Journal of Plant genetics and breeding

Research Article

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Combining Ability for Grain Yield, Agronomic Traits and *Striga hermonthica* Resistance of Yellow Endosperm Maize

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Received June 30, 2018; **Accepted** August 07, 2018; **Published** August 17, 2018

Citation: Sangar® S, Menkir A, Ofori K, Gracen V (2018) Combining Ability for Grain ' ᛘ ژ ế)w ƙ = z]

station of Sotuba has an infested field for evaluating genotypes response to *Striga hermonthica* infestation.

Fifteen Striga resistant maize inbreed lines and three testers with different reaction pattern to Striga hermonthica were crossed in line by tester fashion to generate 45 F1 hybrids in the Regional Agronomic Research Centre of Sotuba/ Mali. The inbreed lines and testers were obtained from the International Institute of Tropical Agriculture (IITA). The three testers were TZSTRI106, TZSTRI1207 and TZSTRI1033. They have different reaction to Striga hermonthica. Inbreed tester TZSTRI106 is a Striga resistant line derived from a backcross containing Zea diploperennis in its genome, TZSTRI1207 is a Striga tolerant line derived from a backcross containing a temperate inbreed line (B73) and TZSTRI1033 is a Striga susceptible line derived from a bi-parental cross between a temperate line (B73) and a line from Thailand (KI21).

E

The hybrid trial was composed of 48 entries made up of 45 testcrosses obtained from a line by tester cross plus three hybrids checks. The checks included one tolerant hybrid, Mata (TZE-Y Pop DT STRC4 × TZEI 13) and two susceptible hybrids. Farako and Tieba. The 48 hybrids along with the 18 parents were evaluated in Sotuba and Sanankoroba during the growing season of 2014 and 2015 under Striga-infested and Striga-free conditions.

In each location, the 45 single cross hybrids and 3 checks were arranged in a 6 × 8 alpha lattice design with three replications and the parents were arranged in a RCBD with three replications. Hybrids and parents were randomized within each replicate. An experimental plot consisted of a 5m long single row with plants within a row spaced 0.25m apart and 0.75m distance between rows. The fields were planted with two seeds and later thinned to one plant per hill at two weeks after emergence to give a population density of 53,333 plants per hectare. A compound fertilizer at both Sotuba and Sanankoroba consisted of two applications. The first application was carried out 30 days after planting at the rate of 30 kg ha-1 each of N, P and K. Urea was used as top-dressing at the rate of 30 kg/ha^{-1} N two weeks later. Under Striga-infested environments weeds were manually controlled.

A *Striga*

The artificial *Striga* infestation was carried as described by Kim [15] and Kim & Winslow [16]. Matured *Striga* plants were collected in infested maize field from previous season in Sanankoroba. Then the mature *Striga* plant were air dried for 7-9 days. After drying, the *Striga* plants were threshed and seed collected were stored for a minimum of six months to allow the conditioning of the seeds and breakage of dormancy. Germination test was conducted as described by Menkir [13] and germinable *Striga* seed were thoroughly mixed with finely sieved sand at the ratio 1:99 by weight. The sand served as the carrier and provided adequate volume for rapid and uniform infestation. For the field infestation, artificial inoculation with *Striga* seeds was carried out by digging small holes at the crop planting hill along the ridge and infesting with about 3000 germinable *Striga* seeds (8.5g sand/*Striga* mixture). Field infestation was done using by Menkir et al. [17] method. Apart from the *Striga* seed infestation, management practices were the same for both *Striga*-infested and non-infested plots.

D C

Under both *Striga*-free and *Striga*-infested conditions, ten traits including grain yield (Yield), days to 50% silking (DYSK), days to 50% anthesis (DYTS), anthesis silking interval (ASI), ear aspect (EASP), ear height (EHT), ears per plant (EPP), plant aspect (PASP), plant height (PLHT) and husk tip cover (HUSK) were measured from each experiment at each location. Under *Striga* infestation, additional data were collected on *Striga* related traits such as *Striga* damage ratings (STRA) and *Striga* emergence count (STRC) at 8 and 10 weeks after planting (WAP). *Striga* damage rating was on a scale of 1-9 as described by Kim [18] where 1=Normal plant no visible symptoms growth, 2=Small and vague purplish- brown blotches visible leaf, 3=Mild leaf blotching with some purplish-brown necrotic spots, 4=Extensive blotching and mild wilting, slight but noticeable stunting and reduction in ear and tassel size, 5=Extensive leaf blotching wilting and some scorching moderate stunting; ear and tassel size reduction., 6=Extensive leaf scorching with mostly grey necrotic spots some stunting and reduction in stem diameter ear size and tassel size, 7=Definite leaf scorching with grey necrotic spots and leaf wilting and rolling severe stunting and reduction in stem diameter ear size and tassel size often causing stalk lodging brittleness and husk opening at a late growing stage, 8=Definite leaf scorching with extensive grey necrotic spots conspicuous stunting leaf wilting rolling severe stalk lodging and brittleness reduction in stem diameter ear size and tassel size and, 9=Complete scorching of all leaves causing premature death or collapse of host plant and no ear formation.

Ear aspect which is the assessment of the general appeal of the ears without the husks was rated on a scale of 1-9, where 1=excellent with no disease/insect damage, large cobs, uniform ears and fully filled grains, 2=very good with no disease/insect damage and fully filled grains, one or two irregularity in cob size, 3=good with no disease/insect damage and fully filled grains, one or two irregularity in cob size, 4=mild insect damage, no disease, fully filled grains, one or two irregularity in cob size poor, 5=mild disease/insect damage and fully filled grains, one or two irregularity in cob size, 6=severe disease/insect damage and fully filled grains, smaller cobs, non-uniform cob size, 7=severe disease/insect damage, scanty grain filling, few ears, non-uniformity of cobs, 8=severe disease/insect damage, scanty grain filling, very few ears and, 9=only one or no ears.

The factors considered included ear size; uniformity of size, color and texture; extent of grain filling and insect and disease damage.

Husk tip cover was rated on a scale of 1-5 where 1 indicates very tight husks extending beyond the tip and 5 indicates exposed ear tip.

D A

SAS was used to perform analysis of variance for alpha lattice design.

The analysis of combining ability was based on the model described by Kempthorne, Comstock & Robinson [19,20]. The general combining ability (GCA) and specific combining ability (SCA) effects were estimated for each environment and across environments.

The statistical model used for the combined analysis is as follows:

a. Model of combining ability for each environment

$Yijk=\mu+rk+fi+mj+ (f \times m)\ ij+eijk$

Yijk: The observed measurement for the kth replication of the ixjth progeny; μ: experimental mean; fi: is the effect of the ith line (GCAlinei); I=1, 2, 3….21; tj: is the effect of the jth tester (GCAtesterj); j=1, 2, 3; (f x m) ij: is the interaction effect of the ith line with the jth male (SCAij);

SCA mean squares were larger than GCA mean squares for grain yield, days to silking, anthesis-silking interval, plant height, ear aspect, plant aspect and husk cover (Table 2).

[illegible]

The proportion of the GCA over the total genetic effect of the sum of squares was used to determine the relative importance of GCA and SCA effects. The predictability based on GCA [23] is higher when the ratio is almost equal to one. Across environments the SCA percent contribution was greater than GCA line plus GCA tester percent contribution for most traits except DYSK, DYTS, and Husk. The SCA percent contribution varied from 67% (grain EPP) to 53% (PLHT and EASP). GCA line percent contribution varied from 41% (Husk) to 15% (EASP). The line percent contribution was the highest from Husk (41%) followed by EHT (35%), PASP (34%), ASI (33%), EPP (28%), PLHT (25%), and grain yield (20%), respectively. While the contribution of tester varied from 37% (DYSK) to 1% (ASI) (Figure 1a). Under *Striga*-free conditions, the relative contribution of SCA was greater than GCA (GCA line +GCA tester) for all traits measured. The highest SCA percent contribution was 87.93% (ASI) and the lowest percent contribution was 50.54% (DYSK). Lines percent contribution varied from 44% (Husk) to 12% (ASI), the lines contribution was greater than the testers contribution for all traits measured (Figure 1b) under *Striga*-free conditions. Under *Striga*-infested conditions the percent contribution of SCA was greater for grain yield and *Striga* related traits (Figure 1c). The lines and testers contributed similarly for husk tip cover. However, the relative contribution for lines was greater for GY, ASI, PLHT, EHT and STRA 10WAP.

GCA effects of line and testers for various traits under *Striga*-infested and *Striga*-free conditions. Among the lines, *TZISTR112*, *TZISTR1214*, *TZISTR1222* and *TZISTR1223* exhibited positive GCA effects for GY under *Striga*-infested and *Striga*-free conditions. Among

had negative and four positive SCA effects. For EPP, seven crosses displayed significant SCA effects, five had negative and two positive SCA effects. Six crosses showed significant SCA for PLHT; four had negative and two positive SCA effects.

Twenty-four hybrids showed significant SCA for EASP; eleven had negative and thirteen showed positive SCA effects. The entire crosses showed significant SCA for EHT; twenty had negative and twenty-four showed positive SCA effects. Twelve hybrids showed significant SCA for PASP; half had negative and the other half had positive SCA effects (Table 3).

Under *Striga*-infested condition; nineteen crosses exhibited significant SCA effects for grain yield; ten had negative and nine displayed positive SCA effects. Cross *TZISTR1033/TZISTR1227* recorded the highest positive SCA effect for grains yield while the lowest was recorded by the cross *TZISTR1207/TZISTR1226*. Twelve crosses displayed significant negative SCA effects for both DYSK and finding is in disaccord with finding of Gethi and Smith [29] who reported significant GCA mean squares for *Striga* emergence counts and non-significant GCA mean squares for *Striga* damage rating. The proportion of the SCA mean squares over GCA for grain yield and most other traits under *Striga* infestation indicates that non-additive as well as additive effects are important and that non-additive genetic effects were more important than additive effects. This is consistent with the findings of Badu-Apraku et al. and Choukan [36,37] that GCA and SCA are mostly used to identify inbred line with good characters. Lines, *TZISTR1214*, *TZISTR1226* and *TZISTR1237* exhibited desirable negative GCA effects for *Striga* damage rating. However, lines *TZISTR110*, *TZISTR113*, *TZISTR1218*, *TZISTR1227* and tester, *TZISTR106* exhibited desirable negative GCA effects for *Striga* damage rating and *Striga* emergence count making them good combiners for maize *Striga* resistance traits and can be used to improve maize for *Striga* resistance. Lines *TZISTR1214*, *TZISTR1223*, tester *TZISTR106* and *TZISTR1207* had significant positive GCA effect for grain yield and negative effect for *Striga* damage rating and *Striga* emergence count. These lines and testers are good combiners for grain yield and maize *Striga* resistance traits. Testers TZISTR106 and *TZISTR1207* resistant and tolerant to *Striga* respectively, had significant negative GCA effect for *Striga* emergence count while the susceptible Tester *TZISTR1033* had significant positive GCA effect for STRC. This is in disagreement with Rodenburg and Bastiaans [34] who suggested that *Striga* emergence count would not be a sufficient criterion to point out genetic control of *Striga* tolerance of maize.

Lines *TZISTR113*, *TZISTR1218* and *TZISTR1227* had significant negative effect for grain yield and negative effect for *Striga* counts, they can be utilized as source of *Striga* resistance in maize breeding. Significant negative GCA for ASI indicates that the silk and pollen shed are done together ensuring good synchronization. Line *TZISTR112*, testers *TZISTR106* and *TZISTR1207* had significant positive effect for grain yield and negative effect for ASI, these line and testers had pollen grain and silking appearing at the same time which ensures good synchronization under *Striga* infestation despite the fact that the parasitic weed can delay flowering period. They are therefore suitable for hybrid seed production. Testers *TZISTR106* and *TZISTR1207* had positive GCA effect for grain yield this finding is in agreement with finding of Karaya et al. [38]. Lines *TZISTR1222*, *TZISTR1223*, testers *TZISTR106* and *TZISTR1207* had positive GCA for grain yield and negative effects for plant height indicating that they can resist to plant height reduction due to *Striga* effect on plant.

Reduced emergence, resulting from effective host-plant resistance,

and economic evaluation of some Striga control packages in maize in the