Physiological and morphological changes associated with selection for yield under low soil nitrogen in maize (Zea mays L.)

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Introduction

Recurrent selection methods have been widely used by maize breeders for population improvement. Studies have also shown that correlated gains have also been obtained in physiological traits that promote efficiency in growth, development, and partitioning in plants (Buck 2005). Gains in grain yield from selection have been reported in the populations used in this study (Ajala et al., 2012) but little information is available on the physiological traits that may have resulted in the observed increase in yield. The study was therefore carried out to identify the morphological and physiological traits that were associated with yield in the populations that had undergone two to three cycles of selection for tolerance to low nitrogen and to determine the relationship between the physiological traits and yield of maize.

Materials and methods

The experiments were conducted at IITA Ikenne (6°8′N, 3°7′E) and Ibadan (7°30′N, 3°54′E) stations, Nigeria. The populations used for this study were: TRL Comp 1C, BRR928 DMRSR, Acr 97 T2L Comp 1-W, LNTP-W, and TRL Comp 1-W, 197, and TRL Comp 1-W, 198, with high vs. low soil nitrogen environments (previously grown) to compare physiological traits in the two environments. The plants were separated within each low-N (45 kgN/ha) and high-N (90 kgN/ha) environments obtained by supplying the balance of required nitrogen from previously depleted fields, while trials in Ibadan were planted in three high-N and one low-N environments generated in similar way to that of Ikenne. Trials in each N-block were laid out as a randomized complete block (RCBD) with four replications. The N-fertilizer levels were separated from one another by 5 m to minimize N movement. For each N-level, plots consisted of two rows of 5 m length spaced at 0.75 m between rows and 0.25 m between rows within the plot. The rows were bordered by an early maturing shorter variety to aid collection of data from the two test rows. Both high and low-N blocks received 45 kgN/ha from NPK 15:15:15 application at 2 weeks after sowing (WAS), while the high-N blocks received an additional 45 kgN/ha for application of urea at 6 WAS. Normal agronomic practices were maintained all the growth period of the crops.

One of the two test rows was used for yield determination while the other row was used for destructive sampling. Data collected were plant height, anthesis-silking interval, and leaf chlorophyll concentration using SPAD. Destructive sampling was done at 6 and 10 WAS. Leaf area was measured using a leaf area meter LICOR 3100. Plant parts were separated in the laboratory and dried for 24 h at 75°C in a forced draft oven to constant weight. From the dry weight and leaf area measurements, the following growth parameters were computed on the basis of the formula used by Watson (1952) : Leaf area index (LAI), Leaf area ratio (LAR), Leaf area duration (LAD), Crop growth rate (CGR), and Net assimilation rate (NAR). At harvest, rob length (cm), ears per plant, number of kernels per row, 100 kernel weight, and kernel length were determined. Grain yield was measured in mg/ha adjusted to 15% moisture content.

ANOVA for RCBD was carried out on agronomic and physiological traits using the GLM procedure from SAS statistical software (SAS Institute Inc. 2013). Correlation coefficients were also determined between traits. Gains from selection for the two populations that had recently undergone two cycles of selection for enhanced levels of tolerance to low-N were estimated using regression analyses with cycles of selection evaluated in each population as the independent variable and the corresponding trait as the dependent variable. The comparison of means of different cycles of selection in each population was also done by partitioning the cycle’s sum of squares into linear contrasts.

Results

- CGR and SPAD chlorophyll readings had significant positive correlation with grain yield (P < 0.01) under low and high-N conditions (Table 1).
- LAD increased in Acr T2L Comp 1-W, TRL Comp 1-W, and in Acr T2L Comp 1-W, 198, in response to selection in both low and high N (P < 0.05). Improved cycles of BRR928 DMRSR, LNTP-W, and TRL Comp 1-W, 198, had higher LAI than the earlier versions in both N-environments (Table 2).
- CGR increased in response to selection in Acr T2L Comp 1-W, BRR928 DMRSR, and TRL Comp 1-W at 90 kgN/ha and in Acr T2L Comp 1-W, LNTP-W, and TRL Comp 1-W at 90 kgN/ha (Table 2).
- Significant yield gains were obtained in Acr T2L Comp 1-W, TRL Comp 1-W, and TRL Comp 1-W at 45 kgN/ha. At 90 kgN/ha, yield increased subsequent cycles of selection in Acr T2L Comp 1-W, TRL Comp 1-W, and Acr T2L Comp 1-W, 198, in response to selection in both low and high N environments (Table 3).
- Increment in Acr T2L Comp 1-W was accompanied by increment in kernel rows, 100 kernel weight and number of kernels per row, while the increment in grain yield obtained in LNTP-W was accompanied by increase in 100 kernel weight at both low and high-N environments (Table 3).

Table 1. Correlation coefficients between selected agronomic and yield traits and physiological traits at silking of populations of maize grown under low-N and high-N conditions at Ikenne and Ibadan.

Table 2. Means of physiological traits obtained from the evaluation of different cycles of selection for tolerance to low soil nitrogen (N) in six maize populations at two N levels in Ikenne and Ibadan in 2012 and 2013.

Table 3. Means of yield and yield traits obtained from the evaluation of different cycles of selection for tolerance to low soil nitrogen (N) in six maize populations at two N levels in Ikenne and Ibadan in 2012 and 2013.

Conclusions

- Crop growth rate and chlorophyll concentration were the traits most associated with grain yield under low soil nitrogen.
- Response to selection was significant in some populations while additional cycles of selection will be required in others to significantly shift gene frequencies in the desired direction.

References


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