Heritability and genetic advance in recombinant inbred lines of tef (Eragrostis tef)

Hailu Tefera, Kebebew Assefa, Fufa Hundera, Tiruneh Kefyalew & Tesfaye Teferra
Debre Zeit Agricultural Research Center, Ethiopian Agricultural Research Organization, P.O.Box 32, Debre Zeit, Ethiopia; (for correspondence; e-mail: DZARC@telecom.net.et)

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Summary
Recombinant inbred lines (RILs) of the tef cross Kaye Murri × Fesho were evaluated for nine quantitative traits at three locations in the central highlands of Ethiopia during the 1998/99 main season in order to estimate the genetic coefficient of variation (GCV), heritability and genetic advance expected from selection. Highly significant differences were obtained among the RILs for all traits studied. Grain yield, panicle weight and yield per panicle showed a relatively high GCV (12–16%). A comparatively high heritability was obtained from days to heading (31%) followed by panicle length (25%) and grain yield (23%). Moderate amounts of heritability values were obtained for panicle weight and yield per panicle. High genetic advance as percent of the mean were obtained from grain yield (16%), yield per panicle (12%) and panicle weight (10%) at 5% selection intensity, which indicated the possibility of improving these traits. Several RILs were identified that have exceeded the better yielding parent at all locations. Grain yield showed a strong positive association (r = 0.26–0.70) with shoot biomass, lodging index, panicle length, plant height, panicle weight and yield per panicle. Overall, the present results showed a) the availability of genetic variance for some useful traits in the RILs for exploitation through selection, b) the existence of significant genotype × location interaction that indicated the need to test inbred populations in more environments, and c) the availability of superior inbred lines for further breeding work.

Introduction
Of the 350 species of the genus Eragrostis of the grass family Poaceae, tef (Eragrostis tef) is the only cultivated species as a staple cereal. It is a self-pollinating and allotetraploid species with 2n=4x=40 (Berhe, 1981; Tavassoli, 1986). Tef is one of the contributions of the Ethiopian farmers to our world in domesticating this unique cereal crop. It is a highly valued crop in Ethiopia both by farmers and consumers. It is primarily grown for its grain that is used for making the special Ethiopian bread known as injera, which is very popular in the national diet. For Ethiopian farmers tef is the most resilient crop that grows in diverse agroecological areas with low risk of failure and fetches high price in the market compared to other cereals. The preference of consumers for its best quality injera has led this crop to be in high demand that encourages farmers to grow it on a large hectarage. Currently, tef is cultivated on about a little over two million hectares of land, which is 30% of all cereals grown in the country (Central Statistical Authority, 2000). It contributes about 22% of the annual grain production of cereals. The total annual production of tef is surpassed by maize because the national average grain yield of tef is low (0.9 ton/ha). In contrast to maize, most tef areas are not covered by highly improved varieties.

Little effort has been made to improve tef as compared to the other cereals because the importance of tef as food crop in the world has hitherto been localized. Efforts to improve tef in the past have mainly relied on pure line selection, mass selection and composite evaluation from the locally available germplasm pool. Although the crossbreeding technique for tef has been discovered 25 years ago, variety development through
trait recombination has so far been little exploited in the breeding program. The main reason is that the tiny florets of tef are not amenable for easy manipulation by the naked eye. The requirement of a dissecting stereomicroscope for emasculation and pollination has hindered routine use of the technique.

The limited crossbreeding effort in the past indicated that varieties developed through trait recombination have shown a 9% yield advantage as compared to those developed through direct selection from germplasm materials (Teklu, 1998). However, information on the level of genetic variability, heritability and genetic advance of traits in recombinant inbred lines of tef is non-existent. This study was, therefore, aimed to estimate the level of genetic coefficient of variation, heritability and genetic advance in recombinant inbred lines of tef.

Materials and methods

Cultivars Kaye Murri and Fesho were crossed to produce the F_{0} recombinant inbred lines (RILs) used for this study. Kaye Murri is a tall, thick-culmed, and late maturing cultivar with compact panicle. On the other hand, Fesho is a short, thin-culmed and early maturing cultivar with very loose panicle. Kaye Murri has relatively better lodging resistance because of its good culm characteristics. The cross between these cultivars was done in 1990 and F_{2} seeds kept from the cross (Tefera, 1993) were germinated in petri dishes in 1995 and a total of 400 individual plants were raised to maturity in 12-cm pots in the glasshouse at the Debre Zeit Agricultural Research Center in Ethiopia. The RILs were developed through single seed descent method up to F_{7} generation. It was possible to raise three to four generations per year under glasshouse conditions. The F_{2}-derived F_{8} seeds obtained from individual F_{7} plants were increased and lines were established.

One hundred sixty five F_{9} RILs were randomly selected and grown in a randomized complete block design with four replications at Debre Zeit, Akaki and Alemtena in the central highlands of Ethiopia in the 1998/99 main growing season. The altitude and mean annual rainfall at Debre Zeit were 1900 m and 812 mm, respectively. On the other hand, the Akaki site had an altitude of 2200 m with an annual rainfall of 1000 mm. The site at Alemtena had an altitude of 1600 m with annual rainfall of 638 mm. The soils at Debre Zeit and Akaki are black clay (Vertisols), whilst that of Alemtena is sandy loam. Akaki is a relatively cool highland with minimum/maximum temperature of 9.3/23.7 °C and Alemtena is warmer lowland 14.1/28.3 °C site. Debre Zeit is a mid-altitude site with min./max. temperature of 11.8/27.6 °C.

The RILs were sown in three-row plots each having one meter length on July 21, August 4 and August 20, 1998 at Alemtena, Debre Zeit and Akaki, respectively. The distance between rows within a plot was 10 cm and one-meter spacing was used between plots. The parents were also included in the experiments and each parent was represented with two plots in each replication. Plots were fertilized as per the recommendation for each location. Nitrogen at the rate of 60 kg/ha and P_{2}O_{5} at the rate of 60 kg/ha were applied at Debre Zeit and Akaki and the N rate was reduced to 40 kg/ha for the sandy loam soil of Alemtena. Other crop management practices were followed as per the recommendation for each location.

During the course of the study, nine traits were measured. These included days to heading, days to maturity, panicle length (cm), plant height (cm), panicle weight (g), yield per panicle (g), shoot biomass (g), grain yield (g) and lodging index. Lodging assessment was performed as per the procedure of Caldicott & Nuttall (1979). Shoot biomass, grain yield, lodging index, days to heading and maturity were measured on a plot basis. The remaining traits were measured as an average of ten random samples of plants per plot. At heading time, ten random main tillers were tagged for measuring plant height and panicle component traits.

Plot means were used for all forms of analyses. Variance analyses were carried out using MSTATC statistical package. In this paper main emphasis is given on the combined analysis. Of the 165 RILs planted at Debre Zeit, Alemtena and Akaki, 118 RILs that were common across the three locations were considered for combined analysis.

Estimate of heritability (h²) values was carried out following Singh & Ceccarelli (1996). For this experiment, which is conducted in a randomized complete block design with 118 RILs (g) and four replications (r) over three locations (L), the model of the experiment is as follows.

\[ Y_{ijk} = \mu + g_i + \alpha_k + \delta_{ik} + \beta_{jk} + \epsilon_{ijk} \]

Where \( \mu \) is the general mean, \( g_i \) is effect of the i-th line, \( \alpha_k \) is effect of the k-th location, \( \delta_{ik} \) is interaction effect between the i-th line and the k-th location, \( \beta_{jk} \) is effect of the j-th replication within the k-th location. The effects \( g_i \)'s, \( \delta_{ik} \)'s, and \( \epsilon \)'s are assumed independ-