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Phenotyping methods to assess grain yield of maize inbred lines and hybrids under different water regimes

Diploma – Thesis

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Introduction

Maize is the most important cereal crop for food in Sub-Saharan Africa and Latin America, and a key fodder crop in Asia. Declining soil fertility and environmental stresses affect maize production and health in less developed regions (CIMMYT 2007). Among the agronomically important grasses, maize is the most susceptible to drought at flowering (Sangoi & Salvador 1998), but is grown under rainfed conditions more often than rice and wheat. Of the approximately 138 million hectares of maize grown in the world, 82 % is rainfed. Over 60 % of the total maize area worldwide is located in developing countries, where the average rainfed maize production is 3.4 tons per hectare. Rainfed maize production contributes 66 % of the total yield in developing countries, 81 % in developed countries, and 74 % globally (Rosegrant et al. 2002).

Increasing drought tolerance is one way to achieve the goal of higher yielding crops to guarantee food security. Therefore, breeding for drought tolerant cultivars is important, in order to deal with climate change and increasing world population. Regardless to this fact, abiotic stress tolerance is often ignored by commercial breeders in developing countries because for them, high yielding and high-input farmers are a more attractive target (Bänzinger 2000). The goal of the International Maize and Wheat Improvement Center (CIMMYT) is to supply resource poor farmers in developing countries with stress tolerant cultivars. They initiated breeding for drought tolerance in maize in 1975 (Monneveux et al. 2006).

The best breeding strategy for drought tolerant cultivars is often matter of dispute in scientific literature. Ceccarelli et al. (1994) stated that selection was often conducted in favourable environments as it is believed that these allow the full expression of genetic differences for yield potential. Selection under drought has been considered less efficient because of lower heritabilities for grain yield under stress (Blum 1988). This effect occurs because genetic variance for yield decreases more rapidly than the environmental variance among plots with increasing stress (Bolaños & Edmeades 1996). On the other hand, the breeder should be aware of lodging and disease resistance, which should be better selected for in the target environment because ideal conditions may be irrelevant (Ceccarelli et al. 1994).

Another issue often discussed in breeding for drought tolerance is the use of secondary traits versus the primary trait grain yield or other yield parameters (Blum 1988). There are many benefits expected from breeding with the help of secondary traits, which could be the time and money saving assessment of the ears per plant (EPP) or flowering parameters like the anthesis-silking interval (ASI), as described in Bolaños & Edmeades (1996), Bertrán et al. (2003) and Bänziger et al. (2000). An ideal secondary trait should be: genetically associated with grain yield under stress; highly heritable; genetically variable; cheap and fast to measure; stable within the measurement period; not associated with a yield penalty under unstressed conditions; observed at or before flowering, so that undesirable parents are not crossed and finally a reliable estimator of yield potential before final harvest (Edmeades et al. 1998). Bänzinger et al. (2000) stated that many recommendations on the use of secondary traits have been made to breeders, based on genotypic correlations between such traits and grain yield. Unfortunately, many such correlations have been calculated from few varieties where outlying values may greatly affect the sign and magnitude of the correlation. In addition, for a breeder it is not sufficient to know that a secondary trait is related to drought or low N tolerance. Rather, it is important to know that breeding progress using grain yield and a given secondary trait in selection is greater than progress using grain yield alone. Thus, secondary traits must not only be identified, but their value in breeding must be proven.

A special secondary trait attracting interest is the use of spectral reflectance during the crop cycle. The aim is to relate special spectral indices like the normalized difference vegetation index (NDVI) or the whole range of wavelengths with yield parameters in order to obtain predictions of yield. Spectral reflectance of the plant canopy is a non-invasive phenotyping technique that enables the monitoring with high temporal resolution of several dynamic complex traits, such as biomass accumulation (Montes et al. 2007).

With this study, we are aiming to investigate the potential of indirect traits and novel phenotyping methods to predict grain yield of maize under different water regimes. The objectives are (i) to estimate variance components and repeatabilities/heritabilities for grain yield and other physiological traits related to grain yield, (ii) to estimate the phenotypic and genotypic correlations of the traits in each water regime and among different water regimes, and (iii) to assess the potential of spectral reflectance for prediction of grain yield under drought.

Conclusion

The assessed traits of the present study proposed for selection of drought tolerant genotypes are related to physiological bases of drought tolerance in plants. The most promising secondary physiological traits are flowering time, ASI, and number of ears. While the highest gain of selection of these traits can be assessed in the stressed target environment, selection for grain yield can take place in both, stressed and well-watered environments. Other secondary traits like SPAD, NDVI or LR are easy to measure but do not show a stable development in their behaviour under the three different water regimes. The use of spectral reflectance for prediction of grain yield does not show promising results in the present study. Technical improvements and modifications should be made in the procedure of data assessment.