Indicators of weed competition on Organic Winter Wheat

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Abstract

Organic winter wheat production is limited by climatic and agronomic factors, including weed competition. The incidence of weeds on yield limitation can be characterized through various early indicators to predict weed occurrence and competition. A network of 10 fields of organic winter wheat was implemented in the South East of France in 2005-2006. Results showed that weed density, dynamics and diversity are good indicators for weed occurrence and competition.

Introduction

The low and variable organic wheat grain yields (David et al., 2004a) are essentially explained by climatic and agronomic factors including nitrogen deficiency, soil compaction and weed competition (David et al., 2005 and Taylor et al., 2001). It is now critical for organic farmers to improve and stabilize grain yield throughout a better control of limiting factors. Optimal N fertilization strategies can be derived from the Azodyn-Org model (David et al., 2004b) in order to avoid the most detrimental N deficiencies as soon as the occurrence and effect of the major limiting factors can be predicted (Casagrande et al., 2006). The aim of the work presented here is to assess early indicators of weed competition on organic winter wheat.

Previous studies linked weed density to grain yield (Dew, 1972) by considering crop density (Cousens, 1985) and weed emergence period (Cousens et al., 1987). Previous results tried to modelize the relationship between weed density and crop yield (Swinton and Lyford, 1996). However, all those models were assessed on field experiments using only one weed specie. The objective of this study is to work on natural (and complex) weed populations observed on organic fields to evaluate the relationship between grain yield and weed population.

Materials and methods

Experimental design

A farmers' fields network was designed for this experiment including 10 organic winter wheat fields,grown in 2005-2006 in various locations in the Southeast of France. The fields were chosen in order to cover a large range of environmental conditions (particularly soil types and water availability) and cropping systems, leading *a priori* to various weed pressures. Variations in weed pressures were increased, through controlled treatments with (no weeding) or without (by-hand weeding) weeds

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compared with the farmers practices. and various fertilization strategies on 2 fields. An irrigated treatment was added in 3 fields to avoid water stress..

Measurements

An homogeneous zone (around 1000 m²) regarding soil type was identified per field. Within this area, 4 to 7 sample plots (0.25 m²) per treatment were collected at harvest to measure grain yield at 0% moisture content, thousand kernel weight (TKW) and kernel number (KN).per square meter. According to the yield elaboration, KN variations expressed the vegetative period from sowing to flowering and TKW variations expressed the grain-filling period after flowering.

On these plots weed pressure and wheat development were characterized at five stages (beginning of tillering Feekes 2.0, tillers formed Feekes 3.0, first and second nodes Feekes 6.0 and 7.0, flowering Feekes 10.0 and harvest Feekes 11.0) through several variables: weed density developmental stage, and height per specie, cover rate by visual estimation and picture analysis Leaf Area Index, aboveground biomass and N content for the whole population,. Wheat was characterized by mean height, aerial biomass and N content.

Diversity indices are used to characterize communities, taking into account the richness of the community and the evenness of each species (Magurran, 1988 in Légère et al., 2005). Shannon's index (H) takes into account specific diversity and abundance (Schaepfler, 2002):

$$H = -\sum_{i=1}^{S} \frac{n_i}{N} \log \frac{n_i}{N}$$

where S is the total number of species per plot, n_i the number of individuals per species per plot and N the total number of individuals per plot.

Statistical analysis

All statistical analyses were performed by using the SAS System 8.02. Analysis of variance were conducted with the PROC GLM procedure (significance at the p=0.05 level) and the Scheffe test was used for mean comparisons when significant differences were detected (P≤0.05).

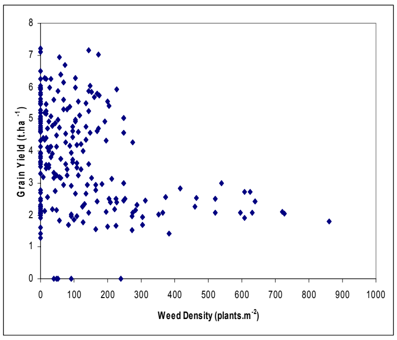
Results

Density as an indicator of weed pressure

We analysed several relationships between grain yield (GY) ($t.ha^{-1}$) and weed density (WD) ($plants.m^{-2}$) at different wheat stages. The closest relationship has been found for GY and WD at wheat flowering stage (Fig. 1). When WD ranges from 0 to 200 $plants.m^{-2}$, GY ranges from 0 to 7 $t.ha^{-1}$. When WD ranges from 200 to 300 $plants.m^{-2}$, GY decreases until 3 $t.ha^{-1}$ and beyond 300 $plants.m^{-2}$ maximum GY is about 3 $t.ha^{-1}$. Therefore, the high variability for grain yield, for each weed density should be explained by other limiting factors.

Weed dynamics as an indicator of weed pressure

It is difficult to link weed density at wheat flowering stage to density at prior wheat stages because evolutions of weed density are different from one field to another. For each field, weed density evolution was characterized either by "increasing density", "decreasing density", "constant density" or "increasing-decreasing density" depending on the behaviour of weed densities along the wheat crop cycle. We considered weed density evolution and weed density at different wheat stages as possible factors explaining wheat yield loss. Analysis of variance showed that the effect of weed dynamics with weed density as covariable was significant only at wheat flowering stage (Tab.1).



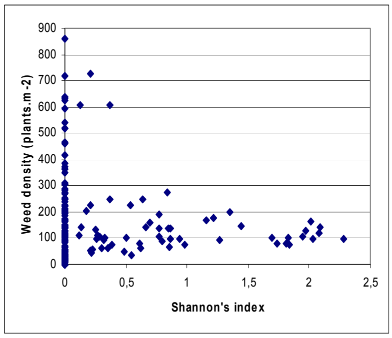


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Figure 1 (left): Effect of weed density (plants.m^{-2}) on grain yield (t.ha^{-1}) in 10 fields in Southeast of France (2005-2006)

Figure 2 (right): Relationship between the Shannon's Index at tillering and weed density at wheat floweringTab. 1: Variance analysis based on the model: GY = dynamics + WD (WD as covariable measured at wheat flowering stage)

Source	DF	SS Type III	Pr > F
Weed density Feekes 10.0	1	5427	<0.0001
Weed dynamics	3	8219	<0.0001

Grain yield was the most affected when weed density evolution was "increasing" (mean GY: 3.40 t.ha^{-1}) and the least when evolution was "constant" (average GY: 5.64 t.ha^{-1}). Mean comparisons showed non significant difference between "increasing-decreasing" (average GY: 4.24 t.ha^{-1}) and "decreasing" (average GY: 4.15 t.ha^{-1}) but significant differences between this group of dynamics and the two others: "constant" and "increasing". Then weed density dynamic seems to be a good indicator of weed pressure on grain yield.

Diversity indices as indicators of weed pressure

We tried to link weed density at flowering to the Shannon's index (H), expressing the weed diversity on field, at beginning of tillering to define an early indicator of the weed composition (Fig. 2). High weed densities (over 300 pl/m²) linked with grain yield limitation yield are related with Shannon index below 0.5 (when the weed diversity was under 2 species per field). Consequently, dominant population can affect grain yield.

Discussion

Next step will be to fit a function for the relationship between grain yield and weed density in order to determine whether the function is linear, quadratic or sigmoidal. Effect of weed density evolution was significant on crop yield. This result substantiate that previous studies showed that predicting weed emergence was critical for development of crop yield loss models (Conley et al, 203). There is also a real stake at studying diversity indicators because previous studies showed that the relative impact of weed species on crop yield varies not only with density but with ratio (Swanton et al, 1999).

If we assume that we can predict weed dynamics and density when we know weed composition at early stages, there is a great opportunity to identify weed population compositions in order to predict grain yield limitation.

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