Modelling plant diseases impact with the Belgian Crop Growth Monitoring System

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Introduction

The grain yield of wheat has been related linearly to the size and duration of the photosynthetic canopy after ear emergence, whether duration is influenced by climate, agronomy or genotype (Evans et *al.*, 1975). Effects of contrasting diseases on yield of wheat grain can be related to effects on green leaf area, or more precisely, absorption of photosynthetically active radiation by healthy green tissues (Bryson et *al.*, 1997 in Gooding et al., 2000). Thus yield increases following fungicide-use can be similarly related to the fungicide effects on the size and duration of the canopy (Gooding et *al.*, 2000); whether green tissues is maintained by controlling known pathogens (Ruske et *al.*, 2003) or through direct physiological effects of the fungicide on the plant. Despite the importance of green leaf area duration, simulation of senescence processes has received less attention than leaf area development processes in models used to predict effects of disease on yield (Ruske et *al.*, 2003). The Belgian Crop Growth Monitoring System (B-CGMS) model which is used operationaly for crop yield forecasting at national and regional level in Belgium since 2002 but the senescence process modelled doesn't take into account the influence of the disease. The objective of this research is to adapt B-CGMS in order to integrate the disease influence in the Leaf Area Index (LAI) decreasing curve. The pattern of the top three leaves senescence can be complex as it can be induced by many factors but Gooding et al (2000) showed that the incidence of diseases on LAI decreasing curve shape usually follows a simple Gompertz function pattern.

Material and Methods

After analyzing how diseases affect LAI decline curve using a Gompertz function modified by Gooding *et al.* (2000), parameters of B-CGMS potentially able to correctly simulate this diseases impact on the LAI decline will be determined and adjusted.

The data

Field experiments were carried out in Belgium and the G-D of Luxembourg over 2003 to 2009. Weather data were gathered from weather stations within 1 km of the field sites. All the experiments were led in different climatic and pedologic situations. Several wheat cultivars were sown in a randomized block design with four replicates. Each plot was 8 m x 1,5 m in size and each replicate block consisted of treated or untreated plots of each cultivar The fungicide treatment was always a mix of strobilurin and triazol. The control plot did not receive any fungicide application. The cultivars studied were Parador, Novalis, Drifter, Centenaire, Achat, Flair, Aron, Urban, Dekan, Bussard, Akteur, Cubus, Rosario, Folio, Schamane, Tommi, Privilège, Boomer and Vivant. Fertiliser and herbicides were applied according to standard agricultural practices prevailing in Belgium and Luxembourg. Leaves were assessed before and during the period of green leaf area decline by visually estimating the percentage area of green surface and area covered by sporulating *Septoria tritici* (sexual stage *Mycosphaerella graminicola*) lesions for the top three leaves. However, a minimum of 10 samples is often used for cereal plots. For each fungicide treated and untreated plots, 40 plants (10 per replicate) were assessed at four different dates from May to June.

The model

The Gompertz function adjustment of the LAI decreasing curve shape was carried out using software SAS (vers. 9.1.3 pack 2). The Gauss method of adjustment was applied. In its simplified version, only two parameters, k and m, are needed for describing a Gompertz modified decreasing curve shape. *k* represent the relative rate of decline of the green material and *m* is the time to curve inflection with initial values of *k* and *m* being set at -0.2 day^{-1} and 55 days respectively. Usually 4 observations were available for adjustment during the decreasing phase of the LAI curve. Gompertz curves were adjusted for all the plots of each site on the seven-year period 2003 – 2009.

Among the long list of parameters of B-CGMS, the one expressing the mortality due to the age and more exactly the lifespan of leaves (the SPAN parameter in B-CGMS) was the more interesting: It was noted previously that by changing the SPAN parameter in B-CGMS, we modified the time to reach the inflection point of the downward curve of the LAI simulated progress curve.

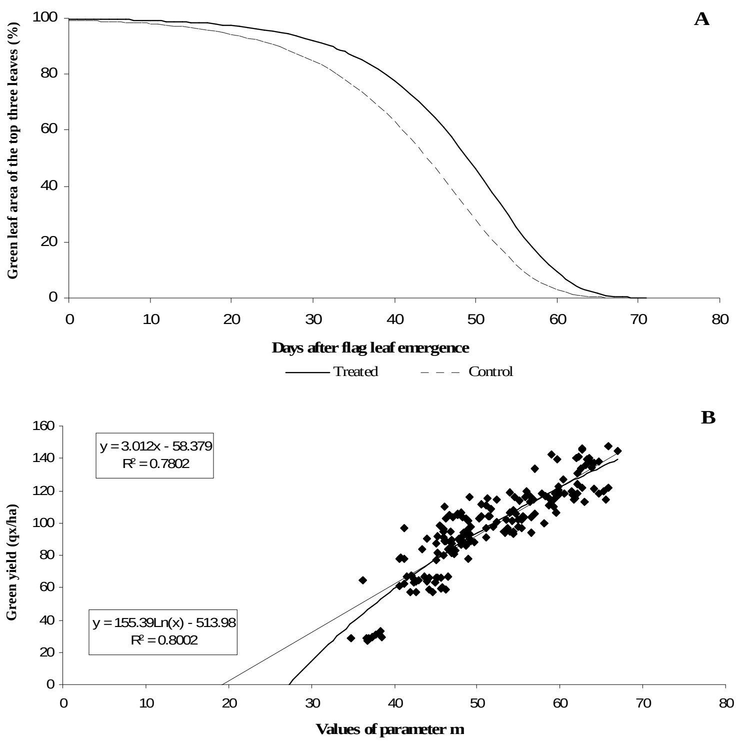

Figure 1: Reduction of the green leaf area of the top three leaves for control and treated plots over 2003 to 2009 [A]; Linear and logistic correlation between grain yield and values of parameter m [B].

The SPAN parameter equals the life time of a leaf (in days) kept at 35°C. The recalibration thus consisted in identifying the value of the SPAN parameter which could best simulate the LAI decreasing curve modeled by the simple Gompertz function adjusted on actual field observations.

For each one of these situations, a set of values of the SPAN parameter ranging from 23.3 to 39.3 (default value = 31.3) was checked by step of 0,8 units and model outputs were analysed.

Then, it was possible to determine for each situation of the calibration data file the relation binding the values of SPAN and the values of *m* obtained by the adjustment.

Results

On the whole experiments and cultivars there was no effect of fungicide on k but it was highly significant on m ($P<0.001$). When main effects are considered, fungicide delayed green leaf area decline rather than reduced its rate of progress once started (Fig 1A). Fungicide effects on m varied greatly among experiments and cultivars, reflecting the disease levels on untreated plots. Fungicide also had variable effects on grain yield, largely reflecting variation in disease infection pressures in the different years and susceptibility of the different cultivars. There was no correlation between values of k and grain yield while m was very closely associated with grain yield (r = 0.894) (Fig 1B).

Discussion and conclusion

We found a highly significant relation between the values of the parameter m of each situation and the corresponding grain yields (R^2=0.81; P<0.001). We were able to determine the relation between the values of SPAN and the values of m.

Considering that parasitic pressure reduces leaves lifespan and therefore the photosynthetic capacity, we concluded that estimation of the parameter m and recalibration of SPAN makes it possible to take into account the influence of this pressure on yield predictions in the Belgian Crop Growth Monitoring System.

References

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