Variety Types and Adaptation to Environmental Constraints

- Objective

During this first project on GXE Interaction, the different types of plant varieties and their advantages and disadvantages in terms of adaptation to environmental and cultivation constraints will be studied.

CASE STUDY 1. Analysis of the performance of different maize genotypes in different growing environments: Analysis of the Genotype X Environment (GXE) interaction.

A seed company has developed 10 new F1 hybrid varieties of maize (*Zea mays*) and wishes to know if some of these varieties are particularly well adapted to the growing conditions of 5 different production zones of the Corn Belt in the USA. Which variety(ies) to develop and sell according to the environmental conditions of each production area? This is the question the company wants to answer.

To answer this question, a performance evaluation of the 10 maize varieties (namely Gen_1 to Gen_10) is conducted in 5 test stations (namely Env_1 to Env_5) characterized by different environmental conditions. For each variety in each site, the grain yield (measured in quintals per hectare) was evaluated by measuring four samples taken randomly (Rep 1 to 4 for each environment).

In the analysis of this case study, statistics will be used as a decision tool to determine which varieties to develop in different growing environments.

Guidelines for analysis.

1. *By relying on graphical representations of the data,*
   - *you will discuss the quality of your dataset (ex. existence of outliers…),*
   - *you will discuss the potential existence of an effect on the yield of the genotype of the variety, the environment and the interaction between the genotype and the environment (these effects will of course then have to be validated -or not- statistically!)*

2. *You will conduct statistical analysis to test the effect on yield of variety genotype, environment, and the interaction between genotype and environment.*
   After showing that the postulates of the statistical method you will have used are verified, you will interpret the results as to the effects of the two factors of interest (genotype and environment) and their interaction.
   What does this mean for the seed company?

3. *After having statistically proven the significant effect of the study factors and/or their interaction (see question 2), you will continue your statistical analysis of the data by implementing a method making it possible to identify the genotype(s), environment(s) and/or genotype/environment combinations giving significantly superior performance.*
   Based on the results of this statistical analysis, what commercial strategy would you adopt (choice of variety(ies) to market, distribution of these varieties in which production area(s)…)? Justify.

Varieties of the 'F1 hybrid' type are the most marketed for allogamous species for which it is easy to control crosses between the parental lines. However, in some unstable growing environments, it is possible to grow blend varieties (i.e. A seed mixture or seed blend intentionally produced, randomly mixed set of two or more kinds of crop seed genotypes).

4. *Present these 2 types of varieties* - 'F1 hybrids' and mixed varieties, *including their genetic characteristics. What are their advantages and disadvantages (particularly in terms of selection, marketing, crop itinerary constraints and agronomic outlets, etc.)?*

The Env_3 production area is particularly prone to Stewart's disease, or Stewart's wilt, a serious bacterial disease of field corn caused by a bacterium, *Pantoea stewartii*. This bacterium affects plants, especially different types of corn, including sweet corn and flint corn. The disease is endemic in the United States, particularly in the southern part of the Corn Belt. The corn flea beetle (*Chaetocnema pulicaria*) is the primary insect vector and overwintering host of *Pantoea stewartii*. The bacterium overwinters in the digestive tract of the adult insect and in the spring, spreads when the adult beetles feed on the young seedlings. Thus, the survival of the insect vector during the winter months, particularly in north-central America, is the key factor in the development of the disease. This occurs in two stages: wilting of the seedlings, when the growing point dies, and "burning" of the leaves, in the form of white streaks along the veins on the leaves of adult plants. Sweet corn has been found to be more susceptible than other corn varieties, although some hybrids and inbred lines are also very susceptible. The incidence of Stewart's wilt can be effectively controlled through the use of flea beetle insecticides and disease resistant maize hybrids, the latter being the most effective method.

The hybrid identified as the best performer in Env_3 is very susceptible to this disease.

5. *Could a blend variety be developed for growing maize in the Env-3 region? If so, what mix would you suggest? What are the characteristics of the genotypes to be mixed to be checked beforehand?*

Joint Regression Analysis (JRA) has been widely used in crop sciences, to structure and understand Genotype by Environment Interaction (GEI) (Eberhart and Russell, 1966; Finlay and Wilkinson, 1963; Gusmão, 1985; Mooers, 1921; Pereira and Mexia, 2008; Yates and Cochran, 1938; Zheng et al., 2009).

In this model, the data is expressed as follows:

$$y_{ijk} = \beta_0 + \alpha_{\text{genotype i}} + \beta \cdot \text{Index} + \gamma_{\text{genotype i}} \cdot \text{Index} + \varepsilon_{ijk}$$
$$= \beta_0 + \alpha_{\text{genotype i}} + (\beta + \gamma_{\text{genotype i}}) \cdot \text{Index} + \varepsilon_{ijk}$$

6. *Using joint regression analysis (JRA), a model based on the Finlay-Wilkinson regression to analyze multi-environment trials, you will refine the analysis of the genotypes response to environmental variations and characterize the F1 hybrids as follows:*
   - which are the genotypes which behave as expected regarding the improvement of environmental growing conditions?
   - which are the genotypes that make the best of the environmental resources available?
   - which are the genotypes that waste resources?