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Analysis of spread of Phytophthora foot rot disease of black pepper by STCLASS - software*

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ABSTRACT: Phytophthora foot rot of black pepper *(Piper nigrum* L.) caused by *P. capsici* is severe during the wet monsoon season. The pattern of spread was studied and analyzed using STCLASS computer software. The pattern of spread was non-random and the initially infected vines served as source and focus of secondary spread.

Key words: Black pepper, Phytophthora foot rot, pattern of spread, spatio-temporal distance class

Black pepper *(Piper nigrum* L.) is one of the export oriented spice crops of India. Crop losses due to Phytophthora foot rot are recognized as one of the major causes for the low productivity in India (Sarma and Anandaraj 1997). The fungus infects all parts of the vine and expression of symptoms depends upon the site of infection and extent of damage (Anandaraj, 1997). Infection on the collar is fatal. This occurs either through the runner shoots or roots. Root infection which culminate in foot rot takes a longer incubation time and often shows declining symptoms. The occurrence of this disease was monitored over a period of time and the pattern of spread was studied using STCLASS (Spatio temporal distance class) computer software (Nelson 1995a, 1995b).

MATERIALS AND METHODS

Spatio-temporal distance class analysis

In the spatio-temporal distance class analysis the randomness of newly diseased plants from one assessment date to the next is evaluated and quantified from the data obtained from a regularly spaced lattice of rows and columns. If 'm' is the diseased units on first observation, 'n' is the diseased units on second observation, it is assumed that 'n' diseased units are distributed randomly within the lattice. If this is rejected, attributes of non-random pattern can be described by the statistical comparison of observed lattice with computer generated "expected" patterns. A minimum of 400 expected maps are generated for each of observed data set. The tabulation begins at one corner of the observed lattice, termed as 'reference unit 1' and assigned a X,Y coordinate. Each of the remaining (m + n) - 1 diseased units within a lattice are also mapped. The XY distance separation between each of the (m + n) - 1 diseased units and reference units are calculated for all the infected units. This is repeated till each of the m + n diseased units are used as a reference unit. The observed count frequency for each distance class is standardised by the total number of possible unit pairs in each respective distance class. The standardised count frequency (SCF) values for distance classes from each of the 400 expected patterns are calculated similarly. Significance of the observed SCF for each XY distance class is determined by calculating per cent of times it exceeds or is exceeded by the 400 expected patterns of SCFs tabulated for the same distance class. If observed SCFs exceeds expected SCF values > 95% of times, it is decreed significantly greater than expected (Probability, P=0.05). More diseased unit pairs are separated by that X, Y distance that would be expected with a random occurrence of newly diseased units. Similarly when the value of SCF exceeds the expected pattern value < 5% of the + time, the SCF is deemed to be significantly less than expected (P=0.05). These are plotted in the XY lattices and the results of the analysis are printed (Gray *et.al.,* 1986; Nelson 1995a, 1995b).

Analysis of Phytophthora foot rot disease

Observations on foot rot disease incidence were recorded on 6 year old black pepper cv. *Karimunda* vines which were trailed on *Garuga pinnata* standards

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Fig. 1. Distribution class matrix showing the observed positions of disease on observations 1 and 3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	+	+	+	-	-	+	+	+	D	+	D	+	D	D	D	+	D	-	-	-	+	+	-	-	-	-
2	+	D	D	-	+	+	+	+	+	+	-	D	+	+	+	+	+	+	-	D	-	-	-	-	-	-
3	-	+	-	D	+	+	+	+	+	+	D	+	-	D	+	-	+	-	+	-	-	-	-	-	-	-
4	-	-	-	+	-	+	D	D	D	+	D	+	+	+	+	-	-	-	+	+	-	-	-	-	-	-
5	+	+	+	+	-	+	+	+	+	+	+	D	+	+	+	-	+	-	-	-	+	-	-	-	-	-
6	+	+	+	-	-	+	+	D	D	-	-	D	-	+	-	-	+	-	+	-	-	-	-	-	-	-
7	-	-	-	+	-	+	-	-	+	+	+	+	+	+	+	-	+	+	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	+	+	+	-	D	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	D	D	+	+	-	-	+	+	+	-	-	-	-	-	-
10	-	-	-	-	-	-	+	-	-	-	-	-	-	+	+	-	+	-	D	-	-	+	-	-	-	-
11	-	-	-	-	-	+	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	D	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

- = Healthy plant, D = Infected plants on day 1

+ = Newly infected plants between observations 1 and 3

planted in a rectangular plot at a spacing of 3 x 3m at the experimental farm of Indian Institute of Spices Research, Peruvannamuzhi. Disease incidence was recorded at fortnightly intervals for a period of two years. Although the plot had a population of over 400 vines, for analysis, data from 15 rows and 26 columns were used. The plants were marked as diseased if symptoms such as foliar yellowing and defoliation were noticed. The data on disease incidence was converted into numerical values namely, 1, 2 and 3 which indicated healthy, diseased and missing plants respectively and the initial occurrence and subsequent spread were analyzed using the STCLASS computer software developed by Nelson (1995a, 1995b).

A pair of infected plants with in the lattice are identified and assigned to a (X,Y) distance class. The standardised count frequency (SCF) is the number of pairs of infected plants occurring within each X,Y distance class divided by the total number of living plants occurring within the same distance class. It is the frequency of occurrence of pairs of infected plants in that distance class relative to the number of pairs of infected plants in all other distance class in the lattice. In a spatio temporal distance class analysis the observed SCFs in each X,Y distance class are compared to the expected SCFs determined when the same number of infected plants are randomly assigned locations within a lattice of the same dimensions.

RESULTS AND DISCUSSION

Biological organisms are reported to be constantly associated in a spatial framework in a continuum of a high degree of aggregation to high degree of regularity, which is determined by physical, biological and environmental influences. Spatial analysis provides quantitative information on the cultural, biological and environmental factors on the population dynamics of soil borne pathogens and root disease development (Campbell and Noe 1985). The spatial distribution pattern and its interpretation would help in understanding the process by which a pathogen is distributed in the field and the development of disease. To test the distribution of a soilborne disease and to analyze whether the disease occurs in a random or a clustered pattern several computer programmes and software packages have been developed for the personal computer.

The distance class may be defined as the distance between two infected plants and is obtained from the absolute value difference between their X and Y values. Evaluation and quantification of the randomness of the increase in newly diseased plants from one assessment date to another was done using STCLASS computer software (Nelson 1995a, 1995b). The plants were in a rectangular plot with 15 rows (horizontal X) and 26 columns (vertical Y) representing 390 matrix positions. The two dimensional distance classes 'X Y' refers to absolute distance between plants within a pair. The distance between two infected plants is obtained from the absolute value differences between their X and Y values. The number of pairs of infected plants observed in each (X, Y) distance class are directly compared to expected values obtained from plots contain-

Fig. 2. STCLASS analysis map for observations 1 and 3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	$	$	$	$	$	$	$	$	$	$	-
2	+	+	+	+	+	+	+	+	+	+	+	+	-	-	$	$	$	$	$	$	$	$	$	$	$	-
3	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	$	$	$	$	$	$	$	$	$	$	-
4	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	$	$	$	$	$	$	$	$	$	$	-
5	+	+	+	+	+	+	+	+	+	-	+	-	-	-	-	$	$	$	$	$	$	$	$	$	$	-
6	+	+	+	+	+	+	+	+	+	-	-	-	-	-	$	$	$	$	$	$	$	$	$	$	$	-
7	-	+	+	+	+	+	+	-	-	-	-	-	$	$	$	$	$	$	$	$	$	$	$	$	$	-
8	-	-	-	-	-	-	-	-	-	-	-	$	$	-	$	$	$	$	$	$	$	$	$	$	$	-
9	$	$	-	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	-
10	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	-	-
11	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	-	-
12	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	-	-	-
13	$	$	$	$	$	$	$	$	$	$	$	-	$	$	$	-	$	-	$	-	-	-	-	-	-	-
14	$	$	$	$	$	$	$	$	$	$	-	-	-	$	$	-	-	-	$	-	-	-	-	-	-	-
15	-	$	$	$	-	$	$	$	-	$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

+ = SCF Significantly greater than expected: (P <=0.05)
$ = SCF Significantly less than expected: (P >= 0.95)
- = SCF not significant

Edge effect and other observations
Number of distance classes with SCFs greater than expected : 72
Number of distance classes with SCFs fewer than expected : 219
Strongly non random data set — Proportion of significant SCFs > = 0.08
Number of distance classes with SCFs greater than expected at the edges of the distance class matrix=0
Significant edge effect not detected

Total number of positions in matrix = 390
Number of vacancies (missing values) = 0
Number of infected plants = 128
Number of newly infected plants = 102
Percentage of newly infected pairs = 28%
Number of healthy plants = 262

ing the same number of randomly distributed infected plants and their test statistics generated by computer simulation. Pair of infected plants within the lattice are identified and assigned to a (X, Y) distance class (Gray *et.al.* 1986). Statistical comparison of observed lattice with computer generated expected patterns were mapped in a distance class matrix. The disease incidence on the first and third dates of observation is presented in Fig. 1. Standardized count frequency (SCF) for each observed (X, Y) distance class is obtained by tabulation of number of times that diseased units are separated by a given (X, Y) distance. The total number of (X, Y) distance class equals the (row x colunm) dimensions of the observed lattice. Significance of the observed SCF for each X, Y distance class is determined by calculating per cent of times it exceeds or is exceeded by the 400 expected patterns of SCFS, tabulated for the same distance class. The STCLASS matrix showing the SCFs for observation 1 and 3 are presented in Fig 2. The 2DCLASS matrix for the 3 observation is presented in Fig 3. The distance class matrix for STCLASS and 2DCLASS is presented in Fig 4. The initial occurrence and subsequent spread has shown a non-random occurrence, and the diseased plants were clustered together.

In black pepper the soil inoculum was reported to be around the base of the infected vines and the populations tend to decrease from the distance and depth of the infected vine (Ramachandran *et al.,* 1986; Kueh and Khew 1982). It is reported, based on artificial inoculation of black pepper vines under simulated field conditions that, when root infections occur, the occurrence of aerial symptoms such as foliar yellowing and defoliation are delayed till a considerable portion of roots are damaged (Anandaraj *et al.,* 1991, 1994). The spatial pattern analyses for the initial occurrence and subsequent spread for 3 observations show that the disease occurs non-randomly. Before the appearance of symptoms the infected roots must be adding inoculum into the soil, which continue the process of re-infections in the soil (Neher and Duniway 1991). Besides active movement of a pathogen, passive spread by soil water and other methods such as root contacts must be adding to new foci of infection. During the peak monsoon season the soil is saturated which is ideal for *Phytophthora* for sporangiogenesis and liberation of zoospores. This study indicates that spatial pattern of spread of the disease follows a distinctly non-random pattern and previously affected vines are

Fig. 3. 2DCLASS analysis for observation 3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	$	$	$	$	$	$	$	$	$	-
2	+	+	+	+	+	+	+	+	+	+	+	+	-	-	$	$	$	$	$	$	$	$	$	$	$	-
3	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	$	$	$	$	$	$	$	$	$	$	-
4	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	$	$	$	$	$	$	$	$	$	$	-
5	+	+	+	+	+	+	+	+	+	+	-	+	-	-	-	-	-	$	$	$	$	$	$	$	-	-
6	+	+	+	+	+	+	+	+	+	-	-	-	-	-	$	$	$	$	$	$	$	$	$	$	$	-
7	-	-	+	+	+	+	+	-	-	-	-	-	$	$	$	$	$	$	$	$	$	$	$	$	-	-
8	-	-	-	-	-	-	-	-	-	-	$	$	$	-	$	$	$	$	$	$	$	$	$	$	-	-
9	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	-	$	$	-	-
10	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	-	$	$	-	-
11	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	-	-	-
12	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	-	-	-
13	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	-	-	-	$	$	$	-	-	-	-	-
14	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	-	-	-	$	-	-	-	-	-	-	-
15	$	$	$	$	$	$	$	$	$	$	$	$	$	$	-	-	-	-	-	-	-	-	-	-	-	-

+ = SCF Significantly greater than expected (P < = 0.5%)

$ = SCF Significantly less than expected =(P >= 0.95)

- = SCF not significant

Edge effect and other observations

Number of distance classes with SCFs greater than expected = 72

Number of distance classes with SCFs fewer than expected = 223

Strongly non-random data set — Proportion of significant SCFs >= 0.08

Number of distance classes with SCFs greater than expected at the edges of the distance class analysis matrix = 0

Significant edge effect not detected

Total number of positions in the matrix = 390

Number of vacancies (missing values) = 0

Number of infected plants = 128

Number of healthy plants = 262

Fig. 4. Distance class matrix for 2DCLASS and STCLASS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	#	#	#	#	#	#	#	#	#	#	#	#	>	-	-	-	-	S	S	S	S	S	S	S	-	-
2	#	#	#	#	#	#	#	#	#	#	#	#	-	-	#	S	S	S	S	S	S	S	S	S	S	-
3	#	#	#	#	#	#	#	#	#	#	#	#	-	-	-	S	S	S	S	S	S	S	S	S	S	-
4	#	#	#	#	#	#	#	#	#	#	#	#	-	-	-	S	S	S	S	S	S	S	S	S	S	-
5	#	#	#	#	#	#	#	#	#	+	-	#	-	-	-	S	S	S	S	S	S	S	S	S	S	-
6	#	#	#	#	#	#	#	#	#	-	-	-	-	-	S	S	S	S	S	S	S	S	S	S	S	-
7	-	#	#	#	#	#	#	-	-	-	-	-	S	S	S	S	S	S	S	S	S	S	S	S	-	-
8	-	-	-	-	-	-	-	-	-	-	$	S	-	S	S	S	S	S	S	S	S	S	S	<	-	-
9	S	S	$	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	<	-	S	S	-
10	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	<	S	S	-
11	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	<	-	-
12	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	-	-	-
13	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	-	<	-	S	$	$	-	-	-	-	-
14	S	S	S	S	S	S	S	S	S	S	$	$	$	S	S	-	-	-	S	-	-	-	-	-	-	-
15	$	S	S	S	$	S	S	S	$	S	$	$	$	$	-	-	-	-	-	-	-	-	-	-	-	-

= SCF significantly greater than expected in STCLASS and 2DCLASS (P<=0.05)

S = SCFSignificantlylessthanexpectedinSTCLASSand2DCLASS (P>=0.95)

+ = SCF Significantly greater than expected in STCLASS only (P < = 0.05)

$ = SCF Significantly less than expected in STCLASS only (P > = 0.95)

> = SCF Significantly greater than expected in 2DCLASS only (P < = 0. 05)

< = SCF Significantly less than expected in 2DCLASS only (P > = 0.95)

. = SCF not significant

the foci of secondary spread. Black pepper being a perennial crop, and occurrence of *Phytophthora* foot rot is seasonal, phytosanitation by removal of inoculum source would reduce the inoculum load and retard the progress of epidemic. This would form a component of integrated disease management strategy.

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