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Short communication

A model to study the effect of certification of planting material on the occurrence of leek rust

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Abstract

Based on a simple model, the possible effects of certification of planting material on the occurrence of leek rust in a region can be derived from information on the proportion of infected fields (v) and the proportion of newly planted fields with infected planting material (i) in that region. If $v \leq \sqrt{i}$, certification of planting material will be highly effective.

The biology of leek rust, caused by *Puccinia allii* Rud., and its management at the farm level in the Netherlands is discussed in de Jong *et al.* [1995]. Preventive measures can also be taken at a regional level which reduce the amount of inoculum and increase the distance between sources of inoculum and endangered fields. In this context, a region is defined as an area where the cultivation of a crop is concentrated. Examples of preventive measures at a regional level in other pathosystems in the Netherlands are the provincial regulations concerning the timely clearing of fodder beets silage so preventing spread of beet yellow viruses, clearing or covering of heaps with harvest debris of potatoes that may house *Phytophthora infestans*, and the designation of protected regions preventing the spread of fire blight into pear orchards [Anonymous, 1993; Schouten, 1992]. Reviews on the effectiveness of sanitation measures can be found in Zadoks and Schein [1979] and Lester [1986]. Possible preventive measures against the spread of leek rust at a regional level include a strict certification of planting material ensuring that only healthy material is used and a minimal distance between leek crops and a crop-free period in a whole (sub-)region. The last two measures have a strong impact on farm management and are unlikely to be accepted as regulations by leek growers.

To explore the effects of certification of planting material on disease occurrence at a regional level, a simple extension of Levin's [1969] metapopulation model was constructed. As a simplification it is assumed that every harvested leek field is replaced immediately by a newly-planted field. Thus, the number of leek fields is assumed constant. The temporal change in the fraction of infected fields (v) can then be described as a function of a parameter reflecting the colonization ability of leek rust (c), the instantaneous harvest and planting rate (h) and the fraction of newly-planted fields with infected planting material (i):

$$\mathrm{d}v/\mathrm{d}t = cv(1-v) - hv + ih$$

in which $(1 - v)$ is the fraction of fields that are not infected. It is assumed that the colonization ability c is independent of the level of infection in individual fields, because these levels are kept low by chemical control. For the same reason it is assumed that the harvest rate h is the same for infected and non-infected fields. The harvest rate h will be rather constant. A reduction in the growing period of a leek crop of one month will cause a substantial reduction in yield, but will increase h by only 10 to 20%. The colonization ability c can vary much more, depending on the distance between the leek fields in a region. The equilibrium for v, i.e. the value for v when $\mathrm{d}v/\mathrm{d}t = 0$, is

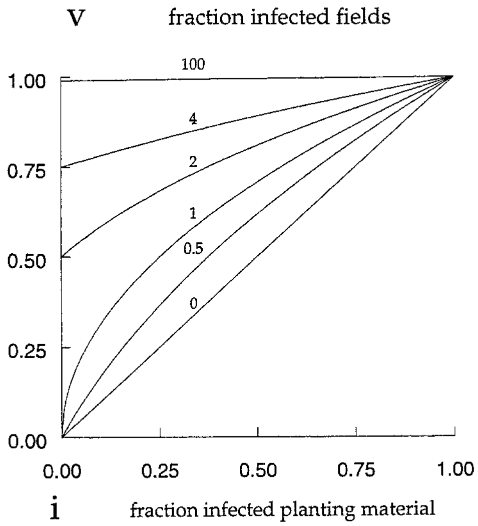

Fig. 1. The fraction of fields infected (v) at equilibrium as a function of the fraction of newly planted fields with infected planting material (i) according to the model; entries: c/h, the ratio between a parameter reflecting colonization ability (c) and the harvesting and planting rate (h); note that for c/h $\leq$ 1, v = 0 if i = 0, and that for c/h > 4, v is relatively independent of i.

dependent on the ratio c/h and i (see appendix). In Fig. 1, the equilibrium for v is given as a function of i at different values of c/h. At a ratio c/h larger than 4, reduction in i has little effect on the fraction of infected fields. If the ratio c/h equals 1, then $v = \sqrt{i}$. At values for c/h equal or lower than 1, v is larger than zero if i is larger than zero; thus the persistence of leek rust in a region is caused by the use of infected planting material and the disease may be eradicated from the region by strict use of healthy planting material (see Fig. 1).

When information on the actual fraction of infected leek fields in a region (v) and on the proportion of newly planted fields with infected plant material (i) is available, Fig. 1 can be used to estimate the ratio c/h. A representative survey of planting material and leek fields, until now not performed, is necessary to provide this information. If $v \leq \sqrt{i}$, then the ratio c/h is estimated between 0 and 1 and the fraction of infected fields will be highly dependent on the proportion of fields planted with infected planting material. In this situation, an obligatory certification of planting material will be highly effective and may even cause the complete eradication of leek rust from the region. For estimated values of c/h greater than 1, the reduction in the disease intensity on a regional level will be less dramatic and there will be less justification for an obligatory certification of planting material. Implementation on a voluntary basis of the certification of planting material can still be very useful, delaying the start of rust epidemics in individual leek fields and hence reducing the number of fungicide sprayings required.

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Appendix. Equilibrium for *v*

$$cv(1-v) - hv + ih = 0 \tag{1}$$

$$\frac{c}{h}v(1-v) - v + i = 0 \tag{2}$$

$$-\frac{c}{h}v^2 + (\frac{c}{h} - 1)v + i = 0 \tag{3}$$

For $c = 0$ the solution is:

$$v = i \tag{4}$$

For $c > 0$ and $i > 0$, there is a positive solution:

$$v = \frac{\left(\frac{c}{h} - 1\right) + \sqrt{\left(\frac{c}{h} - 1\right)^2 + 4\frac{c}{h}i}}{2\frac{c}{h}} \tag{5}$$

$$= \frac{1}{2}\left(1 - \frac{h}{c}\right) + \frac{1}{2}\sqrt{\left(1 - \frac{h}{c}\right)^2 + 4i\frac{h}{c}} \tag{5b}$$

For $i = 0$ and $c/h > 1$, there is a positive solution:

$$v = 1 - \frac{h}{c} \tag{6}$$

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