Genetic gains in grain yield of extra-early maturing maize cultivars of three breeding eras under multiple stress environments

Introduction

Maize is an important staple food, animal feed, and industrial crop in sub-Saharan Africa (SSA). The savannas of West and Central Africa (WCA) offer ideal environments for maize production because they are characterized by high incoming solar radiation, low incidence of pests and diseases, and low night temperatures. However, recurrent, low soil nitrogen (low-N), and Striga hermonthica (Del.) Benth. act and interact to limit maize production and productivity in the savannas. Drought can reduce grain yield of maize by as much as 90% when it occurs at the most sensitive stage of the crop growth, i.e., a few days before anthesis to the beginning of grain filling period (NeSmith and Ritchie 1992). Nitrogen is a major requirement for high levels of maize productivity but it is the most limiting nutrient in tropical soils. A fertilizer rate of 90–120 kg N ha⁻¹ is recommended for increased maize grain yield in SSA. However, fertilizer application rates are far below the recommended doses in the sub-region due to the unavailability or the exorbitant prices of inorganic fertilizer for resource-poor farmers. The estimated annual loss of maize yield due to low-N stress varies from 10 to 50% per year in SSA (Wolfe et al. 1988). Breeding for tolerance to low-N offers the most economical and sustainable approach for increased maize yield in WCA. Striga infestation can cause total crop failure (Badu-Apraku et al. 2010) and in the recent past has forced farmers in the sub-region to abandon their farmlands. Under field conditions, drought, Striga, and soil nutrient deficiency occur simultaneously and the combined and individual effects can be disastrous. Studies by Badu-Apraku et al. (2004) have shown a substantial loss of 53% under drought stress and 42% under Striga infestation. Consequently, breeding for extra-early maturing cultivars with enhanced tolerance to drought and resistance to Striga is crucial for improved productivity and stability in drought-prone areas in WCA. The International Institute of Tropical Agriculture has developed extra-early maturing maize cultivars during three breeding eras (Era 1, 1995–2000; Era 2, 2001–2006; and Era 3, 2007–2012). The availability of these extra-early maize cultivars has resulted in the expansion of maize production into new frontiers replacing the traditional early maturing cultivars such as sorghum (Sorghum bicolor) and pearl millet (Pennisetum glaucum) in the savannas of WCA. However, information is completely lacking on the genetic gains in grain yield and other agronomic traits during the three breeding eras. The identification of traits associated with yield improvement during the three breeding eras under multiple stress and non-stress environments, and identify high-yielding and stable cultivars across environments for commercialization in the sub-region.

Materials and methods

Fifty-six extra-early maturing maize cultivars comprising 12 from Era 1, 19 from Era 2, and 25 from Era 3 were evaluated under 23 multiple stress (drought, Striga, and low-N) and 29 nonstress environments in WA (Nigeria, Benin, and Ghana) in 2013 and 2014. The trials were laid out in a 8 × 7 lattice design with three replications. Each experimental plot consisted of two rows, 5 m long, spaced 0.75 m apart with 0.40 m between plants within the row in all environments. Three seeds were planted per hill and seedlings thinned to two per stand about 2 weeks after emergence, resulting in a final plant population density of 66 667 plants/ha. Data were collected on grain yield and other agronomic traits in the stress and non-stress environments. Analyses of variance, combined across multiple stress and non-stress environments were performed on plot means of each trial with PROC GLM in SAS 9.3 (SAS Institute 2011). Regression of each variable of year cultivar development was done to estimate gain/year. The regression analysis and the graphical display of the regression lines as well as the distinction among the different eras were performed using Excel software 2007. The GGE biplot software was used to identify the highest yielding and stable cultivars across test environments.

Results and Discussion

Under multiple stress environments, grain yield ranged from 1752 kg/ha for cultivars bred during Era 1 to 2066 kg/ha for those developed during Era 3 with a corresponding genetic gain of 4.24% per year. Under non-stress environments, grain yield ranged from 3017 kg/ha for cultivars bred during Era 1 to 3673 kg/ha for those developed during Era 3 with an annual genetic gain of 1.07%. The average rate of increase in grain yield was 24 kg/ha per year under multiple stress and 34 kg/ha per year under non-stress environments (Table 1).

Genetic gains in grain yield from first to third era cultivars under multiple stresses was associated with improved ear aspect, increased days to silking, reduced anthesis-silking interval, and decreased root and stalk lodging whereas no significant gain was observed for grain yield under non-stress environments. However, good progress was made for improved husk cover, increased ears per plant, and reduced anthesis-silking interval from first to third era cultivars (Table 1).

Conclusion

Based on the relatively high average rate of increase in grain yield of 24 kg/ha per year under multiple stress and 34 kg/ha per year under nonstress environments, with a corresponding annual genetic gain of 1.42 and 1.07%, respectively, it may be concluded that considerable progress has been made in breeding for maize tolerant, extra-early maize cultivars in the sub-region. Commercialization of these cultivars should contribute to food security and improved livelihoods of farmers in SSA.

Acknowledgement

The authors are grateful for the financial support of the Drought Tolerant Maize for Africa (DTMA) project and IITA for this research. The technical assistance of the staff of the Maize Improvement Program of IITA is gratefully acknowledged.

References


