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Will growth characteristics describe yield differently in different environments?

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Abstract

The growing interest in organic farming has increased the interest in examining if different growing characteristics among varieties would explain differences in yield differently in conventional and organic systems. The analyses were performed using data from trials with spring barley in Denmark and Sweden. The growing characteristics were included as covariates to see which growing characteristic could be used to explain the variation between varieties and the variation caused by the interaction between varieties and environments. The analyses showed that the relation between yield and the growth characteristics volume weight or grain weight depended on the growing system but in different ways in the two countries. The relation between yield and the disease powdery mildew were stronger in the conventional grown trials than in the organic grown trials. There was a tendency for the same difference to apply for the diseases leaf rust, net blotch and scald in the Danish trials and net blotch in Northern Sweden, but not for scald in Northern Sweden. None of the tendencies were significant at the 5% level.

Introduction

The increasing interest in organic grown cereals has let to the question whether the growth characteristics of the varieties describe the yield differently in a conventional growing system and an organic growing system. The paper here tries to answer this question for barley.

Data

The investigation was based on two existing datasets where trials with both systems were carried out under comparable weather and soil conditions. The two dataset were from Sweden and Denmark, respectively. For both datasets the crop was spring barley.

From Sweden the used data consisted of: 44 trials (22 conventional and 22 organic) arising from 4 locations in Northern Sweden and 9 years (between 1994 and 2004) and 50 varieties. There were in total 393 combinations of trials and varieties

From Denmark the data consisted of: 8 trials (4 conventional and 4 organic) arising from 2 locations and 2 years (2002 and 2003) and 146 varieties. There were in total 891 combinations of trials and varieties

The trials from Sweden was laid out as split-plot designs, with two different seed rates (400 and 500 germinating seeds per m^2) as main plots in the organic grown trials and two fertiliser levels in the conventional grown trials (40 and 80 kg per ha). However in 1996, 1997 and 1998 only one level of nitrogen (60 kg per ha) was used in the conventional grown trials. In order to make the seed rate and nitrogen level as equal as possible only the underlined treatments were used in the analysis. Diseases were not controlled in any of the trials. There were 2 complete replicates in all trials except for one trial where only data from replicate 1 was present.

The Danish trials were laid out as α-designs (Patterson, Williams and Hunter, 1978) with two replicates in the conventional grown trials and three replicates in the organic grown trials. The seed rate was 250 germinating seeds per m^2 in organic grown trials and 300 germinating seeds per m^2 in the conventional grown trials. In the conventional grown trials the level of fertiliser nitrogen ranged between 95 and 110 kg N ha^{-1}. In the organic grown trials the level of nitrogen in the applied manure ranged between 79 and 92 kg total N ha^{-1} (66 to 79 kg ammonium N ha^{-1}). In the conventional grown trials weeds were controlled using herbicides whereas mechanical weed control was applied in the organic grown trials. Diseases and pests were not controlled in any of the trials. The diseases was recorded 1-3 times per year and in order to have comparable data we used values interpolated to growth stage 70 (Lancashire et al., 1971). These interpolated disease data required at least 2 disease recording son both sides of growth stage 70 and were available in the data.

The following growing characteristics were used: volume weight, grain weight, heading date (only Swedish trials), lodging, powdery mildew (only Danish trials), leaf rust (only Danish trials), net blotch and scald.

Methods

For each dataset the trials were first analysed by linear mixed model in order to estimate the yield and growth characteristics for each variety in each trial. The estimates of the variety performance were then analysed in the following linear mixed model:

$$X_{slyv} = \mu_s + \upsilon_s v_{slyv} + \tau_s g_{slyv} + \eta_s h_{slyv} + \lambda_s l_{slyv} + \beta_s p_{slyv} + \gamma_s r_{slyv} + \rho_s n_{slyv} + \delta_s s_{slyv}$$

$$+\theta_s^{vg} v_{slyv} g_{slyv} + \theta_s^{pr} p_{slyv} r_{slyv} + \theta_s^{pn} p_{slyv} n_{slyv} + \theta_s^{ps} p_{slyv} s_{slyv} + \theta_s^{rn} r_{slyv} n_{slyv} + \theta_s^{rs} r_{slyv} s_{slyv} + \theta_s^{ns} n_{slyv} s_{slyv}$$

$$+A_y + B_{sy} + C_l + D_{sl} + E_{yl} + F_{syl} + G_v + H_{sv} + I_{yv} + J_{syv} + K_{lv} + L_{slv} + M_{ylv} + (N_{sylv} + P_{sylv})$$

where

X_{slyv} is the average variety performance for variety v in system s at location l in year y (as estimated in each trial)

μ_s is the estimated intercept for the 2 systems

υ_s, τ_s, η_s, λ_s, β_s, γ_s, ρ_s and δ_s are the system dependent effect of the growth characteristics v_{slyv} (volume weight), g_{slyv} (grain weight), h_{slyv} (heading date), l_{slyv} (Lodging), p_{slyv} ($\sqrt[3]{\text{powdery mildew}}$), r_{slyv} ($\sqrt[3]{\text{leaf rust}}$), n_{slyv} ($\sqrt[3]{\text{net blotch}}$) and s_{slyv} ($\sqrt[3]{\text{scald}}$) - leaving out the growth characteristics that were not present in the actual dataset

θ_s^{vg}, θ_s^{pr}, θ_s^{pn} θ_s^{ps}, θ_s^{rn}, θ_s^{rs} and θ_s^{ns} are the system dependet interactions between some of the growth characteristics - i.e. between Volumenvewight and Grain weight and between all pairs of diseases

A_y, B_{sy}, C_l, D_{sl}, E_{yl}, F_{syl}, G_v, H_{sv}, I_{yv}, J_{syv}, K_{lv}, L_{slv}, M_{ylv}, N_{sylv} and P_{sylv} are the random effects of year, system × year, location, system × location, year × location, system × year × location variety, system × variety, year × variety, system × year × variety, location × variety, system × location × variety, year × location × variety, system × year × location × variety and residual variation

A_y, B_{sy}, C_l, D_{sl}, E_{yl}, F_{syl}, G_v, H_{sv}, I_{yv}, J_{syv}, K_{lv}, L_{slv}, M_{ylv} and N_{sylv} are all assumed to be idependently and identically normally distributed with mean zero and constant variances

P_{sylv} is summed to be identically normally distributed with mean zero and know variance,

$\sigma_P^2 = \frac{1}{2k}\sum_t^k \sigma_t^2$ and thus σ_N^2 was estimated as $\hat{\sigma}_{N+P}^2 - \sigma_P^2$

k is the number of trials included in the analysis

σ_t^2 is the average variance in the differences between varieties in trial t

For more information on linear mixed models see e.g. McCulloch and Searle (2001). All analyses were preformed using the procedure Mixed of SAS (SAS Institute, 2002):

The interactions between growth characteristics depended in no case significant on the growing system. Therefore the model was simplified by using a model were only a common effect for each of the interactions was present. Therefore, the first effects to be left out were the system dependent interactions terms so that the interaction terms became common for both systems. Secondly the model was further reduced in a stepwise manner by removing the least significant growth characteristics until all remaining growth characteristics were significant at the 10% level.

Results

The effect of net blotch and scald are kept in the model for Sweden even they are not significant because the interaction term between those two diseases were significant. This model showed that the marginal effect of diseases was positive in Sweden as long as the infection rate of the other disease was less than 1.1% or 1.8%. If the infection rate of both diseases was above 1.1/1.8% then the marginal effects of both diseases were negative. If the interaction term between the diseases is ignored (even it is significant, P=1.9%) then the effect of both diseases became negative (bottom lines of Table 1), but none of them were significant different from zero. For Sweden only the effect of volume weight were significant different in two growing systems. For Denmark both the effect of grain weight and powdery mildew were significant different in the two growing systems.

Table 1. Estimated parameters and their standard errors for the effects that were significant at the 10% level

Parameter	Sweden			Denmark		
System	Conven-tional	Organic	P[a]	Conven-tional	Organic	P[a]
Volume weight	81±10	45±8	0.3	131±47		
Grain weight				189±74	203±73	0.7
V×G				-2.4±1.1		-
Lodging				-59±14		
Powdery mildew	-	-	-	-234±42	-151±36	1.9
leaf Rust	-	-	-	-172±68		
Net blotch	38±32			-236±40		
Scald	45±39			-137±50		
P×S	-		-	77±40		
R×N	-		-	172±99		
N×S	-37±16			104±53		
Volume weight for Grain weight=43	81±10	45±8	0.3			-
Grain weight for Volume weight=65	-	-	-	30±6	45±6	0.7
Net blotch when ignoring N×S	-4±27	-	-	-	-	-
Scald when ignoring N×S	-29±25	-	-	-	-	-

[a)] Probability in percent for testing the hypothesis that the dependence is equal for the two growing systems

Conclusions

The relation between yield and the growth characteristics volume weight or grain weight depended on the growing system but in different ways in the two countries. The relation between yield and the disease powdery mildew were stronger in the conventional grown trials than in the organic grown trials. There was a tendency for the same difference to apply for the diseases leaf rust, net blotch and scald in the Danish trials and net blotch in Northern Sweden, but not for scald in Northern Sweden. None of the tendencies were significant at the 5% level.

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