Spatial Pattern of *Claviceps purpurea* and *Gloeotinia temulenta* in the Willamette Valley of Oregon

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ABSTRACT

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Incidence of blind seed, caused by *Gloeotinia temulenta*, among fields of perennial ryegrass (*Lolium perenne*) and tall fescue (*Festuca arundinacea*) grown for seed was determined for three production areas within the Willamette Valley, Oregon, in 1988 and 1989. Incidence in the southern, central, and northern areas of the valley was 32, 21, and 0%, respectively, in 1988 and 15, 7, and 0%, respectively, in 1989. Spatial autocorrelation of blind seed incidence among tall fescue and perennial ryegrass fields in each of the three areas was not detected by means of a join-count technique. Spatial autocorrelation of ergot, caused by *Claviceps purpurea*, among bentgrass (*Agrostis tenuis*) and chewing festuca (*F. rubra* var. *commutata*) fields grown for seed in the east-central area of the Willamette Valley was not detected in 1988 or 1989. No spatial autocorrelation of ergot incidence was detected in 1988 or 1989 among grasses growing as weeds along roadways and field margins throughout the Willamette Valley. Results of this study suggest that assessment of blind seed could be based on random sampling of fields within each of the production areas and that assessment of ergot could be based on random sampling throughout the Willamette Valley.

Additional keywords: join-count analysis, spatial analysis

Forage grasses and turfgrasses are important crops in Oregon, with more than 162,000 ha planted for seed (14). Two important floral-infecting pathogens that directly affect seed production are *Claviceps purpurea* (Fr.:Fr.) Tul., causal agent of ergot, and *Gloeotinia temulenta* (Prill & Delacr.) M. Wilson, M. Noble, & E. Gray, causal agent of blind seed.

In disease surveys conducted in the Willamette Valley during 1988 (1), blind seed was observed in 26 and 30% of the perennial ryegrass (*Lolium perenne* L.) and tall fescue (*Festuca arundinacea* Schreb.) fields sampled, respectively. Ergot was observed in 13 and 3% of the colonial bentgrass (*Agrostis tenuis* Sibth.) and chewing festuca (*F. rubra* L. var. *commutata* Gaudin) fields, respectively. Although infrequently observed in commercial ryegrass and tall fescue fields, ergot was commonly observed throughout the valley among tall fescue growing as weeds along roadways and field margins (1).

Although these surveys (1) of ergot and blind seed established the incidence and relative distribution of the pathogens, the spatial pattern of infested fields within the Willamette Valley was not defined. Understanding the spatial pattern of ergot and blind seed could be helpful in developing sampling strategies and in monitoring disease levels in the area.

Various techniques are available for spatial pattern analysis, including geostatistics (4,11), variance to mean relationships (3,16), ordinary runs (13), and the indices of Moran, Geary, or Mantel (12). However, defining the distribution of pathogen-infested fields relative to noninfested fields within the 80 × 320 km region of the Willamette Valley is complicated by a clustered arrangement of fields within the region.

For disease presence/absence data, join-count analysis represents a simple means of detecting spatial autocorrelation in regional, mapped data (5), and the method has been proposed as an alternative to quadrat and distance based methods (2). Moran (15) and Krishna Iyer (10) introduced join-count statistics, and Cliff and Ord (5) and Sokal and Oden (18) described the application of the join-count analysis for mapped data. Insights into spatial topography can be derived from distance-based correllograms derived from the join-count analyses (19).

During the past 40 yr, grass fields in the Willamette Valley have been burned to control ergot and blind seed (9).

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Recent concerns over adverse health effects of smoke from field burning have resulted in legislative proposals and ballot initiatives to ban the practice. Hectarage of grasses burned in the Willamette Valley in recent years has declined; 64,428 ha were burned in 1990, as compared with 66,916 ha in 1989 and the previous 7-yr average of 80,661 ha (13). The effect of reduced burning on the incidence, severity, and distribution of floral pathogens is not clear, and quantitative studies describing current conditions could be helpful in assessing the impact of further reductions in field burning. In addition, a knowledge of spatial pattern of ergot and blind seed could be helpful in establishing sample size, sampling pattern, and sampling efficiency (3). The objective of this study was to determine the spatial pattern of fields infested with ergot and blind seed in the Willamette Valley of Oregon during 1988 and 1989.

Table 1. Proportion of fields with blind seed in each of three seed production areas in Willamette Valley, Oregon, in 1988 and 1989

Area[a]	1988	1989
1	0.02 ± 0.03[b]	0 ± 0
2	0.21 ± 0.13	0.07 ± 0.08
3	0.32 ± 0.07	0.15 ± 0.07

[a] 1 = Northeast, 2 = west central, 3 = south central.
[b] Proportion and associated standard error of the estimate ($P \leq 0.05$).

Table 2. Observed and expected number of joins and *z* statistic for perennial ryegrass and tall fescue fields with blind seed in each of three areas in Willamette Valley, Oregon, in 1988 and 1989

	1988				1989			
Area[a]	Observed	Expected	Critical value[b]	*z*[c]	Observed	Expected	Critical value	*z*
1	0	0	...[d]	...	0	0	...	...
2	0	1.3	0.1	−1.30	0	0	...	...
3	17	16.9	23.67	0.25	2	2.70	0.67	−0.25

[a] 1 = Northeast, 2 = west central, 3 = south central.
[b] Based on single-tailed value of X^2 ($\alpha = 0.025$ or 0.975).
[c] Standard normal deviate.
[d] No joins observed.

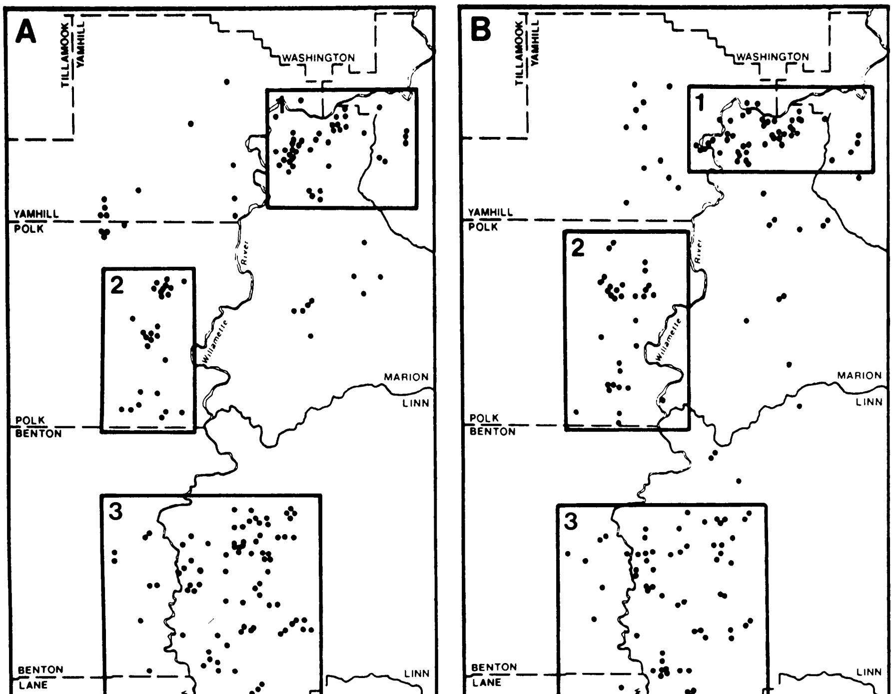

Fig. 1. Location of tall fescue and perennial ryegrass fields sampled in the Willamette Valley, Oregon, and arbitrary assignment of three production areas in **(A)** 1988 and **(B)** 1989. County names and lines are indicated.

MATERIALS AND METHODS

The locations of fields or sites with ergot or blind seed were obtained from a disease survey I conducted during 1988 (1) and 1989. In 1988 the number of fields sampled were 88 of perennial ryegrass, 122 of tall fescue, 45 of bentgrass, and 39 of chewing festuca, representing 25, 25, 42, and 27% of the total registered fields, respectively. Fields sampled were randomly selected from listings registered with the Oregon State University Seed Certification Office. Blind seed was detected with a seed washing technique (7), and ergot was assessed by examining seed heads for sclerotia of *C. purpurea*. In each field, 400 seed heads were collected at random by someone walking a diamond-shaped pattern extending to the field perimeters. A similar survey was conducted in 1989 except that 63 fields of perennial ryegrass, 130 of tall fescue, 38 of colonial bentgrass, and 71 of chewing festuca were sampled, representing 19, 26, 31, and 38% of the total registered fields, respectively.

Perennial ryegrass and tall fescue are grown primarily in three areas in the Willamette Valley: northeast, west central, and south central. Data on perennial ryegrass (cvs. Linn and Pennfine) and tall fescue (cvs. Falcon, Rebel II, Fawn, Forager, and Bonanza) from each area were pooled because all cultivars are susceptible to blind seed (8) and similar levels of blind seed were detected in each grass in 1988 and 1989. Data on bentgrass (cv. Highland) and chewing festuca (cvs. Koket and Cascade) were pooled because both grasses were grown in the

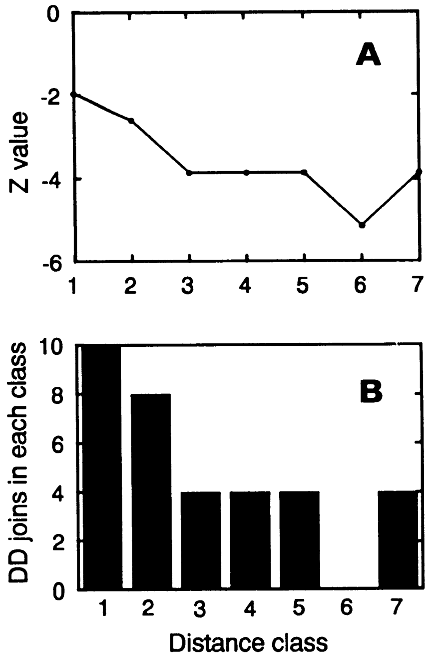

Fig. 2. (A) Correlogram of *z* statistic for seven distance classes and **(B)** number of joined fields infested with blind seed (data from 1988). Distance classes increase from 0 to 914 m in class 1 through 6.4 km in class 7 in 914-m increments.

Table 3. Observed and expected number of joins and z statistic for ergot-infected bentgrass and chewing festuca fields and ergot-infected weed grasses in Willamette Valley, Oregon, in 1988 and 1989

	1988				1989			
Grass	Observed	Expected	Critical value[a]	z[b]	Observed	Expected	Critical value	z
Bengrass and chewing festuca	2	0.9	3.16	1.98	5	2	5.3	2.75
Weed grasses	69	68	74.3	0.25	23	21	26.0	0.56

[a]Based on single-tailed value of X^2 ($\alpha = 0.025$ or 0.975).
[b]Standard normal deviate.

east-central area of the valley and had similar levels of ergot.

Ergot among grasses grown as weeds along roadways or field margins was evaluated at an arbitrary point (6 × 120 m) in each of 82 township-range sections (1.6 km^2), selected at random (1). In 1989, 102 sites were examined.

Join-count analyses were conducted in 1988 and 1989 for blind seed in perennial ryegrass and tall fescue in each of the three production areas of the Willamette Valley, for ergot in bentgrass and chewing festuca in the east-central area of the valley, and for ergot among weed grasses throughout the valley. Analyses were conducted using mapped data. Locations of sampled fields were plotted on a digitized map of Willamette Valley with AutoCad (Autodesk, Inc., Sausalito, CA). For presence-absence data, grass in seed production fields was defined as diseased (D) or healthy (H). Joined (connected) diseased-diseased, diseased-healthy, and healthy-healthy fields were defined as DD, DH, and HH. Fields were joined as DD, DH, or HH as described by Gabriel and Sokal (6) for irregularly distributed data (fields). Any two fields, designated A and B, were considered joined if no other field lay on or within a circle whose diameter was the line AB.

The statistical approach of Sokal and Oden (18) was used to analyze spatial pattern. The standard normal deviate, z, was defined as $z = (\text{observed pairs} - \mu_1)/\sqrt{\mu_2}$, where μ_1 is the expected number of DD joins and μ_2 is the variance. A computer program written in Turbo Pascal (Borland, Scotts Valley, CA) was used to calculate z. Program inputs included number of fields, number of diseased fields, and, for each field, number of joins and DD joins. The program was written by and is available from me. Critical values used to determine if the number of observed joins was significantly higher or lower than expected were calculated using $DD_{0.05} = \mu_2 X^2_{0.05}/2\mu_1$ with single-tailed values of X^2 ($\alpha = 0.025$ or 0.975). Degrees of freedom were estimated by $v = 2(\mu_1)^2/\mu_2$. Since the analysis was independent of distance between fields, distance weights were not used. Distances were used in establishing distance classes for correlograms. Distances between joined fields were determined with AutoCad.

RESULTS

Definition of three production areas within the Willamette Valley was based on the pattern of fields sampled in 1988 and 1989 (Fig. 1). The proportions of fields with blind seed in areas 1, 2, and 3 were 0.02, 0.21, and 0.32, respectively, in 1988 and 0, 0.07, and 0.15, respectively, in 1989 (Table 1). Incidence of blind seed increased from the north to the south in the valley.

In area 3, 17 joins of blind seed fields (DD) were observed in 1988 and two were observed in 1989 (Table 2); the number of DD joins was neither higher nor lower than expected. In area 2, no joins were observed in 1988 or 1989. No joins were observed in area 1. Values of z, calculated from 1988 data, declined with increasing distance through 1.8 km (Fig. 2A). About one-half of the joined blind seed fields were within 1.8 km of one another and the other half were distributed among the remaining distance classes (Fig. 2B).

The proportions of fields with ergot-infected bentgrass and chewing festuca in 1988 and 1989 were 0.09 and 0.13, respectively. No spatial autocorrelation for ergot among bentgrass and chewing festuca fields grown for seed in the east-central area of the Willamette Valley was detected in 1988 or 1989 (Table 3).

Ergot was detected at 66 of 82 sites in 1988 and at 34 of 102 sites in 1989. Ergot was distributed throughout the Willamette Valley among grasses growing as weeds, but the number of DD joins was as expected (Table 3).

DISCUSSION

A decrease in incidence of blind seed (proportion of fields with infected plants) from the southern to northern areas of the Willamette Valley was apparent. The reason for less blind seed in area 1 than in area 2 or 3 is not clear but may be related to a greater diversity of crops grown in the northeastern area of the valley and the more common use of crop rotation, which has been reported to control blind seed (7).

Although differences among the three production areas were apparent, distribution of infested fields within each area was not spatially autocorrelated. Assessment of blind seed should take into consideration the variation in incidence of blind seed among and within production areas. Randomly selecting fields within each of the production areas from lists of fields registered for seed certification could provide reliable estimates of blind seed incidence within the Willamette Valley. Since the number of fields in each area can be determined from lists of registered fields, the minimum number of samples within each area needed for a given confidence interval could be determined using sample survey statistics (17).

Ergot distribution among weed grasses was widespread, but spatial autocorrelation was not observed. Such a common and widespread distribution of inoculum sources may contribute to epidemics within the valley when the environment is favorable. However, despite the abundance of inoculum from weed grasses, incidence of ergot in ryegrass and tall fescue is low (1), and what conditions would favor epidemics of ergot in these grasses is not clear. Weed grasses on field perimeters are generally not burned but may be plowed to help contain a field burn. Ergot commonly occurs in bluegrass, bentgrass, and chewing festuca, and incidence and severity of ergot in these grasses may increase without field burning.

Little is known about the competitive association between *C. purpurea* and *G. temulenta*. Although host ranges overlap, the pathogens appear to have a differential grass preference. Blind seed was most common in tall fescue and perennial ryegrass, whereas ergot was most severe in chewing festuca, Kentucky bluegrass, and bentgrass. Among the 294 fields sampled in 1988, and also among the 302 sampled in 1989, only one field of chewing festuca was observed with both ergot and blind seed.

The reduction in field burning in the Willamette Valley and subsequent changes in management of straw residues may have an impact on blind seed or ergot levels or distributions. This study provides a baseline for comparison with future incidence and spatial patterns of these diseases in the Willamette Valley. This study suggests that assessment of blind seed could be based on random sampling of fields within each production area and that assessment of ergot could be based on random sampling throughout the valley.

LITERATURE CITED

1. Alderman, S. C. 1988. Distribution of *Gloeotinia temulenta, Claviceps purpurea*, and *Anguina agrostis* in the Willamette Valley of Oregon during 1988. J. Appl. Seed Prod. 6:6-10.
2. Arvanitis, L. G., and Daley, R. 1982. Join count statistics: An alternative to quadrat and distance sampling. Pages 406-409 in: Proc. In-place Resource Inventories: Principles and Practices. T. B. Brown, L. O. House IV, and H. G. Lund, eds. Society of American Foresters, Bethesda, MD.
3. Campbell, C. L., and Noe, J. P. 1985. The spatial analysis of soilborne pathogens and root diseases. Annu. Rev. Phytopathol. 23:129-148.

4. Chellemi, D. O., Rohrbach, K. G., Yost, R. S., and Sonoda, R. M. 1988. Analysis of spatial pattern of plant pathogens and diseased plants using geostatistics. Phytopathology 78:221-226.
5. Cliff, A. D., and Ord, J. K. 1981. Spatial Processes: Models and Applications. Pion Limited, London. 266 pp.
6. Gabriel, K. R., and Sokal, R. H. 1969. A new statistical approach to geographic variation analysis. Syst. Zool. 18:259-278.
7. Hardison, J. R. 1948. Field control of blind seed of perennial ryegrass in Oregon. Phytopathology 38:404-419.
8. Hardison, J. R. 1962. Susceptibility of Gramineae to *Gloeotinia temulenta*. Mycologia 54:201-216.
9. Hardison, J. R. 1980. Role of fire for disease control in grass seed production. Plant Dis. 64:641-645.
10. Krishna Iyer, P. V. A. 1949. The first and second moments of some probability distributions arising from points on a lattice, and their applications. Biometrika 36:135-141.
11. Lecoustre, R., Fargette, D., Fauquet, C., and de Reffye, P. 1989. Analysis and mapping of the spatial spread of African cassava virus using geostatistics and the kriging technique. Phytopathology 79:913-920.
12. Legendre, P., and Fortin, M-J. 1989. Spatial pattern and ecological analysis. Vegetatio 80:107-138.
13. Madden, L. V., Louie, R., Abt, J. J., and Knoke, J. K. 1982. Evaluation of tests for randomness of infected plants. Phytopathology 72:195-198.
14. Miles, S. D., and Young, W. C. 1990. Background on Oregon's grass and legume seed industry. Oreg. State Univ. Ext. Bull. EC1364.
15. Moran, P. A. P. 1948. The intrepretation of statistical maps. J. R. Stat. Soc. Ser. B. 10:243-251.
16. Nicot, P. C., Rouse, D. I., and Yandell, B. S. 1984. Comparison of statistical methods for studying spatial patterns of soilborne plant pathogens in the field. Phytopathology 74:1399-1402.
17. Scheaffer, R. L., Mendenhall, W., and Lyman, O. 1986. Elementary Survey Sampling. 3rd ed. PWS Publishers, Boston. 324 pp.
18. Sokal, R. R., and Oden, N. L. 1978. Spatial autocorrelation in biology. 1. Methodology. Biol. J. Linn. Soc. 10:199-228.
19. Upton, G., and Fingleton, B. 1985. Spatial Data Analysis by Example: Point Pattern and Quantitative Data. Vol. 1. John Wiley & Sons, New York. 410 pp.