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Development of chickpea wilt (*Fusarium oxysporum* f. sp. *ciceri*) incidence in relation to soil edaphic and aerial environments

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ABSTRACT

Correlation between incidence of chickpea wilt [*Fusarium oxysporum* f. sp. *ciceri* (Padwick) Matua & K Sato (foc)] and soil edaphic factors on four lines, viz. JG 315, IGP 187, IGP 29 and JG 62 was studied. There was a significant correlation between disease incidence and soil temperature and moisture (%). The test entries showed positive correlation with soil temperature and negative correlation with soil moisture as well as contributed 54.7% (JG 315), 56.32%, (IGP 187), 54.88% (IGP 29) and 39.42% (JG 62) in development of wilt. Three different levels of temperatures, viz. 20, 27 and 34, two different levels of relative humidity, viz. 60, 80% and two inoculum load (5 and 10%) exhibited positive correlation with wilt incidence. Statistically, aerial temperature (0.7226**) and inoculum load (0.6435**) showed significant positive correlation with wilt incidence, while relative humidity (0.1315) was found to be non-significant.

Key words: Aerial temperature, *Fusarium oxysporum* f. sp. *ciceri,* Inoculum load, Soil moisture, Soil temperature, Wilt incidence

Chickpea (*Cicer arietinum* L.) is the most important pulse crop of Indian sub-continent. India is the largest producer as well as consumer of chickpea in the world. It is an ancient conventional rainfed pulse crop widely adopted by the farmers especially in poor natural resource availability. Chickpea is a main crop of *rabi* widely cultivated in rainfed areas of Malwa Plateau, Jhabua hills and Nimar Valley region of western Madhya Pradesh. Soybean-chickpea and soybean - wheat is the predominant cropping pattern of black cotton soil in the region, as the depth of soil is mostly shallow to deep. Black cotton soil has the natural property of ploughing and in drought conditions large, sized, cracks appear in the field. The area is well known for production of export quality extra-large seeded *Kabuli* (ELSK) chickpea locally called as Dollar and the best quality desi varieties for dal and floor preparation. The changing scenario of climate not only affects normal physiological processes of chickpea but also the pathogenic behavior. The pathogens related to crops always take their nourishment from their host and in fact their, survival, multiplication, vigourness and comparative infectiveness to desirable host is determined by the congenial microclimatic conditions. Soil borne pathogens especially hemibiotroph growth rate and multiplication have to be determined by the microclimatic conditions of rhizosphere, rhizoplane and availability of nutrients in surrounding. The population dynamics of types and number of rhizospheric microbes in crops have the great variation in colonisation of microbes in rhizosphere, rhizoplane and even in non rhizospheric soils. (Wieland *et al.* 2001). Chickpea wilt caused by *Fusarium oxysporum* f. sp. *ciceri* (Padwik) Matuo & K. Sato (foc) is responsible for wilting, flagging and consequently loss of the yield. The environmental conditions play a vital role in the incidence and development of chickpea wilt disease (Merkuz and Getachew 2012). Chickpea wilt disease is caused by a soil and seed borne pathogen, (Pande *et al.* 2007) and faster growth and multiplication of wilt pathogen is dependent on the soil temperature, soil moisture, pH, inoculum load and availability of organic substrate in the micro climate of rhizospheric soil (Chaudhary *et al.* 2001). Epidemiological studies are therefore essential to determine the effects of all environmental factors. The objective of this study was to identify the environmental/soil conditions favourable for chickpea wilt disease.

MATERIALS AND METHODS

For characterization of soil factors (Soil moisture and soil temperature) conducive to chickpea wilt disease development, four resistant to highly susceptible lines (JG -315, IGP187, IGP29 and JG62) were raised in experimental field (Continuously chickpea crop laid out from five years) with four replications at College of Agriculture, Indore (Madhya Pradesh), which was being used for germplasm

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evaluation against chickpea wilt. The experiment was laid on 25 November, 2014 and 2015. The plot size ranged from 1.2 m × 4.0 m. All the standard agronomical practices and pest control measures were followed during the growth period of chickpea except fungicidal treatment. The disease incidence observations started from 10 December, 2014 and 2015 at 7 days interval till 4 March 2015, and 2016. Data pertaining on disease incidence were pooled of both the year undertaken for statistical analysis.

Influence of soil temperature and soil moisture was examined on the wilt of chickpea in the field. Disease incidence was calculated weekly and soil moisture and soil temperature was also recorded weekly. Ten places were randomly selected from the experimental site to record soil temperature. Soil moisture was also recorded from 10 places by hot-air oven drying method. The data on disease incidence were plotted against soil moisture and soil temperature to predict the simple and multiple correlation between disease, soil moisture and soil temperature.

Twelve different combinations of aerial temperature and relative humidity (%) were evaluated to know the effect of different aerial temperature and relative humidity on the wilt of chickpea at 5% and 10% inoculum load. Inoculum of *F. oxysporum* f. sp. *ciceri* was multiplied on chickpea grains. The well multiplied inoculum mixed in the soil @ 50 and 100 g chickpea seeds multiplied 10 days old inoculum kg^{-1} soil for maintaining 5% and 10% inoculum load, respectively. Twenty seeds were surface sterilized with 0.1% sodium hypo chloride and sown in plastic pots containing pre-sterilized soil (black cotton soil + sand @ 1:1) and respective inoculum for each set of temperature and relative humidity (%) was maintained in the environmental chamber. Plants germinated in inoculated pods were observed regularly for appearances of disease symptoms led to the wilting and final observations of wilted plants recorded when JG 62 (A susceptibile variety) showed 100% wilting in the experiment, wilt incidence calculated from all the treatments. The statistical analysis were done by plotting of disease incidence data against aerial temperature, relative humidity and inoculum load to predict the correlation between the factors.

RESULTS AND DISCUSSION

Development of chickpea wilts in relation to soil edaphic factors

The development of wilt incidence was studied in relation to soil temperature and soil moisture**.** The absolute wilt incidence was recorded every week and correlated with soil temperature and soil moisture. Correlation coefficient (r) value was computed for each parameter (Table 1).

During the experiments in 2014-15 considerable variations were observed in the mean of soil temperature and soil moisture %. The mean soil temperature and soil moisture (%) were in the range of 15.89-23.88°C and 11.05-13.37%, respectively (Fig 1). For this experiment, disease incidence of four chickpea cultivars was recorded and correlation coefficient with wilt incidence was calculated with soil temperature and soil moisture. Data presented in the Table 1 showed that all the four entries were showing

Table 1 Incidence of wilt on lines in relation to soil temperature and soil moisture

Date of observation	Wilt incidence (%)				Soil temperature (°C)	Soil moisture (%)
	JG 315	IGP 187	IGP 29	JG 62		
10-12-2014	0	1.33	3.08	15.38	21.43	12.48
17-12-2014	0	1.33	3.08	22.57	18.64	12.78
24-12-2014	0	1.33	3.08	30.77	17.50	13.03
31-12-2014	1.05	2.60	4.50	37.52	15.89	13.23
07-01-2015	1.22	4.00	6.15	43.15	16.09	13.37
14-01-2015	2.68	5.08	6.59	46.15	18.60	12.94
21-01-2015	3.66	6.67	7.69	46.96	17.84	12.02
28-01-2015	3.66	8.89	9.47	55.23	17.94	11.97
04-02-2015	3.66	10.67	10.77	61.54	20.30	11.82
11-02-2015	4.94	11.06	14.26	71.29	20.73	11.65
18-02-2015	6.1	12.00	18.46	84.62	23.36	11.15
25-02-2015	6.48	13.68	21.30	94.67	23.88	12.67
04-03-2015	7.32	14.67	23.08	100	20.76	11.05
Simple correlation coefficient (r) between soil temperature and disease incidence	0.6364*	0.6490*	0.7090*	0.6083*		
Simple correlation coefficient (r) between soil moisture % and disease incidence	-0.7514*	-0.7561*	-0.6981*	-0.6498*		
Multiple correlation coefficient ($r_{1.23}$)	0.7890*	0.7975*	0.7899*	0.7037*		

Significant at 5% level.

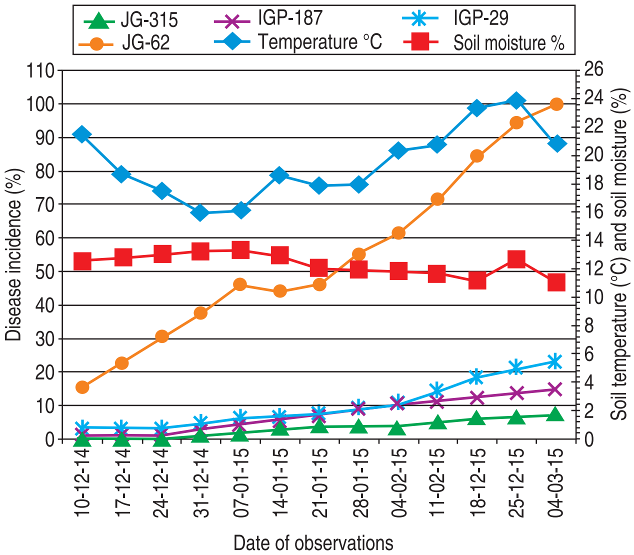

Fig 1 Wilt incidence in relation to soil temperature and soil moisture.

positive correlation with soil temperature. JG 315, IGP 187, IGP 29 and JG 62 showed positive correlation with "r" value 0.6364, 0.6490, 0.7090 and 0.6083 respectively. The regression equation showed that wilt incidence increased by 0.626% (JG 315), 0.334% (IGP 187), 0.255% (IGP 29) and 0.056% (JG 62) with the increase of 1°C soil temperature. Regression equation between wilt incidence (%) and soil temperature (°C) for entries JG 315, IGP 187, IGP 29 and JG 62 were y=0.626x + 17.49; y=0.334x + 17.06; y= 0.255x + 16.87 and y=0.056x + 16.35, respectively (Fig 2). Data presented in Table 1 shows negative correlation with soil moisture. JG 315, IGP 187, IGP 29 and JG 62 showed negative correlation with "r" value -0.7514, -0.7561, -0.6981 and -0.6498, respectively. The regression equation showed that wilt incidence decreased by 0.224% (JG 315), 0.118% (IGP 187), 0.076% (IGP 29) and 0.018% (JG 62) with the increase of 1% soil moisture. Regression equation between per cent wilt incidence and soil moisture (%) were y= -0.224x + 13.02 (JG 315); y= -0.118x + 13.16 (IGP 187); y= -0.076x + 13.09 (IGP 29) and y = -0.018x + 13.33 for JG 62 (Fig 3).

Combined effect of soil temperature and soil moisture on development of wilt

To compute the combined effect of soil temperature and soil moisture, multiple correlation, multiple regression line and Coefficient of determination (R^2) were calculated and multiple regression equation and coefficient of determination (R^2) between wilt incidence and soil moisture and soil temperature of entries JG 315, IGP 187, IGP 29 and JG 62. (Fig 2 and 3). Regression equation and coefficient of determination (R^2) were respectively calculated for each entry, *viz.* $y=21.008 + 0.303x_1 + -1.292x_2$ ($R^2 = 0.5470$); $y=40.435+0.608x_1 + -3.667x_2$ ($R^2 = 0.5632$); $y=33.991+1.270x_1 + -3.944x_2$ ($R^2 = 0.5488$); $y=180.98+3.519x_1 + -15.815x_2$ ($R^2 = 0.3942$); (x_1 denote for soil temperature and x_2 denote for soil moisture. All the four entries showed significant correlation with soil temperature and soil moisture. JG 315, IGP 187, IGP 29 and JG 62 showed multiple correlations with "$r_{1.23}$" value 0.7890, 0.7975, 0.7899 and 0.7037, respectively. The multiple regression equation showed that wilt incidence increased by 0.303 and 1.292% (JG 315), 0.608 and 3.944% (IGP 187), 1.270 and 3.944% (IGP 29) and 3.519 and 15.815% (JG 62) with the increase of 1°C soil temperature and decreases 1% soil moisture, respectively. Coefficient of determination (R^2) showed that both the factors contribute 54.70% (JG 315), 56.32%, (IGP 187), 54.88% and 39.42% in development of wilt.

Effect of aerial temperature and relative humidity (%) on chickpea wilt incidence

Pot experiment was carried out in environmental

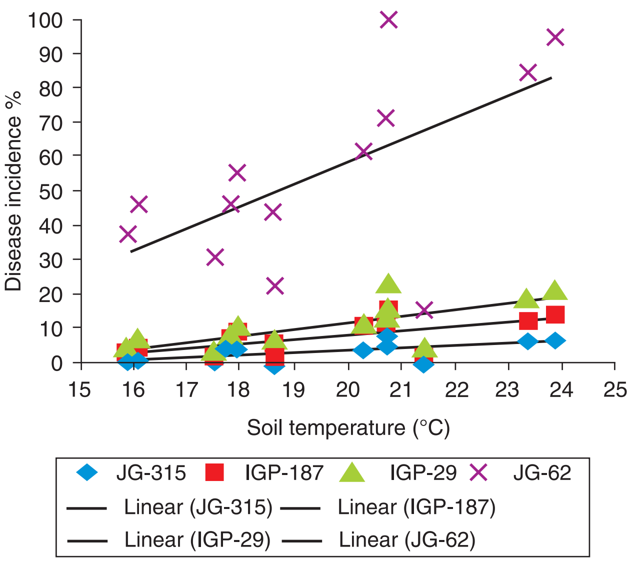

Fig 2 Regression line between disease incidence and soil temperature.

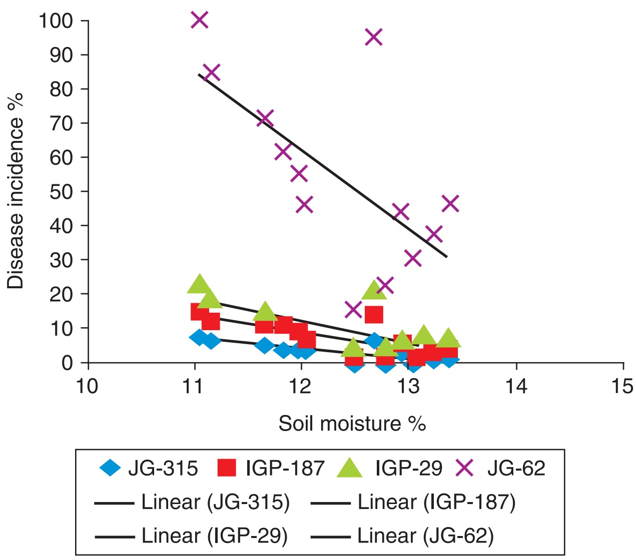

Fig 3 Regression line between disease incidence and soil moisture.

growth chamber with combination of three different levels of temperatures, viz. 20, 27 and 34°C, two different levels of relative humidity, viz. 60, 80% and two inocula load (5 and 10%) were evaluated.

Data presented in Table 2 revealed that air temperature, relative humidity and inoculum load were positively correlated with wilt incidence. Statistically significant positive correlation was found with aerial temperature (0.7226**) and inocula load (0.6435**) with wilt incidence, while relative humidity (0.1315) was found non-significant. Maximum disease incidence was recorded in combination-12 (10% inoculum load, 34°C temperature and 80% relative humidity), whereas minimum disease incidence was recorded in combination-1 (5% inoculum load, 20°C temperature and 60% relative humidity). Among the different combinations of aerial temperature and relative humidity, 34°C of aerial temperature along with 60% of relative humidity was found most suited combination for the development of wilt incidence in chickpea.

The temperature, inoculum load, relative humidity and interaction between temperature and inoculum load significantly influenced the disease incidence, while interaction between inoculum load and relative humidity, temperature and relative humidity, temperature, inoculum load and relative humidity were found non-significant. Among the inoculum load, maximum disease incidence was recorded in 10% inoculum (33.40%) load followed by 5% (20.36%) inoculum load. With respect to temperature maximum disease incidence was recorded at 34°C (36.65%) followed by 27°C (25.27%), while minimum disease incidence was recorded at 20°C (18.72%) (Table 3). Among relative humidity, maximum disease incidence (28.21) was recorded at 80%; however minimum disease incidence (25.55%) was recorded at 60% relative humidity.

Climate change not only affects plants but also affects the pest and pathogen (Anderson *et al.* 2004). The classical disease triangle recognizes the role of environmental and soil factors on the development of diseases of different crops. Abiotic factors, including soil moisture and temperature, may significantly influence development of Fusarium wilt of chickpeas (Navas-Cortés *et al.* 2000, Gupta *et al.* 2016). In particular, temperature may modify plant-pathogen interactions by affecting metabolic processes and development of the plants, as well as pathogen growth and virulence (Landa *et al.* 2004). Understanding the precise influence of temperature on Fusarium wilt of chickpea is important for management of the disease, e.g. through adjustment of sowing date and the use of host resistance (Landa *et al.* 2004).

In the present study, correlation between chickpea wilt disease incidence and edaphic factors on resistant to highly susceptible four lines revealed that there exist a significant strong correlation between disease incidence and soil temperature and soil moisture (%).All the four entries showed positive correlation with soil temperature, and negative correlation with soil moisture. With respect to soil temperature, JG 315, IGP 187, IGP 29 and JG 62 showed positive correlation with "r" values 0.6364, 0.6490, 0.7090 and 0.6083 respectively. With respect to soil moisture, JG 315, IGP 187, IGP 29 and JG 62 showed negative correlation with "r" values -0.7514, -0.7561, -0.6981 and -0.6498, respectively. Yasir *et al.* (2013) reported that maximum, minimum soil temperature and soil moisture were positively correlated with fusarium wilt disease incidence with "r"

Table 2 Effect of aerial temperature, relative humidity and inoculum load on incidence of chickpea wilt

Combination	Inoculum load (%)	Temperature (°C)	Relative humidity (%)	Disease incidence (%)
Combination-1	5	20	60	13.48
Combination-2	5	20	80	14.89
Combination-3	5	27	60	18.20
Combination-4	5	27	80	20.09
Combination-5	5	34	60	26.39
Combination-6	5	34	80	29.14
Combination-7	10	20	60	22.11
Combination-8	10	20	80	24.41
Combination-9	10	27	60	29.84
Combination-10	10	27	80	32.96
Combination-11	10	34	60	43.27
Combination-12	10	34	80	47.79
Correlation coefficient (r)	0.6435*	0.7226*	0.1315	

* Significant at 5% level.

Table 3 Effect of aerial temperature, relative humidity and inoculum load on wilt of chickpea

Name of level		Disease incidence (%)
Inoculum load (factor A)		
5%		20.36
10%		33.40
Temperature °C (factor B)		
20		18.72
27		25.27
35		36.65
Relative humidity % (factor C)		
60		25.55
80		28.21
Factors	SE(m) ±	CD (P=0.05)
Factor(A)	0.71	2.19
Factor(B)	0.87	2.69
Interaction A × B	1.23	3.80
Factor(C)	0.71	2.19
Interaction A × C	1.01	N/A
Interaction B × C	1.23	N/A
Interaction A × B × C	1.74	N/A

values of 0.65, 0.58 and 0.69 respectively on four resistant to susceptible lines/varieties. Mina and Dubey (2010) reported that soil moisture was positively and significantly correlated with wilt incidence. Chand and Khirbat (2009) in India and Westerland *et al.* (1974) in California also attributed variation in the *Fusarium* wilt severity to differences in temperature in soil.

To know the combined effect of soil temperature and soil moisture, multiple correlation, multiple regression line and coefficient of determination (R^2) were calculated for all the four lines. All the four entries showed significant correlation with soil temperature and soil moisture. JG 315, IGP 187, IGP 29 and JG 62 showed multiple correlation with "$r_{1.23}$" values 0.7890, 0.7975, 0.7899 and 0.7037, respectively. Coefficient of determination (R^2) showed that both the factors contributed 54.70% (JG 315), 56.32%, (IGP 187), 54.88% and 39.42% in development of wilt. Yasir *et al.* (2013) reported the contribution of maximum aerial temperature was explained by linear regression which showed 90-99% variability in disease development on four highly susceptible lines during the both years of investigations, while minimum air temperature showed 83-99% contribution in the disease development. Linear regression for soil temperature and soil moisture contributed 79-96% and 90-99% influence on disease development.

Pot experiment was carried out in environmental growth chamber with combination of three different levels of temperatures, viz. 20, 27 and 34°C, two different levels of relative humidity, viz. 60, 80% and two inoculum loads (5 and 10%) were evaluated to find out the influence of combination of temperatures, relative humidity and inoculum load on disease incidence of chickpea wilt. All the three factors, viz. air temperature, relative humidity and inoculum load had positive correlation with wilt incidence. Perhaps among the different combinations of aerial temperature and relative humidity, 34°C of aerial temperature along with 60% of relative humidity was the most suited combination for development of wilt incidence in chickpea. Among the inoculum load, maximum disease incidence was recorded in 10% inoculum load followed by 5% inoculum load. With respect to temperature maximum disease incidence was recorded at 34°C followed by 27°C. Among relative humidity, maximum disease incidence was recorded at 80%. Mina and Dubey (2010) reported maximum ambient and soil temperature were positively and significantly correlated with wilt incidence of Pusa 212. Landa *et al.* (2006) reported Ayala chickpea cultivar was moderately resistant to *F. oxysporium* f. sp. *ciceri* when grown in temperature regime of 21-24°C, but highly susceptible at a temperature regime of 25-27°C. The underlying mechanism of the effect of temperature on increased susceptibility of resistant cultivars to diseases is not clear. Several studies have described cellular and biochemical changes induced by high temperatures in plants, which suggested that high temperatures (22-30°C) could alter products of a virulence or resistance genes, their interactions, later steps in the resistance response, or the ability of the pathogen to overcome certain types of host resistance (Prabhavathi and Rajam, 2007).

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