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Effects of Pre-anthesis Drought Stress and Nitrogen on Yield, Nitrogen Use Efficiency, and Grain Minerals of Tropical Maize Varieties

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by

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1. SUMMARY

In the tropics, water and nitrogen (N) are the factors that limit the grain yield of maize (*Zea mays* L.) the most. The risk of water shortage in Thailand is greatest during the vegetative stages of maize development. A three-year study with two water regimes (pre-anthesis drought vs. irrigation throughout the vegetative phase), three levels of N fertilization (0, 80, 160 kg N ha^{-1}), two open-pollinated varieties (Suwan 1 and La Posta Sequia), and two hybrids (KTX2602 and DK888) was conducted in the tropical lowlands of Thailand on an ustic, isohyperthermic, kaolinitic oxisol. The main aim of the study was to determine the interactive effects of pre-anthesis drought stress, N fertilizer rate, and variety on the grain yield, yield components, and harvest index of maize. Several N-related parameters, such as the total amount of shoot N, N utilization efficiency (grain yield per unit shoot N), shoot N concentration, N harvest index (proportion of grain N to total amount of shoot N), and apparent fertilizer N recovery, were investigated to determine their suitability as breeding traits for increased N use efficiency. A further objective was to determine whether the grains of tropical maize varieties have different concentrations of minerals and to which extent varietal differences are affected by the availability of N and water.

Averaged across the N rates and varieties, drought-stressed maize yielded 32% (1995), 13% (1996), and 21% (1997) less than well-watered maize. Irrespective of the variety, 80 kg N ha^{-1} were sufficient to achieve maximum grain yield under pre-anthesis drought, whereas more than 160 kg N ha^{-1} seemed to be required for maximum yield in the well-watered environment. Pre-anthesis drought significantly reduced the number of kernel rows, the number of kernels per row, as well as the 1000-kernel weight; the effect of the water regime on the ear number of the semi-prolific DK888 varied from year to year. Drought stress consistently resulted in marked increases in the harvest index. There were significant effects of the water regime by variety interaction on grain yield in two of the three cropping seasons (1996 and 1997). KTX2602 was more affected by drought than Suwan 1 in all the years and, in two of the three years more than La Posta Sequia. This was attributed to the fact that KTX2602 was the earliest variety. In 1997, the strong grain yield response of DK888 to continuous irrigation was probably responsible for the significant water regime by variety interaction. The drought stress was much milder in 1996 than in 1995 and 1997. This, in part, explains why the drought-stressed plants yielded best in 1996. In 1996,

DK888, the top yielder, produced almost the same grain yield under drought stress and continuous irrigation. Unfavourable weather conditions shortly after silking (low irradiation in combination with relatively high temperature) seemed to limit the grain yield of well-watered DK888.

Drought increased the shoot N concentration and the N harvest index and decreased the total amount of shoot N and the apparent fertilizer N recovery in all the years; the effect on the N utilization efficiency varied among the years. The adverse effects of drought on total amount of shoot N increased with increasing N rate. The grain yield, the total amount of shoot N, and the shoot N concentration increased and the N utilization efficiency, the N harvest index, and the apparent fertilizer N recovery decreased as the rate of N application increased. The varieties differed significantly in shoot N concentration, N utilization efficiency, and N harvest index in all the years. However, there were several sporadic interactions, suggesting that it is impossible to generalize about the effects of drought, N rate, and variety on the indicators of N use. Selecting for high N utilization efficiency or low shoot N concentration will result in a lower concentration of protein in the grain and stover, thus reducing the dietary value of maize for protein-deficient humans and livestock. Selecting for high apparent fertilizer N recovery may result in varieties that are inefficient in absorbing N from soils low in plant-available N.

The concentrations of N, P, K, Mg, Ca, Mn, Zn, and Cu in the grains were determined. While the water regime did not affect the mineral composition of the grains in any of the years, the application of N fertilizer consistently reduced the concentrations of Ca and Zn and consistently increased the concentration of Mn in the grains. There was genotypic variation in the concentration of all the elements investigated; the top yielder, DK888, consistently had the lowest concentrations of N, P, Mg, and Cu in the grain. In some cases, variety interacted with water regime or N rate, but the interactions were inconsistent across the years. The water and N treatments had a minor impact on the ranking of the varieties. Thus, at a given site, varietal differences in the concentrations of grain N and minerals seem to be fairly stable across wide ranges of water and N supply. The varieties which differed most in the N and P concentrations (KTX2602 and DK888) had about the same endosperm-to-germ dry weight ratio. While the study showed that the concentrations of grain minerals are well buffered and remain stable even when the grain yield increases markedly as a result of water and N fertilizer applications, it must still be determined whether higher grain yields, as a result of breeding progress, lowers the levels of

grain minerals and protein.

It is concluded that selecting for high N utilization efficiency alone is not a promising route to developing nutritious maize in tropical countries. Since there are indications that breeding for drought tolerance simultaneously improves the potential yield of genotypes under low N, it might be wise to focus on drought tolerance only.