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CORRELATION BETWEEN HUMID THERMAL RATIO AND EPIDEMICS OF CERCOSPORA LEAF SPOT OF PEANUT IN POTHWAR

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Abstract

The epidemic of *Cercospora* leaf spot (CLS) frequently led to yield losses on unsprayed peanuts in Pakistan. During 3 successive years of field trials under medium rainfall conditions of Pothwar at Chakwal, it was observed that CLS incidence epidemic differed significantly during crop seasons. Genotypes exhibited significantly different disease response to CLS incidence provided suitable environmental conditions prevailed during crop growth cycle. Among crop seasons, year 2003 was most conducive due to frequent and early rains making humid thermal ratio (HTR) quite favorable for most of the time for disease initiation and development resulting in higher values of AUDPCs and incidence. Six fortnights from July to September were the most critical and risky for crop as the HTR values 2.01 to 3.84 are most likely conducive for significant increase in CLS incidence.

Introduction

Peanut in Pakistan is mostly cultivated in Chakwal, Attock, Rawalpindi and Jhelum Districts, where it is grown under natural precipitation and crop is susceptible to a number of fungal diseases such as *Cercospora* leaf spot, *Alternaria* leaf spot, Anthracnose (*Colletotrichum* spp.), Pepper spot and leaf scorch (*Leptosphaerulina crassiasca* (Rostr.) Pet, *Phyllosticta* leaf spot, Scab (*Sphaceloma arachidis* Bitt & Jenk), Crown rot (*Aspergillus niger* Tiegh), *Fusarium* diseases, Charcoal rot (*Macrophomina phaseolina* Tassi) Goidanich, *Rhizoctonia* diseases, Black hull (*Chalara elegans* Nag Raj & Kendrick*)*, *Sclerotinia* blight and *Verticillum* wilt are common in occurrence in Pakistan and other parts of world (Kokalis-Burelle *et al*., 1997; Rasheed *et al*., 2004; Hassan & Shahzad, 2004).

Although the yield of peanut in Pakistan is quite comparable with the worlds average yields obtained in USA, Egypt and China (Anon., 2004), yield may be enhanced from 33% to 119% with appropriate improvements in the disease management (Yaqoob *et al*., 1989). When fungicide was applied at 14 day interval after initiation of *Cercospora* leaf spot, a pod yield of 3500 kg/ha was achieved at Barani Agricultural Research Institute, Chakwal (Anon., 1992).

Among foliar diseases epidemic of *Cercospora* leaf spot (CLS), the most important disease of peanut, frequently led to yield losses of 10-35% on unsprayed peanuts in Pakistan (Anon., 1992). Peanut, in this region of the world, is cultivated in post spring end of March to first half of April or early monsoon with first shower of monsoon in June. When enough precipitation of monsoon rains makes a film of water on leaves or a relative humidity more than 90% prevails with a temperature of 20 to 29^{0}C for six to seven days, peanut crop is severely affected by Tikka disease (*Cercospora* leaf spot) (Chohan, 1974).

Disease incidence and severity may vary depending on prevailing climatic conditions. Intermittent rains from flowering to pod development stage of the crop favours the infection and development of foliar diseases (Pande *et al*., 2000). Maximum temperature range of 31 to 35^{o}C and minimum temperature range of 18 to 23^{o}C favors *Cercospora* leaf spot out break on peanut (Vankatraman & Kazi, 1979). The influence of climatic elements like temperature and relative humidity on development of *Cercospora* leaf spot of peanut have extensively been studied (Jensen & Boyle, 1965; Vale & Zambolim, 1996; Wu *et al*., 1999). A model was developed by taking in consideration the relative humidity more than 95% and minimum temperature of 22^{o}C and maximum 30^{o}C. This model was used or compared with calendar-based schedule in America (Smith, 1986) Argentina (Pezzopane *et al*., 1998) and Brazil (Moraes *et al*., 1997).

Similar approaches have been used for forecasting the incidence of other host pathogen systems. Correlations between *Ascochyta* blight of gram and maximum temperature, relative humidity and a ratio (humid thermal ratio or HTR) of these two variables identified better agreement between predicted and observed disease incidence values (Jhorar *et al*., 1997). Higher HTR were values observed when maximum temperature was less than 22^{o}C, a condition where progress of *Ascochyta* blight of gram was limited by temperature. Similarly less disease progress was observed at lower HTR values at temperature more than 27^{o}C (Riaz, 2006).

Despite an exhaustive research work available on *Cercospora* leaf spot in different parts of the world, knowledge about pattern of disease progress under rainfed conditions of Pothwar is lacking. The present study was planned with the objective to develop a model for disease development and its forecasting system under rainfed conditions of Pothwar.

Material and Methods

Experiment layout: Field experiments containing 9 genotypes viz., Chakori, SP 96 (Swat phalli), BARI-2000, SP-2000 (Fakhar-e-Swat), Golden, 01CG009, 2KCG005, 2KCG007 and 2KCG020 were sown on April 17, 2003, April 24, 2004 and March 31st, 2005 at Barani Agricultural Research Institute Chakwal. The experiments

were laid out in randomized complete block design with three replications.

Inoculum development: Crops were rotated in the experimental field with wheat- sorghum fodder- winter fallow-peanut during 2003, peanut-winter fallow-peanut during 2004 and Green gram/black gram-winter fallow-peanut during 2005. All the fields were deep ploughed at advent of winter in all the years. Seedbed preparations were done by tractor driven cultivator. Experimental fields were fertilized at 20-80-0 kilogram NPK per hectare. Sowing was done in 5m x1.8m plot with 45cm row to row and 15 cm plant to plant distance with single row hand drill. CLS of peanut is regular in occurrence in peanut fields of rainfed region and especially at Barani Agricultural Research Institute Chakwal. Previous years *Cercospora* infected leaves (about 2 kg dry weight) kept under room temperature in craft paper bags were spread in the experimental plots after sowing (Zhang *et al.,* 2001).

Disease data recording: Observations on disease incidence were initiated 35 days after sowing. Data were recorded bi-weekly after onset of disease in any of the test plot. During 2003 ten plants per plot and during rest of the years 5 plants per plot were tagged for disease observations. Disease infection percent were recorded according to Davis *et al*., (1993). For defoliation data, each time before starting disease assessment on leaves, empty nodes were counted carefully and were considered as defoliated leaves.

Disease incidence values were computed as:

$$\text{Disease incidence} = \frac{\text{(Number of empty nodes+ Diseased leaves)}}{\text{(Number of total leaves+ Number of empty nodes)}} \text{ X } 100$$

Disease progress curve (AUDPC): Area under disease progress curve (AUDPC) was calculated for disease incidence according to Shaner & Finney (1977).

$$AUDPC = \sum [(Y_{i+1} + Yi) /2] (X_{i+1} - Xi)$$

In which Y_i = Infection percent at the *ith* observation and X_i = the date of the *ith* assessment in days after initiation of disease.

Environmental data: Weather data consisting of maximum and minimum air temperature, rainfall (mm), relative humidity and pan evaporation were obtained from Soil and Water Conservation Research Institute about 500 m away from the experimental fields. Averages of all above variables from 10 to 15 days before date of disease observation were calculated. Maximum relative air humidity (on any of the day from 10 to 15 days before disease observation) was used separately. Disease incidence data were recorded up to one month before crop harvest. Collected data were statistically analyzed using analysis of variance technique (Montgomery, 2001) and correlation matrix was constructed by using Statisca 9.6.

Results and Discussion

AUDPC for genotype resistance: The genotype 01CG009 gave the maximum and 2KCG020 the minimum AUDPC values while rest of the genotypes fall between these two (Fig. 1). Years, standard meteorological fortnights (SMF), genotypes and interaction of SMF x years have significant impact on CLS infection percentage. Year x genotype, genotypes x SMF and Year x SMF x genotypes interactions were statistically non significant.

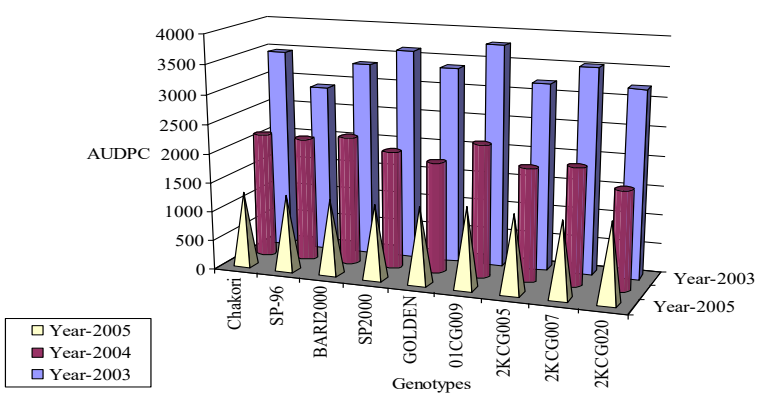

Fig. 1. AUDPC of CLS on peanut genotypes during 2003, 2004 and 2005.

During 2003 disease initiated at the same time on all genotypes. The genotypes 01CG009 and SP-2000 exhibited more than 1% disease while in rest of the genotypes it remained in traces before monsoon. Disease in all genotypes increased simultaneously. During 2004 disease initiated in the last week of June on all genotypes, though remained at low pace. In first week of August (3rd SMF) the maximum infection percentage was recorded on 01CG009 (10.5%) and BARI-2000 (10.01%). At later stages of disease development all genotypes approximately indicated the same level of disease incidence. During 2005 disease initiated early in the season when there were rains in month of April. The disease incidence decreased by degrees to a level of zero on SP-2000, 2KCG005, 2KCG007 and 2KCG020, in rest of the tested genotypes disease decreased to traces.- With the onset of monsoon in first week of July (2nd SMF) disease again started to increase. Disease incidence at terminal stage (near harvesting) remained lower than the previous years (data not in tabulated form).

Fortnightly weather variables of three years indicated that all environmental conditions remained at par among years but these weather variables changed reasonably during the disease and crop development period (Table 1).

Table 1. Environmental conditions at standard meteorological fortnights for CLS of peanut.

SMF	Temp. ºC (max)	Temp. ºC (mini)	Rainfall (mm)	RH% (max)
1st	37.65	24.93	15	50
2nd	35.8	24.23	52.4	81
3rd	34.14	24.24	53.6	85
4th	33	23.96	130.1	84
5th	34.3	23.66	61	84.5
6th	32.33	23.05	41.6	88.5
Year 2003	**34.54**	**24.01**	**58.95**	**78.83**
1st	37.5	23.08	39.1	84.5
2nd	35.9	21.92	87.2	76.5
3rd	35.8	25.01	42.9	63.5
4th	37.8	24.21	4.4	71.5
5th	33.91	23.56	105.9	84
6th	33.73	23.2	63.2	83.5
Year 2004	**35.77**	**23.50**	**57.12**	**77.25**
1st	39.21	23.06	32.5	70
2nd	37.25	25.86	59.6	84
3rd	33.75	24.64	41.7	90.5
4th	35.11	25.02	39.5	87.5
5th	34.02	24.06	59.3	90
6th	34.06	23.24	31.4	89
Year 2005	**35.57**	**24.31**	**44.00**	**85.17**
LSD(0.05)	2.42	1.16	38.64	13.03
LSD(0.01)	3.34	1.60	53.43	18.01

Correlation between disease incidence and weather variables

Temperature (max. & min.): It had consistent negative correlation with infection percentage in all genotypes during three years. There was a strong negative (prob. 0.05) correlation between mean diseases incidence of each genotype over years and mean infection percentage of all genotypes and all years. Minimum temperature had week negative correlation with infection percentage in all years and with all genotypes (Tables 2, 3 and 4).

Table 2. Correlation matrixes of environmental variables, and CLS infection percentage in nine peanut genotypes during crop season of 2003.

	Temp. ºC (max)[1]	Temp. ºC (min)[2]	RFall[3]	ARH[4]	MRH[5]
Chakori	-0.757	-0.214	0.454	0.769	0.765
	0.081	0.684	0.366	0.074	0.076
Sp-96	-0.899	-0.284	0.298	0.861	0.827
	0.015	0.586	0.566	0.028	0.042
BARI-2000	-0.773	-0.106	0.434	0.798	0.766
	0.071	0.842	0.390	0.057	0.076
SP-2000	-0.782	-0.095	0.462	0.807	0.773
	0.066	0.859	0.356	0.052	0.071
Golden	-0.769	-0.112	0.272	0.787	0.741
	0.074	0.833	0.602	0.063	0.092
01CG009	-0.820	-0.230	0.434	0.835	0.840
	0.046	0.661	0.390	0.039	0.036
2KCG005	-0.778	-0.226	0.333	0.776	0.753
	0.068	0.667	0.520	0.070	0.084
2KCG007	-0.770	-0.189	0.448	0.789	0.783
	0.073	0.721	0.373	0.062	0.066
2KCG020	-0.800	-0.188	0.491	0.812	0.802
	0.056	0.721	0.323	0.050	0.055

Cell contents pearson correlation coefficient in every first row against the genotype. Probability value in every second row against the genotype. 1. Temperature (maximum) ºC, 2. Temperature (minimum) ºC, 3. Rainfall (mm), 4. Relative humidity % (average), 5. Relative humidity % (maximum)

Rainfall: It had consistently positive but week correlation with disease incidence. Mean fortnightly rainfall in 2005 was less than 2003 and 2004. Rainfall, although, had a week correlation with disease incidence but its effect was evident from the less mean infection percentage in 2005 due to lesser rain than in 2003 and 2004.

Relative humidity: Relative humidity average of 5 days from 10 to 15 days before disease recording has significant (Prob. 10%) correlation with infection percentage during 2003. It was significant at 20% probability level in 2004 and 2005. Maximum relative air humidity at any of day from 10th to 15th day before disease observation has consistent positive strong (Prob. 0.10)

correlation with infection percentage in 9 genotypes in all three years separately (Tables 2, 3 & 4). Correlation was stronger with mean infection percentage in genotypes and years at probability level of 0.05 (Tables 5 & 6).

Effect of humid thermal ratio (HTR): The three year study revealed that relative air humidity (maximum) and temperature (minimum and maximum) are highly and consistently correlated with CLS infection percentage than other variables like relative air humidity (average) and rainfall so these variables were selected as most highly correlated weather variables for further processing. Since both variables, relative humidity and temperature were significantly correlated with each other separate slopes of disease incidence couldn't be calculated and they could not be combined in bi-variate regression model because of multi-co-linearity effects. To overcome this problem a ratio of relatively humidity (maximum), with mean maximum and mean minimum temperature were calculated. These two ratios are referred as humid thermal ratios. Regression models of all genotypes based on HTRs showed that temperature and relative humidity effects are highly significant but mutually dependent. Among HTR of relative humidity maximum with temperature minimum, and relative humidity maximum with temperature maximum, aforesaid ratio describes the disease incidence better than later one.

Table 3. Correlation matrixes of environmental variables, and CLS infection percentage in nine peanut genotypes during crop season of 2004.

	Temp. ^{o}C (max)[1]	Temp. ^{o}C (min)[2]	RFall[3]	ARH[4]	MRH[5]
Chakori	-0.797	-0.635	0.245	0.713	0.776
	0.057	0.176	0.640	0.111	0.069
Sp-96	-0.763	-0.602	0.373	0.692	0.767
	0.078	0.206	0.466	0.128	0.075
BARI-2000	-0.809	-0.580	0.289	0.734	0.784
	0.051	0.228	0.578	0.097	0.065
SP-2000	-0.781	-0.619	0.253	0.703	0.763
	0.066	0.190	0.628	0.119	0.077
Golden	-0.760	-0.660	0.174	0.673	0.738
	0.079	0.154	0.741	0.143	0.094
01CG009	-0.800	-0.557	0.235	0.733	0.776
	0.056	0.251	0.654	0.097	0.070
2KCG005	-0.789	-0.621	0.311	0.707	0.774
	0.062	0.188	0.548	0.116	0.071
2KCG007	-0.767	-0.676	0.267	0.676	0.754
	0.075	0.141	0.609	0.141	0.083
2KCG020	-0.764	-0.694	0.198	0.666	0.740
	0.077	0.126	0.707	0.149	0.092

Cell contents pearson correlation coefficient in every first row against the genotype. Probability value in every second row against the genotype. 1. Temperature (maximum) ^{o}C, 2. Temperature (minimum) ^{o}C, 3. Rainfall (mm), 4. Relative humidity % (average), 5. Relative humidity % (maximum)

Table 4. Correlation matrixes of environmental variables, and CLS infection percentage in nine peanut genotypes during crop season of 2005.

	Temp. ^{o}C (max)[1]	Temp. ^{o}C (min)[2]	RFall[3]	ARH[4]	MRH[5]
Chakori	-0.735	-0.731	0.216	0.636	0.729
	0.096	0.099	0.681	0.174	0.100
Sp-96	-0.735	-0.732	0.222	0.635	0.729
	0.096	0.098	0.673	0.175	0.100
BARI-2000	-0.733	-0.731	0.236	0.635	0.730
	0.097	0.099	0.652	0.176	0.099
SP-2000	-0.735	-0.732	0.224	0.635	0.729
	0.096	0.098	0.670	0.175	0.100
Golden	-0.736	-0.725	0.241	0.639	0.733
	0.095	0.103	0.645	0.172	0.097
01CG009	-0.734	-0.731	0.218	0.635	0.728
	0.097	0.099	0.678	0.175	0.101
2KCG005	-0.735	-0.725	0.248	0.638	0.733
	0.096	0.103	0.635	0.173	0.097
2KCG007	-0.735	-0.733	0.217	0.635	0.728
	0.096	0.097	0.679	0.176	0.101
2KCG020	-0.732	-0.737	0.209	0.632	0.725
	0.098	0.095	0.691	0.178	0.103

Cell contents pearson correlation coefficient in every first row against the genotype. Probability value in every second row against the genotype. 1. Temperature (maximum) ^{o}C, 2. Temperature (minimum) ^{o}C, 3. Rainfall (mm), 4. Relative humidity % (average), 5. Relative humidity % (maximum)

Table 5. Correlation matrixes of mean environmental variables with mean CLS incidence on peanut during 2003, 04 and 2005.

Statistic	Temp (max)	Temp (min)	Rfall	ARH	MRH
r	-0.828	-0.497	0.339	0.778	0.818
p	0.042	0.031	0.511	0.069	0.047

Table 6. Correlation matrix of HTR Based on temperature (maximum and minimum) and relative humidity maximum (2003-05).

	Temp. (max)	MRH	MRH/ Temp (max)	Temp (min)	MRH/ Temp (min)
Chakori	-0.815	0.81	0.843	-0.496	0.871
	0.048	0.051	0.035	0.317	0.024
SP-96	-0.841	0.818	0.86	-0.529	0.886
	0.036	0.047	0.028	0.281	0.019
BARI-2000	-0.833	0.821	0.855	-0.45	0.87
	0.04	0.045	0.03	0.371	0.024
SP-2000	-0.828	0.818	0.852	-0.453	0.868
	0.042	0.047	0.031	0.367	0.025
Golden	-0.821	0.802	0.84	-0.49	0.864
	0.045	0.055	0.036	0.324	0.027
01CG009	-0.831	0.83	0.86	-0.479	0.886
	0.041	0.041	0.028	0.336	0.019
2KCG005	-0.82	0.806	0.843	-0.501	0.868
	0.045	0.053	0.035	0.311	0.025
2KCG007	-0.815	0.815	0.848	-0.52	0.882
	0.048	0.048	0.033	0.29	0.02
2KCG020	-0.823	0.815	0.851	-0.533	0.884
	0.044	0.048	0.032	0.277	0.019

CLS predictions based on HTR regression models were significant (p=0.03 to 0.06) and describe disease forecast 80-94% in susceptible genotypes and 64-93% in partially resistant genotypes during 2003, 2004 and 2005 (Table 7) The genotypes with partial resistance showed variable results during three years and 01CG009 a highly susceptible genotype showed significant epidemics through out study period such results have been reported by Shew *et al*., (1988) where genotypes with partial resistance to late leaf spot proved most sensitive to high temperatures. CLS incidence reduced to zero during months of May and June in our studies which may be due to conditions of high temperature, under which dew or rain evaporates quickly and humidity declined rapidly, thus delayed spore germination and resultantly infection (Jenkins, 1938; Firdous *et al.*, 2009; Iftikhar *et al.*, 2009).

Table 7. Regression coefficients, and R^2 values for simple regression in intercept less equations, of observed CLS infection percentage on highly susceptible and highly resistant genotypes for models based on single weather variable HTR assessed during six SMF in peanut growing season of 2003, 2004 and 2005.

Year	Genotype	Regression coefficient	R^2	Probability
2003	01CG009	15.35	0.94	0.03
	SP-96	9.61	0.93	0.04
2004	01CG009	11.65	0.80	0.05
	2KCG020	5.63	0.67	0.06
2005	01CG009	9.68	0.82	0.06
	Chakori	5.05	0.64	0.05
2003 to 2005	Mean of highly susceptible genotype	12.17	0.89	0.05
2003 to 2005	Mean of all genotypes except highly susceptible genotype	9.75	0.81	0.05

A slight reduction in average minimum and maximum temperature with augmentation in relative humidity due to considerable rainfall created conducive environment for disease initiation and development (Suleiman & Agashe, 1965). Wangikar & Shukla (1977) like our studies reported a negative correlation between CLS incidence and mean temperature when disease remained on increasing after 40th week while temperature decreased by degrees from 27^{o}C to 20^{o}C. Jensen & Boyle (1965) reported that high relative humidity was most favorable for leaf spot development. High ambient humidity would imply that humidity within canopy when leaves are transpiring would be near 100 at leaf surface. This relative humidity near 100 in leaf canopy did not represent air humidity ≈ 1.2m above ground level used in our studies so air relative humidity would definitely be in low range than in leaf canopy. Correlation between mean maximum air relative humidity and mean minimum temperature represented the night time temperature and dew period at night. Such inferences were drawn by Rizvi & Nutter (1993) in *Uromyces striatus* J., and *Medicago sativa* L., host pathogen relationship. Maximum infections

occurred at 20°C and with increase in temperature to 28°C and above a very few infections took place (Shew *et al*., 1988). Positive correlations between mean values of infection percentage and weather variables and their significant regressions, those described CLS dynamic 81 to 89% in our studies, are in line with the earlier studies where number of infections on all genotypes reduced with reduction in daily high relative humidity periods less than 12 hour (Wu *et al*., 1999) and maximum spore germination occurred at 82-85% RH for 48 hours (Alderman & Buete, 1986).

It may be concluded that by taking into consideration the regression coefficient, coefficient of correlation and probability values, function of HTR relating to CLS incidence explains an efficient model for disease prediction. This HTR function may be used from end of the first SMF as source for advice of fungicide application to manage CLS of peanut.

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