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DISTINCTNESS AND GENOTYPE X ENVIRONMENT INTERACTION

Document prepared by experts from Germany

Distinctness and genotype x environment interaction

1. Introduction

Document TWC/14/7 introduces the combined over years distinctness (COYD) criterion. According to this criterion, two varieties are distinct, when their difference exceeds a least significant difference (LSD), which uses the variety x year interaction mean square as an error term. This criterion is proposed to replace the earlier UPOV distinctness criterion (the "2 x 1% criterion"), which requires the varieties to be significantly different in the same direction at the 1% level in at least 2 out of 3 years in one or more measured characters. The 2 x 1% criterion uses the plot error mean square as an error term.

It is argued in this document that the COYD criterion treats genotype x year and genotype x location interaction differently. Specifically, genotype x year interactions are considered as random, while genotype x location interaction is implicitly taken as fixed. This does not seem consistent. By contrast, the 2 x 1% criterion regards both interaction components as fixed. It is argued that regarding interaction effects as fixed is appropriate for assessing distinctness. Therefore, this note suggests that TWC critically evaluate the COYD criterion relative to the 2 x 1% criterion.

2. Should genotype x environment interaction determine distinctness?

The notion of distinctness among varieties implies that for two varieties to be distinct there must be a genetic difference. Instead of comparing genomes directly, DUS testing is based on an assessment of the expression of the genotype. It is not the genotype itself, that is assessed, but an observable phenotype. The phenotype is the result of an interplay between genotype and environment, in which the expression of the genotype in the observable phenotype is modulated by changing environmental conditions. This phenomenon is closely linked to the concept of genotype x environment interaction. The observed phenotype may be modelled as the sum of effects depending on both genotype and environment (Falconer, 1981):

$$P = G + E + GE \quad (1)$$

where P = phenotypic value, G = genotypic value, E = environmental deviation, GE = genotype x environment interaction. In the context of DUS testing, environments are different years. For simplicity it is assumed here that P does not include experimental error.

For a consistent definition of distinctness it must be agreed upon, whether distinctness should involve GE effects or not. It can be argued that any GE effect is the result of operation of the genotype. A difference in GE effects implies that there must be an underlying difference in the genotype. Otherwise there would be no difference in GE effects. Thus, differences in GE effects can be seen as indicating distinctness. Consequently, a definition of distinctness should involve GE effects.

The COYD criterion regards two varieties as distinct when they differ in their genotypic value G. Thus, distinctness does not involve GE effects. Both E and GE effects are regarded as random variation. This gives rise to a mixed model, in which G is the expected value of a genotype across a population of environments. The error term used for testing distinctness comprises the GE interaction term. By contrast, the 2 x 1% criterion regards two varieties as distinct, when their phenotypic value P differs significantly in at least two years. The differences in the phenotypic value depend on both G and GE effects. The error term for detecting distinctness is the plot error mean square. In summary, distinctness according to the COYD criterion does not involve GE effects (except through the error term used for computing LSD), while the 2 x 1% criterion does involve GE effects as of model (1).

3. COYD handles genotype x location and genotype x year interaction differently

It has been pointed out in the preceding section that COYD and the 2 x 1% criterion differ in how they use information on GE effects. In this section it is argued that COYD differently handles genotype x year and genotype x location interaction.

Since distinctness trials are conducted in one location only, distinctness involves genotype x location interaction effects. To see this, write a three-way model for the phenotype (P) as follows:

$$P = G + L + Y + GL + GY + LY + GLY \quad (2)$$

where L = deviation due to location, Y = deviation due to year, GL = genotype x location interaction, GY = genotype x year interaction, LY = location x year interaction and GLY = genotype x location x year interaction. By conducting DUS trials in only one location, there is an implicit conditioning on location effects, and we can merely use a two-way model as in (1) for analysis. Acknowledging the three-way nature of our data as given by the model (2), however, it is found that we are implicitly using the following model:

$$P = G + L + GL + Y + LY + GY + GLY \quad (3)$$

$$= G' + Y' + GY'$$

where G' = G + L + GL, Y' = Y + LY and GY' = GY + GLY. Equation (3) shows that what appears as a genotypic main effect at a single location (G') is really a genotypic main effect (G) confounded with a genotype x location effect (GL) and a location effect (L). The other effects are confounded similarly. This confounding has important consequences.

To reiterate from the previous section, it can be said that COYD assesses differences among G' effects. Thus, COYD defines distinctness in a way that includes GL interaction effects, which are regarded as fixed, while GY and GLY interaction effects, which are taken as random, are excluded from the definition of distinctness (apart from the fact that these effects are used as an error term for computing an LSD). By contrast, 2 x 1% distinctness assesses distinctness in terms of P in (3), which involves all interaction effects and implicitly treats all effects as fixed.

To summarise this section it can be stated that COYD handles GL interaction effects on the one side and GY and GLY interaction effects on the other side in entirely different ways: GL contributes to distinctness, while GY and GLY do not. By contrast, the 2 x 1% criterion treats all of these three effects in the same way in that they all contribute to the distinctness among varieties. The inconsistency of COYD in the treatment of different interaction effects seems counterintuitive. It is not clear, why GL effects should contribute to distinctness, while GY and GLY effects do not. If interaction effects involving genotypes are to be included in a definition of distinctness, then it seems reasonable to treat them in a "symmetrical" way, i.e. to consider all effects as fixed.

4. Conclusion

It is argued here that both G and GE effects are a result of the operation of the genotype. Any difference in the expression of the genotype among varieties, i.e. any differences in the phenotype among varieties, reflects differences in the genotype and is thus indicative of distinctness. Thus, distinctness should be defined in terms of both G and GE effects. In this connection, Falconer (1981) may be cited, who opined that observations on the same trait in different environments may be regarded as two different traits, because of the expected differences in physiological processes and the sets of genes leading to the expression of the genotype.

Defining distinctness in terms that involve interaction effects implies that a statistical procedure should be based on a model with fixed GE effects. It would seem desirable that such definition treats GL, GY and GLY interaction alike, i.e. as fixed effects. The 2 x 1% criterion is consistent with this requirement, while the COYD criterion is not. Therefore, it is suggested that TWC critically re-evaluate the COYD criterion relative to the 2 x 1% criterion.

5. References

Falconer DS 1981 Introduction to quantitative genetics. 2nd editon. Longman, London.
TWC/14/7 The combined over years distinction criterion (1996).

H P Piepho
Institut für Nutzpflanzenkunde
Gh Kassel
Steinstrasse 19
37213 Witzenhausen
Germany

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