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Cyril Bauland, C Giauffret, Martine Leflon, Maryse Brancourt

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# Grain yield analysis of maize probe genotypes used to determine environmental limiting factors in multi-environment trials



C. Bauland, C. Giauffret, M. Leflon, and M. Brancourt-Hulmel

INRA, Unité de génétique et d'amélioration des plantes  
Estrées-Mons, BP 136, 80203 Péronne cedex, France

E-mail: brancour@mons.inra.fr

## Introduction

Genotype x environment interaction was investigated in multi-environment trials for grain yield of maize hybrids (*Zea mays*) using a crop diagnosis of yield-limiting factors. Factors that limit yield in multi-environment trials, can be identified *a posteriori* by a crop diagnosis of physical, meteorological and biological conditions. Crop diagnosis requires measurements of yield and yield components on a specific set of genotypes, called probe genotypes (Cooper and Fox, 1996). Yield can be split into two main components formed at two distinct periods: kernel number per square meter (KN) which is determined before flowering, and thousand kernel weight (TKW) which is determined after flowering. Maximal TKW is related to KN by a boundary line (Webb, 1972) and KN threshold. Maximal TKW is only reached when KN is low, KN threshold is the value beyond which one the boundary TKW decreases due to competition between the kernels during their filling. Such a model was calibrated by Siband et al. (1999) on maize with data coming from an on-farm survey. When yield or yield components of these genotypes, compared with pre-established optimal values are reduced, one or several factors that limited yield or yield components can be diagnosed.

## Material & methods

In our study, the model was calibrated with experimental data corresponding to 6 commercial hybrids tested in 37 environments in France (combinations of year and INRA maize trial network site): Antares (very early flint dent), Banguy (early flint dent), Anjou285 (semi early flint dent), DK312 (semi early dent), Naudi (semi late dent), and Cerbere (dent late).

The maximum values for TKW and grain yield were derived from the data for each probe genotype, assuming that in some sites, the full potential of the cultivar was expressed. For these maximum values, empirical mean and confidence interval were estimated by sampling with replacement 18 individual observations 1000 times (fig 1).

Deviations of yield components were determined for each probe genotype in each environment (fig 1). Deviation of kernel number (DKN) describes the time-period until silking. Reduction of thousand kernel weight (RTKW) describes the grain-filling period.

Genotype\*environment interactions observed for deviations of yield components were related to climatic covariates according to a factorial regression model (Denis, 1988). We assume that differences in genotypes susceptibilities to an environmental limiting factor lead to differences in the regression slopes of the yield component deviation to the climatic covariate.

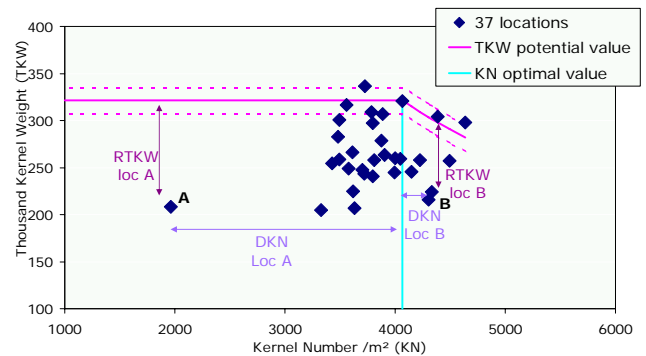


Fig 1. Determination of optimal values for TKW and KN for the probe genotype Antares and example of deviations to optimal value (RTKW and DKN) for two locations A and B.

	Antares	Banguy	Anjou285	DK312	Naudi	Cerbere
Maximum TKM	321	310	280	312	319	361
KN threshold	4068	4261	5037	4839	4406	4923
Highest RTKW	116	105	135	178	210	218
Highest DKN	2104	1547	1085	1896	1051	2654

Tab1. Optimum values of yield components for the six probe genotypes and maximum deviations from these values observed in our study.

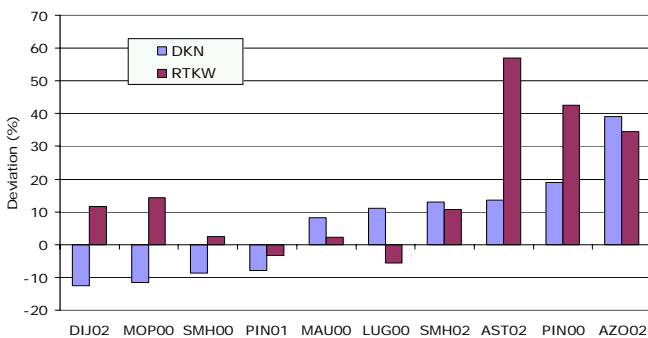


Fig 2. Contrasted environments for reduction of yield components : deviation of KN (DKN) and reduction of TKW (RTKW) observed on probe genotype DK312

## Genotype\*environment interaction study

Genotype\*environment interactions for DKN and RTKW were significantly explained by various environmental indicators used as covariates. For example, indicators related to low temperature stress were used, such as the number of days with mean temperature below 15°C (ndlow15), the number of days with day-night amplitude over 2°C (ampdn) and longest period with photoinhibitory conditions (mean temperature below 10°C and maximum radiation over 130 J/cm²) (photoi130). While these covariates had not always a significant effect on the mean value of environments, they accounted for 14 to 24% of the genotype \* environment interaction sum of squares (fig 3).

Before silking, Antares and DK312 were the most tolerant genotypes to cold stress, while Anjou285 and Cerbere were the most susceptible. During the grain-filling, Banguy and Antares were the most tolerant, Cerbere was the most susceptible.

## Conclusion

Crop diagnosis allowed us to determine the main yield-limiting factors of each environment, and their period of occurrence. The identification of these limiting factors will help in a further analysis of quantitative trait loci involved in maize cold tolerance.

## Average behavior of hybrids and characterization of environments

A great variability was observed among the hybrids for the optimal values and for deviations of yield components in the tested environments (tab 1). Optimal thousand kernel weight exceeded 300 g for all hybrids, except Anjou285. The two semi-early genotypes have formed their yield in a different manner: maximum TKW was higher for DK312 than for Anjou285 while their KN thresholds were similar. The semi-late and late genotypes, Naudi and Cerbere, showed the highest reductions for TKW (in early environments).

Diversity was also observed among environments. According to DK312 behavior, most environments showed limiting factors during the whole formation of yield (fig 2). Few environments were free from stress (SMH00, PIN01) or seemed to be affected only before flowering (MAU00, LUG00) or only after flowering (DIJ02, MOP00). The environment with a very high reduction of both components was AZO02, where a lower nitrogen supply was applied.

In a given environment, yield components could be affected for all probe genotypes (PIN00 for TKW), or for some genotypes (MON00 for TKW) (data not shown). Thus genotype\*environment interactions were further analyzed.

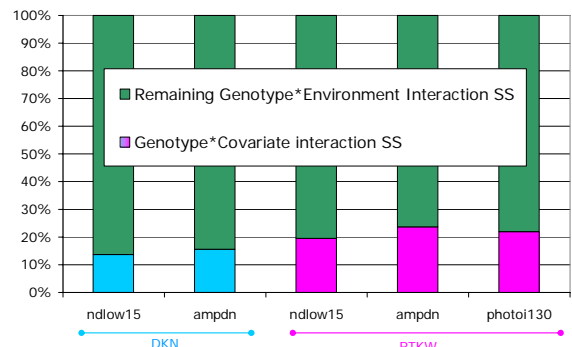


Fig 3. G\*E interaction observed for the reduction of yield components before silking (DKN) and during grain-filling (RTKW) : percentage of the sum of squares accounted for environmental indicators (ndlow15, ampdn, photoi130).

## Acknowledgments

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## References

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