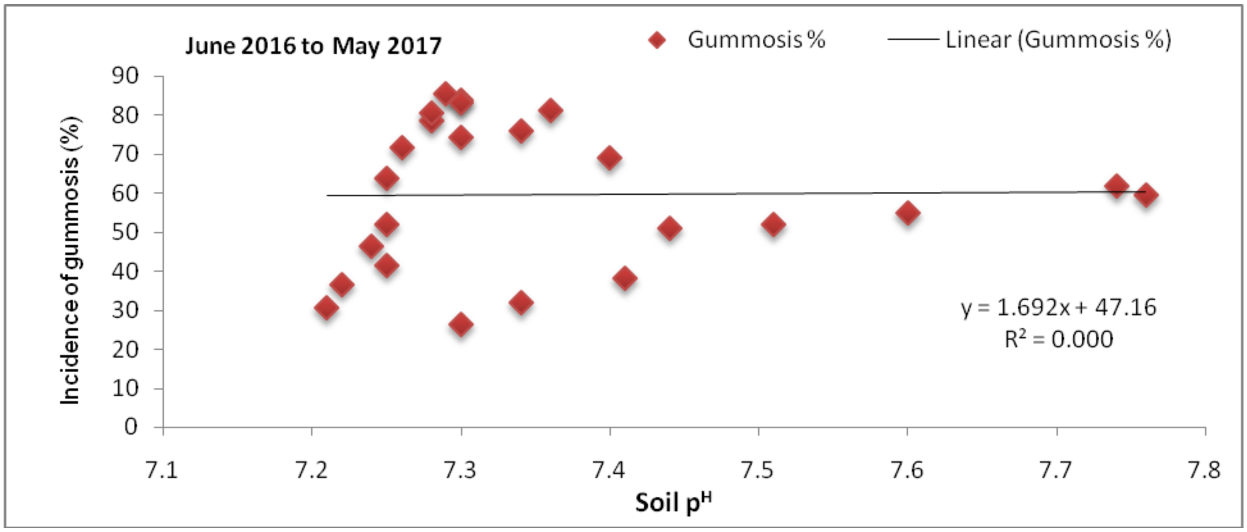
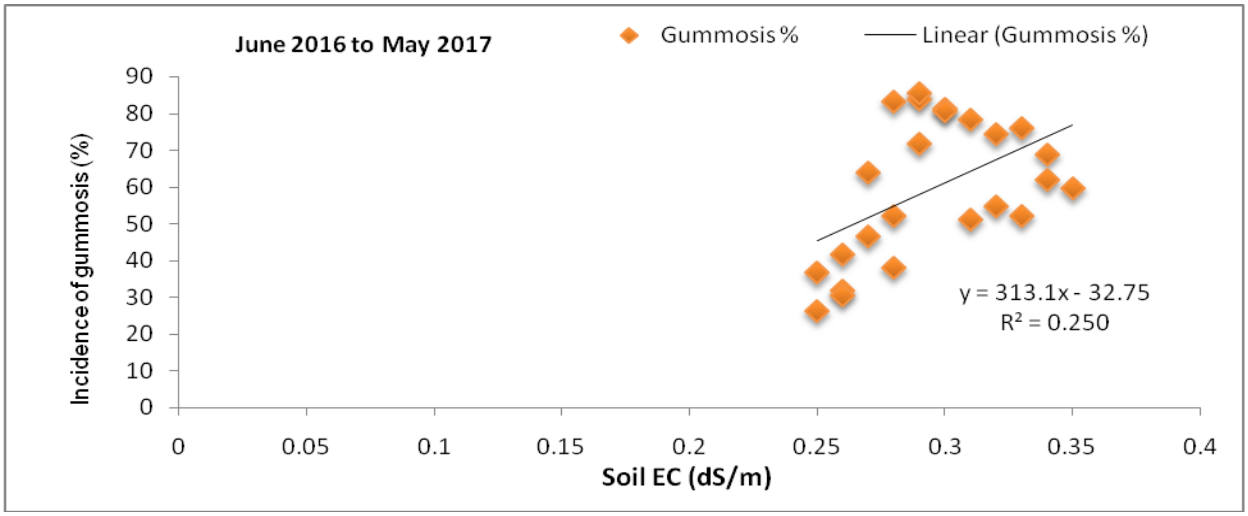


Fig. D Correlation between soil factors and gummosis incidence (%)







References

Benson, D. M., Grand, L. F., and Vernia, C. S. (2006). Temporal and spatial epidemiology of Phytophthora root rot in fraser fir plantations. DOI: 10.1094/PD-90-1171.

Bingham, F.T. and G. A. Zentmyer, (1958). Host nutrition in relation to Phytophthora root rot of avocado seedling. *Phytopathology*, 48:144-147.

Blaker, N. S. and Donald J. D. (1986). The role of salinity in the development of Phytophthora root rot of citrus. *Phytophthology*, 76: 970-975.

Cafe-Filho, H. J.; M. J. Griffiths and E. Jones, (1995). Plant Disease Epidemiology. Population Dynamics and Management, 1: 255–281.

Das, A. K. 2009. Fungal Disease in Citrus and its management. Integrated orchard management in citrus. NRCC, Nagpur, Pp. 53-57.

Erwin, D. C. And O. K. Ribeiro. 1996. Phytophthora diseases worldwide. APS. Press. St. Paul, Minnesota. USA.

Gade, R. M. and Armarkar, S. (2011). Growth promotion and disease suppression ability of *Pseudomonas fluorescens* in Acid lime. *Archives of Phytopath. and Pl. Protec*. 44(10): 943-950.

Gade, R. M. and Koche M. D. (2012). Integrated disease management for root rot and gummosis in Nagpur mandarin. *Indian Phytopath*. 65 (3): 272-275

Goldschmidt, E. E. and A. A. Golomb, (1982).The carbohydrate balance of alternate- bearing citrus trees and the significance for flowering and fruiting. *J. Am. Soc. Hort. Sci*. 107, 206-208.

Gomez and Gomez. (1984). Statistical procedure for agriculture research second edition.

Graciela, G. G. Irma, T. Irma, C. Acosta and M. E. Sánchez, (2016). Environmental factors associated with disease incidence in plant species from a Mexican seasonal tropical dry forest. J. Torrey Botanical Society, 143(3): 254-264

Hardwick. (1998). Dispersal of *Phytophthora cinnamomi* on the island of Hawaii. Phytopathology, 66:457-460.

Jonsson, U. (2006). A conceptual model for the development of Phytophthora disease in Quercus robur. New Phytologist, 171: 55-68.

Matheron, M. E.; M. porchas and J. C. Matejka, (1997). Distribution and seasonal population dynamics of *Phytophthora citrophthora* and *P. parasitica* in Arizona citrus orchards and effect of fungicides on tree health. Plant Dis., 81: 1384-1390.

Mounde, L.G.; E.M Ateka, A.W Kihurani, L. Wasilwa and E.G Thuranira, (2009). Occurrence and distribution of citrus gummosis *Phytophthora* spp. in Kenya Afr. J. Hort. Sci., 2:56-68.

Naqvi, S.A.M.H. 1999. Distribution of *Phytophthora* spp. and mating types pathogenic to citrus in Vidarbha and Marathwada region of Maharashtra and North Eastern States of India. In: *Citrus Proceeding International Symposium on Citriculture*. Pp. 1073-1080.

Ristaino, J. B., R. P. Larkin. and, C. L. Campbell. 1994. Spatial dynamics of disease symptom expression during Phytophthora epidemics on bell pepper. Phytopathology, 84(1): 1015-1024.

Savita, G. Singh, Virk and A. Nagpal, (2012). Citrus diseases caused by *Phytophthora* spp. GERF Bulletin of Biosci. 3(1):18-27

Shew, H. D. (1987). Effect of host resistance on spread of *Phytophthora parasitica* var. *nicotiannae* and subsequent developed tobacco black shank under field condition. *Phytopathology*, 77: 1090-1093.

Singh, S. (2002). Citrus in India: Hi Tech Citrus Management. Pp. 278-303. NRCC, Nagpur.

Timmer, L. W. and J. A. Menge (1988). Induced diseases in compendium of citrus diseases. APS Press, St. Paul, MN, Pp. 22-24.

Timmer, L. W..; S. E Zitako, T.R Gottwald and J. H. Grahan, 2000. Phytophthora brown rot of citrus: temperature and moisture effects on sporangium production and dispersion. Plant Des. 94: 157-163.

Vallvieille, Pope and S. R. Shea, (2000). Environmental factors of the northern jarrah forest in relation to pathogenicity and survival of *Phytophthora cinnamomi*. For. Dep. Bull. 85. Perth W. Aust, 7: 83-88.

Verniere, C., S. Cohen, B. Raffanel, A. Dubois, P. Venard and F. Panabieres. (2004). Variability in pathogenicity among *Phytophthora* spp. Isolated from citrus in Corsica. Phytopathological, 152: 476-483.

Wagh, S. (2016). Epidemiological studies on Phytophthora root rot and gummosis in citrus. M.Sc. (Agri.) Thesis (unpublished) Dr. P.D.K.V., Akola.