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Soil Receptivity to Take-all: Influence of Some Cultural Practices and Soil Chemical Characteristics*

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Abstract

Soils with very close physicochemical characteristics show different levels of receptivity to take-all (*Gaeumannomyces graminis* var. *tritici*), depending on cropping systems. Soils collected from some long term experiments comparing cropping systems in several regions of France may be classified as follows, from the least to the most susceptible to take-all: wheat monoculture $<$ beet-wheat rotation $<$ maize-wheat rotation $<$ maize monoculture. So is measured a poorly understood component of the role of previous crop on take-all development: a maize monoculture, known to decrease the inoculum potential of *Ggt*, increases, on the other hand, the soil susceptibility to take-all. Nitrogen fertilization with ammonium sulfate as compared to calcium nitrate, decreases the soil receptivity to take-all of a soil of Le Rheu.

There is a good relation between soil receptivity levels and the disease indexes measured in the field. The main hypotheses advanced to explain take-all development in soils, such as pH, ratio NH_4/NO_3 and Mn level, are not in full concordance with measures done on these soils. Nevertheless, the dynamic of reduction of Mn seems to be related with some aspects of disease development.

Introduction

Take-all caused by *Gaeumannomyces graminis* (Sacc) von Arx and Olivier var. *tritici* Walker (= *Ggt*) is an important soilborne disease of wheat in France. Despite no method of control, many factors are known to have an influence on take-all development in the field. Among those, cropping system and source of nitrogen fertilization are the most universally efficient. The application of an ammonium source of nitrogen reduces take-all in most situations (Huber, 1981), while crop rotations and nature of the previous crop may have some contradictory effects on the development

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of take-all in different times or locations (Kollmorgen, 1983). These differences can be explained by different soil or climatic conditions or differences in level of inoculum potential in soil at the beginning of the experimentation.

We propose a method (pot bioassay) to measure a part of the mechanisms which explain take-all development in the field: the soil receptivity (Alabouvette et al., 1982). This method will give information on some unknown effects of the previous crop. The results will be put in relation with some hypotheses on the role of chemical factors of soil in take-all development.

Material and Methods

1. Origin of soil samples

a. Soil receptivity and cropping system

In 1987, samples of soil were collected from 3 locations in France where long term experimentation on cropping systems are carried out (Lucas et al., 1989). (Table 1).

Table 1. Cropping systems in place on the 3 experimental sites from which soils are sampled for studying their receptivity to take-all

Location	Code	Cropping system
Grignon	G1	Wheat Monoculture
	G2	Wheat/Wheat – Maize Rotation
	G1b	Wheat/Beat/Wheat Monoculture
Rennes	R1	Wheat Monoculture
	R2	Wheat/Maize rotation
	R3	Maize Monoculture
Quimper	Q1	Wheat Monoculture (WM)
	Q2	Grassland
	Q3	Maize Monoculture (MM)

b. Soil receptivity and source of nitrogen

In a field trial, in Le Rheu, different methods known to reduce the incidence of take-all are combined (Lucas et al., 1988, Lucas et al., 1989). Soil samples were collected from plots fertilized with ammonium sulfate or calcium nitrate.

The sampling was done 40 days after the second application of nitrogen (50 Kg N ha^{-1}, tillering; first application: 50 Kg N ha^{-1}, at sowing).

2. Measure of the soil receptivity to take-all

The method developed (Lucas and Collet, 1988) consists of measuring the ability of a soil to allow expression of pathogenicity by increasing rates of inoculum, in a population of susceptible host plants. The bioassay is carried out over 35–45 days

(15°C, photoperiod 16 h), according to the agressivity of the *Ggt* isolate.

Then, plants are taken from the pots and a disease index for each soil and each rate of inoculum is calculated and used to draw the curve of receptivity of the soil tested.

3. Soil physico chemical characteristics

In accordance with some hypotheses on relations between soil physico-chemical characteristics and take-all development, samples of soil collected in 1987 were analyzed for pH, NH4/NO3 ratio and level of extractible Mn.

4. Field assessment

Plants were sampled in the field in March (tillering), April (beginning of stem extension) and June (flowering). The root system of each plant is washed and examined for evidence of take-all lesions. Each plant is assigned to one of the five disease severity classes (0, 1, 2, 3, 4) corresponding to nil, 1 to 10, 11 to 30, 31 to 60, 61 to 100% of the root system with take-all lesions. A disease index is calculated with the formula:

$$\text{D.I.} = \left(\sum_0^4 n_i \times i\right)\left(\sum_0^4 n_i\right)^{-1}$$

i: severity class, n_i: number of plants assigned to the class i

The disease severity (D.S.) may be calculated in the same way but by taking only the diseased classes $i \geq 1$.

Results

1. Soil receptivity and cropping system

The different curves of soil receptivity obtained from the 3 sites are drawn in Fig. 1.

It appears that soils which have been successively cropped with wheat several years are the less susceptible ones at 2 sites (Grignon, Quimper). In Rennes, on the other hand, the soil from the wheat monoculture does not differ from those from the wheat-maize rotation or maize monoculture. So, after 13 years of wheat monoculture, the take-all decline is not reached in this location. The most susceptible soils to take-all are those cropped continuously with maize (R3, Q3), with grass (Q2) or under 2nd wheat after maize (G2) for which the maximum of the disease index is reached from the first rate of inoculum introduced.

It is also interesting to notice that a break in a wheat monoculture with a crop of beet leads to an intermediate status between take-all decline and high level of receptivity (G1b compared to G1 and G2).

2. Soil receptivity and nitrogen fertilization

Data from 1987 and 1988 expressed in Fig. 2, show that the fertilization with

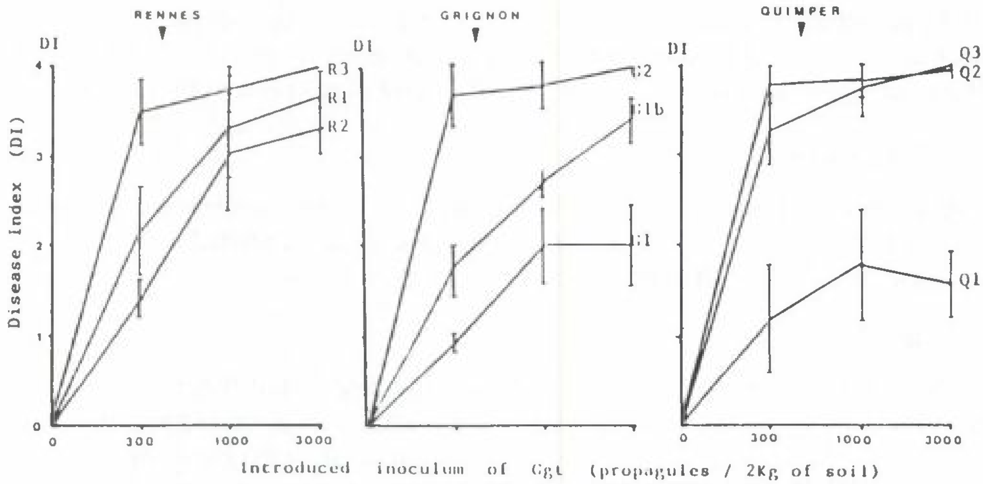

Figure 1: Receptivity to take-all of soils cropped with different rotations in 3 regions of France (see table 1 for codes).

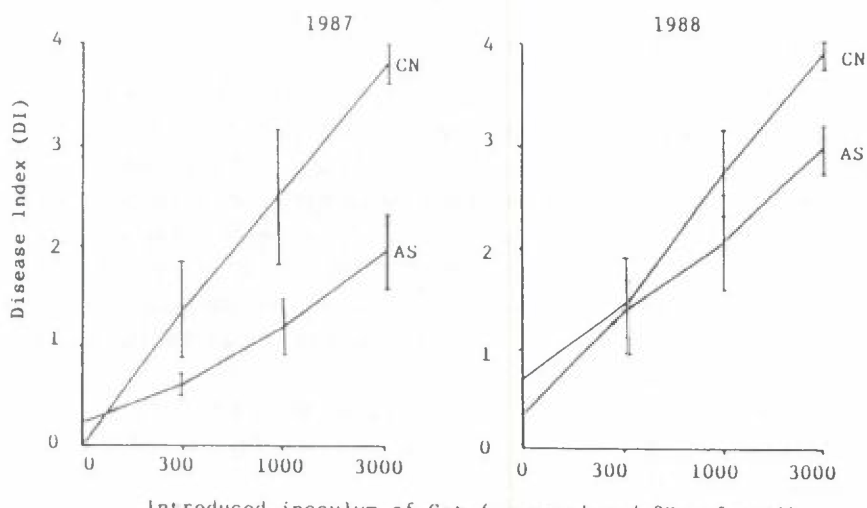

Figure 2: Receptivity to take-all of soil from Le Rheu, fertilised with ammonium sulfate (AS) or calcium nitrate (CN).

ammonium sulfate instead of calcium nitrate decreases the soil susceptibility to take-all and that differences are observed even at mid tillering.

On the other hand, assessments of the disease development in the field (Table 2) show that there are take-all index differences between N sources only for the last assessment made at the end of flowering. The differences so observed are due only to the severity index and not to the percentage of plants having symptoms.

Table 2. Development of take-all in the field depending on the form of nitrogen applied at sowing (50 Kg N ha^{-1}) early tillering (50 Kg N ha^{-1}) and beginning of stem extension (50 Kg N ha^{-1}). DI = Disease index (Scale: 0–4), p. 100 = percentage of plants with take-all, DS = Disease severity (Scale 1–4) (1988). Data followed with different letters are significantly different for $p = 0.05$

Stage	Notation	Ammonium Sulfate	Calcium Nitrate
Mid tillering (Seminal roots)	DI	0.33	0.31
Stem extension (Nodal roots)	DI	0.50	0.30
Flowering	DI	1.95a	2.65b
	p. 100	97.6	98.3
	DS	1.99a	2.69b

3. Soil physicochemical characteristics

Physicochemical analyzes made on soils sampled at the end of the test of receptivity are presented in Table 3.

Table 3. Relation between some soil physico-chemical characteristics and level of receptivity to take-all depending on cropping system or form of nitrogen fertilization. Those which are in concordance with the receptivity level observed, according to the literature, are followed by an asterisk

Soil characteristics	Quimper		Rennes	
	Cropping system		Form of nitrogen	
	WM	MM	AS	CN
pH	6.4	5.8	5.7*	6.6*
NH_4/NO_3	2.7*	14.2*	1.3	1.7
Mn (ppm)	38.5	39.1	80*	57.3*
Receptivity level	low	high	low	high

Discussion and conclusion

The test gives us information on the ability for an inoculum present or introduced, to cause disease depending on the type of soil. All other conditions (cultivar, temperature, water) are the same.

The results we obtain with this method are in concordance with previous literature on low development of take-all in wheat monoculture soils (Lemaire and Coppenet, 1968, Gerlagh 1968, Shipton 1975) or in soil fertilized with an ammonium source of nitrogen (Huber et al., 1968, Christensen and Brett, 1985).

Of course this information concerns only one aspect of the disease development in the field which is dependent on the inoculum potential at sowing date and on the climatic conditions. In his way there is a good relation between levels of receptivity measured and take-all development in wheat plots fertilized either with ammonium sulfate or calcium nitrate but cropped in the same field (same inoculum level and climatic conditions).

On the other hand, as we could expect no take-all in a first wheat after maize monoculture, it occurs (even at a low level) in a wheat monoculture, even though it is the soil from maize monoculture which has the highest level of take-all receptivity. In such soil, introducing inoculum should be prevented.

Similarly, beet seems to be a better previous crop than maize, because, independent of the effect they can both have on inoculum potential as non-host plant, maize increases soil receptivity to take-all.

Regarding the hypotheses on the role of pH (Smiley amd Cook, 1973), NH4/NO3 ratio (Christensen and Brett, 1985) and Mn (Graham and Rovira, 1984; Lucas and Nignon, 1987), none can fully explain the differences observed between wheat and maize monoculture and between ammonium and nitrate fertilization. Nevertheless, it is interesting to observe (data not presented in table) that after introducing propagules of *Ggt* the level of Mn rises from 39.1 to 47 ppm in the maize monoculture soil and from 38.5 up to 59.7 in the wheat monoculture soil. As the reduction of manganese in soils between pH 5.5 and pH 8 is mainly due to microbial activity (Dommergues and Mangenot, 1970), we also studied the level and structure of some bacterial populations in relation with soil receptivity to take-all (Sarniguet et al., 1989).

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