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Micro area based spatial distribution of apple scab in an organic apple orchard

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Summary: In this study, the objective was to report a two-year investigation on micro area based spatial distribution of apple scab in an organic apple orchard. Results showed that number of symptomatic plant part ranged between 587 and 623 on leaf and between 46 and 78 on fruit for an individual tree. Number of asymptomatic plant part ranged between 1034 and 1321 on leaf and between 119 and 193 on fruit. Disease incidence ranged between 35 and 40% on leaf and between 27 and 33% on fruit. Disease aggregation index ranged between 0.115 and 0.298 on leaf and between 0.117 and 0.221 on fruit. Three of the four trees showed significant within canopy aggregation of disease for leaf apple scab symptoms in both years. For fruit apple scab, two of the four trees showed significant random patterns in both years.

Keywords: *Venturia inaequalis, spatial pattern, organic apple*

Introduction

Apple scab (*Venturia inaequalis*) is a key fungal pathogen of apple. Scab is causing severe econimic loss on susceptible cultivars in every years where apple are grown and 10-20 spray applications are needed annually in environmentally friendly (integrated and organic) apple orchards (Holb *et al*., 2003, 2005, 2006; Holb, 2005, 2006, 2008, 2009).

Spatial analysis, characterizing the inner structure of epidemics in a plant stand/orchard, was widely studied from 1990s after the introduction of novel statistical-mathematical methods (e.g. Gibson & Austin, 1996; Kocks *et al.,* 1999). Epidemics can be investigated in micro-areas for instance inside a plant/tree in any small areas (e.g. Vereijssen *et al.,* 2007; Sposito *et al.,* 2008).

Previous studies examining spatial disease patterns within tree canopies either divided the canopy into layers (Holb & Scherm, 2007) or quadrats (Batzer *et al.*, 2008; Spósito *et al.,* 2008). In a recent study, Everhart *et al.* (2011) used a digitizer to map different brown rot symptom types (blossom blight, shoot blight, and twig cankers) caused by the fungal plant pathogen *Monilinia laxa* in individual sour cherry canopies. More recently, preliminary study was also published on micro area based spatial distribution of *Monilinia fructigena* and *Podosphaera leucotricha* in organic apple orchards (Holb *et al.*, 2014; Holb, 2014). However, micro-area based spatial aspects of apple scab have received very little attention.

In this study, the objective was to report micro area based spatial distribution of *V. inaequalis* in an organic apple orchard.

Materials and methods

Orchard site

The experiment was carried out in an organic orchard located at Eperjeske, Hungary. The orchard was planted with cultivars Mutsu, Jonathan, Prima on M26 rootstocks in 1997. The distance between rows was 5 m, and the distance between trees within a row was 2. The orchard was treated according to the Hungarian Organic Growing Guidelines derived from the IFOAM guidelines. The micro-area based spatial experiment was set in 2014 and 2015.

Assessment of spatial pattern of symptoms

At harvest, fruit and leaf symptom caused by *V. inaequalis* was present and readily distinguishable. Four trees *(Table 1)* of different sizes and with varying levels of disease incidence were selected for digitizing. The x, y and z co-ordinates of all symptomatic elements were digitized, as were all asymptomatic (healthy) leaf and fruit (Table 1). Each digitized canopy element was tagged with coloured tape to ensure that points were not measured twice and that no relevant point was omitted. Disease incidence of leaf and fruit was also measured also for each tree.

Spatial pattern analysis

Spatial patterns of aggregation for a given symptom type within the canopy were characterized based on nearest neighbour distances, i.e. the shortest Euclidian distance between symptoms derived from the x, y and z co-ordinates of points. The frequency distribution of nearest-neighbour distances within each tree could then be used to determine deviation from randomness.

Disease aggregation index (dw) was also determined. The test statistic dw, the maximum departure of the observed cumulative frequency distribution. Values of dw represents the index of disease aggregation and is calculated based on the cumulative frequency distribution of nearest-neighbour distances among apple scab affected leaf and fruit. Significant positive values indicate aggregation, whereas significant negative values correspond to a more regular distribution compared with the random simulation.

Results

Disease pattern

Number of symptomatic plant part ranged between 587 and 623 on leaf and between 46 and 78 on fruit for an individual tree *(Table 1)*. Number of asymptomatic plant part ranged between 1034 and 1321 on leaf and between 119 and 193 on fruit. Disease incidence ranged between 35 and 40% on leaf and between 27 and 33% on fruit.

Table 1. Summary of symptomatic patterns on fruit and leaf disease incidence of apple scab on 4 apple trees within the tree canopy (Eperjeske 2014 and 2015)

Number of tree	Number of symptomatic plant part	Number asymptomatic plant part	Disease incidence (%)
2014–2015, leaf			
I	675	1223	35.56
II	823	1234	40.01
III	743	1321	35.99
III	587	1034	36.21
2014–2015, fruit			
I	54	125	30.16
II	46	119	27.87
III	67	136	33.02
III	78	193	28.78

Disease aggregation

Disease aggregation index ranged between 0.115 and 0.298 on leaf and between 0.117 and 0.221 on fruit (Table 2). Three of the four trees showed significant within canopy aggregation of disease for leaf apple scab symptoms in both years (Table 2). For fruit apple scab, two of the four trees showed significant random patterns in both years.

Table 2. Summary of disease agrregation index and spatial patterns for apple scab symptoms on 4 apple trees within the tree canopy (Eperjeske 2014 and 2015)

Number of tree	Disease aggregation index (dw)	P value	Spatial pattern
2014-2015, leaf			
I	**0.276**	**0.033**	**aggregated**
II	**0.225**	**0.044**	**aggregated**
III	**0.298**	**0.027**	**aggregated**
IV	0.115	0.209	random
2014-2015, fruit			
I	0.117	0.178	random
II	**0.221**	**0.045**	**aggregated**
III	**0.215**	**0.047**	**aggregated**
IV	0.138	0.144	random

dw represents the index of disease aggregation and is calculated based on the cumulative frequency distribution of nearest-neighbour distances among powdery mildew-affected shoot and fruit. Significant positive values indicate aggregation, whereas significant negative values correspond to a more regular distribution compared with the random simulation. Significant dw values ($P \leq 0.05$) are in bold.

Conclusions

Spatial disease incidence of apple scab on leaf and fruit reached more than 20 % in the two years. Most diseased leaf caused by *V. inaequalis* were aggregated within the tree and most of the diseased fruits were also aggregated indicating a notable relationship among apple scab symptoms within tree.

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