Combining Ability of Maize (*Zea mays* L.) Line for Grain Yield in Mali

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Mali experiences irregular and poor distribution of rains which limit maize production greatly. The study objective was to evaluate the performance of various maize hybrids as well as determine general and specific combining ability of the lines under water limited conditions. Two trials were conducted at Sotuba and Kassela in South-Western Mali with 23 genotypes in the first trial and 15 genotypes in the second trial. The experimental design was a completely random Fisher block design. Morphological and agronomic traits were evaluated in a lines/testers crossing scheme where the testers were females and the lines were males. Results showed significant difference (P< 0.05) for ear height, days to anthesis, days to silking, grain yield, leaf width, plant aspect, and 1000 grain weight. In both sites, the general combining ability was significantly different (P< 0.05) between testers whereas the specific combining ability differed significantly (P< 0.05) between the lines. The best performing hybrid at Sotuba in term of grain yield was observed with TZI1876/9071 (6,003 kg/ha), and at Kassela the highest yielding was TZI1876/CML442 (6,320 kg/ha).

Keywords: Performance; hybrids; combining ability.

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1. INTRODUCTION

The Savana ecology of sub-saharan Africa has the potential to support expanded maize production due to the ambient solar, healthy soils, and available moisture [1]. As a result, maize has been adopted extensively in the zone, replacing the traditional crops, sorghum [*Sorghum bicolor* (L.) Moench] and millet [*Pennisetum glaucum* (L.) R. Br.] [2].

In sub-Saharan Africa, maize (*Zea mays* L.) is the most important cereal crop while the average is still very low (1.3t/ha) compared to 8.6 t/ha obtained in developed countries [3]. In Mali, maize is a staple food providing carbohydrate, vitamin B, and minerals to an estimated 50% of the population.

A study that evaluated 200 maize producers reported that hybrids had a positive impact on the to Malian smallholder farmers [4] A vast majority of maize growers prefered the hybrids because of the good quality of the seed, the superior rates of germination, the size of grains, and productivity [4]. However, farmers lack information on the recommended high yielding hybrid maize lines to grow despite existence of many entries.

Based on genetic makeup, hybrids of several types are possible in maize. However those derived from inbred lines are commonly used for commercial production. The theory of specific combining ability (SCA) and general combining ability (GCA) have been used broadly in breeding of several commercial crop species [5]. The general combining ability was observed to be relatively more important than specific combining ability for maize yield determination of unselected inbred lines, while specific combining ability was more important than general combining ability for previously selected lines. Previous findings also show that the general combining ability is largely due to the additive effect of genes while in specific combining ability dominance or epistatic effects of genes are commonly involved. [6] compared estimates of the variances of general combining ability and specific combining ability for yield and their interaction with locations and years. They stressed that the variance of specific combining ability includes not only the nonadditive deviations due to dominance and epistasis but also a considerable portion of the genotype × environment interaction.

Sprague et al. [7] recommended two replications per location and three to five environments for evaluation of maize crosses, because the additive by environment interaction is usually a significant factor. Therefore, the objective of this work was to evaluate the performance of maize hybrids and determine the combining ability of maize lines.

2. MATERIALS AND METHODS

2.1 Experimental Sites

The study was conducted in two sites, at the Sotuba agronomic research station (12 $^{\circ}$ 39'47" North, 7 $^{\circ}$ 55'02" West), soil is and in Kassela village (12°35'42" N and 7°39'58" W) soil is sandy-clayey. Sotuba agronomic research station has 268 ha research land and is located on the left bank of the Niger River. The average annual rainfall in Sotuba ranges between 1000 – 1200 mm. Kassela village is a part of Baguineda commune and receives annual rainfall ranging from 900 – 1 000 mm. The previous crop in both site was cowpea.

2.2 Plant Materials and Experimental Design

Two testers TZI1876 and V481-73 were used in two different trials composed of. 23 and 15 hybrids (Table 1). The hybrids were obtained from Sotuba station.

Two trials composed of 23 and 15 hybrids were conducted in two sites todetermine maize line combining ability. The genotypes were different from one trial to another and were composed of single hybrids having two testers in common, namely TZI1876 and V481-73. The row spacing was 0.75 m by 0.25 m while the row length was 5 m. The experimental design was randomized complete block design with three replications. Fertilization was performed with urea (150kg/ha) and NPK (100 kg/ha).

2.3 Measurements

The measurements conducted included grain yield, ear aspect, plant aspect, days to silking, days to anthesis, ear height, leaf width, plant height and thousand kernel weight.

Table 1. List of maize hybrids for two trials per site

Hybrids: 23 entries trial		Hybrids: 15 entries trial	
1-TZI1876/CML538	14-V481-73/CML502	1-TZI1876/CML53	14-TZI1876/S6 7-14
2-V481-73/CML538	15-TZI1876/S6 104-109	2-V481-73/CML538	15-V481-73/S6 7-14
3-TZI1876/CML505	16-V481-73/S6 104-109	3-TZI1876/CML505	
4-V481-73/CML505	17-TZI1876/J16-1	4-V481-73/CML505	
5-TZI1876/EXP 124-1	18-V481-73/J16-1	5-TZI1876/CML442	
6-V481-73/EXP 124-1	19-check	6-V481-73/CML442	
7-TZI1876/S6 1-6	20-TZI1876/9071	7-TZI1876/S6 1-6	
8-V481-73/S6 1-6	21-V481-73/9071	8-V481-73/S6 1-6	
9-TZI1876/CML 442	22-TZI1876/ 7-14	9-TZI11876/J16-1	
10-V481-73/CML 442	23-V481-73/ 7-14	10-V481-73/J16-1	
11-TZ1876/1368+PAC		11-TZI1876/9071	
12-V481-73/1368+PAC		12-V481-73/9071	
13-TZI1876/CML502		13-check	

Yield grain was estimated using the following formula:

Yield/ha = (X*FY*0.75*10000)/S

(100 − M) / (100 − 15) = X= grain yield moisture adjusted to 15%

Where M is moisture recorded during harvest for each plot

Where FY is field yield and S plot areas.

15: Standard moisture content during harvest

0.75 (75%) Shelling percentage

100: Maximum of moisture.

10000: conversion of yield plot to hectare

Ear aspect rated on a scale of 1 to 5, where 1 = uniform well-filled ears and 5 = poorly filled ears with varying grain colours.

Plant aspect rated on a scale of 1 to 5, where 1 = good plant type with uniform ear placement and 5 = poor plant type with varying plant and ear heights.

Day to 50% silking: the number of days from emergence to when 50% of the plants in the plot produce silk.

Days to 50% anthesis: The number of days from emergence to when 50% of the plants started shedding pollen.

Plant height: Mean of three plants height randomly taken from each entry measured from ground to the base of tassel.

Ear height: Mean of three ear height randomly taken from ground to the ear base

Leaf width: width of leaf middle from three plants randomly taken.

Thousand kernel weight: Thousand kernels from each plot were counted by automatic seed conter and were weighted using balance

3. DATA ANALYSIS

Software Gen Stat (12th Edition) was used for data analysis and software ''AGD-R'' for combining ability. The analysis of combining ability was based on the model described by [8] The GCA and SCA effects were examined for each environment.

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

a. Model of combining ability for each environment

$Y_{ijk} = \mu + r_k + f_i + m_j + (f \times m)_{ij} + e_{ijk}$

Y_{ijk}: the observed measurement for the kth replication of the ixjth progeny

μ: experimental mean

f_i: is the effect of the ith line (GCAlinei); I = 1, 2, 3….21

t_j: is the effect of the jth tester (GCAtesterj); j = 1, 2, 3

$(f \times m)_{ij}$: is the interaction effect of the ith line with the jth male (SCAij)

r_k: effect replication within environment; k = 1, 2

eijk: is the error effect associated with the ijkth observation

4. RESULTS

4.1 Twenty-Three (23) Entries Trial at Sotuba Site

There hybrids showed no yield differences (Table 2). However, the highest yield (6003kg/ha) was obtained with hybrid TZI1876/9071 (Table 3).

There was no difference among hybrids for ear aspect Table 2. However, the best ear aspect was observed with V481-73/CML538, TZI1876/S6 1-6 et TZI1876/CML442 (Table 3).

There was significant difference among genotypes for plant aspect (Table 2). Hybrids TZI1876/CML442 et TZI1876/J16-1 had the best plant aspect (Table 3).

There was no difference among hybrids for day to 50% silking Table 2. Day to 50 % silking is from 52 (TZI1876/S6 7-14) to 59 (TZI1876/CML502 et TZI1876/J16-1) (Table 3).

There was no difference among hybrids for day to 50% anthesis Table 2. Day to 50 % anthesis was from 52 (TZI1876/S6 7-14) to 58 (TZI1876/J16-1 et TZI1876/1368+PAC) (Table 3).

There was no difference among hybrids for ear height (Table 2). The ear height was from 0.80 m (V481-73/1368+PAC) to 1.063 m (V481-73/S6 104-109) (Table 3).

There was significance difference among genotypes for leaf width (Table 2). Leaf width was from 0.09 m to 0.113 m (Table 3).

There was no difference among genotypes for plant height Table 2. Plant height was from 1.85m to 2.217 m (Table 3).

Significance difference was observed among hybrids Table 2. Weight of thousand Kernel was from 270g to 380 g for TZI1876/CML502 and V481-73/CML505 respectively (Table 3).

4.2 Fifteen (15) Entries Trial

The ANOVA showed no difference among the genotypes with regards to grain yield, ear aspect, plant aspect, day to 50% silking ear height, leaves width, plant height, and thousand kernels weight (Table 4). However, there was variations

among the hybrids (Table 5). The highest grain yield (5281 kg/ha) was observed with hybrid V481-73/S6 7-14, whereas hybrids TZI1876/CML505, TZI1876/J16-1 and V481-73/J16-1 had the best ear aspect. Hybrids TZI1876/CML505, TZI1876/CML442, V481-73/CML442, TZI1876/J16-1 and V481-73/J16-1 had the best plant aspect (Table 5).

Days to 50% silking ranged from 52 to 59 for V481-73/S6 7-14 and TZI1876/CML442 respectively (Table 5). Ear height was from 0.86 cm to 1.09 cm for V481-73/S6 1-6 and TZI1876/CML442 respectively. Leaf width was from 9 cm to 10.6 cm for V481-73/S6 7-14, V481-73/J16-1, and TZI1876/9071 respectively. Plant height was from 1.95 m to 2.217 m for V481-73/S6 1-6 and TZI1876/CML442 respectively. Thousand kernels weight was from 263.3 g to 340 g for TZI1876/J16-1 and V481-73/S6 1-6 respectively (Table 5).

In converse, there was significant difference (P< 0.05) among hybrids for days to 50% anthesis (Table 4). Days to 50% anthesis ranged from 52 to 59 for V481-73/S6 7-14 and TZI1876/CML442 respectively (Table 5).

4.3 Kassela Site

4.3.1 Results twenty three (23) entries trial

Significance difference was observed among hybrids for grain yield (Table 6). The best grain yield was 6320 kg/ha for TZI1876/CML442 (Table 7).

There was not difference among hybrids for plant aspect (Table 6). Plant aspect was from 1.33 to 6.33 (Table 7).

Significance difference was observed among hybrids for ear aspect (Table 6). Ear aspect was from 1 to 2.66 (Table 7).

Significance difference was observed among hybrids for day to 50% silking (Table 6). Day to 50% silking was from 53 to 63 with V481-73/S6 1-6 and TZI1876/J16-1 respectively (Table 7).

There was significance difference among hybrids for day to 50% anthesis (Table 6). Day to 50% anthesis was from 53 (V481-73/CML505 and V481-73/S6 1-6) to 62 (TZI1876/J16-1) (Table 7).

There was no difference among hybrids Table for ear height 6. Ear height was from 0.74 m to 1.78m for TZI1876/S6 7-14 and TZI1876/CML442 respectively (Table 7).

There was no difference among hybrids for leaf width (Table 6). Leaves width was from 0.1 to 0.7 cm (Table 7).

There was no difference among hybrids for plant height (Table 6). Plant height was from 0.70m to 2.40 m for TZI1876/S6 7-14 and TZI1876/1368+PAC respectively (Table 7).

There was no difference among hybrids for thousand kernels (Table 6). Weight was from 240 to 350g with check and TZI1876/CML505 respectively (Table 7).

4.3.2 Fifteen (15) entries trial

There was significant difference among hybrids for grain wield (Table 8). The best grain yield was 4964 kg/ha with V481-73/S6 7-14 (Table 9).

There was not-significant difference among hybrids for ear aspect (Table 8). Ear aspect was from 2.33 to 1.33 (Table 9).

There was not-significant difference among hybrids for plant aspect (Table 8). Plant aspect was from 2.33 to 3.33 (Table 9).

Significant difference was observed among hybrids for day to 50% silking (Table 8). Day to 50% silking was from 51 to 57 with V481-73/CML505 and TZI1876/CML538 respectively (Table 9)

There was not-significant difference among hybrids for day to 50% anthesis (Table 8). Day to 50% anthesis was from 51 to 57 with TZI1876/S6 7-14 and TZI1876/CML538 respectively (Table 9)

There was not-significant difference among hybrids for ear height (Table 8). Ear height was from 0.670 m to 0.960 m with V481-73/S6 7-14 and TZI1876/CML538 respectively (Table 9)

There was not-significant difference among hybrids for leaves width (Table 8). Leaves width was from 0.06 to 0.09 m (Table 9).

There was not-significant difference among hybrids plant height (Table 8). Plant height was from 1.88m to 2.21 m with TZI1876/CML538 and V481-73/J16-1 respectively (Table 9).

There was not-significant difference among hybrids for thousand kernels weight (Table 8). Grain weight was from 276.7g to 326.7g with TZI1876/CML442 and TZI1876/S6 7-14 respectively (Table 9).

4.4 Grain Yield for Twenty Three (23) Entries Trial at Sotuba and Kassela

There was no difference among genotypes for grain yield at Sotuba and Kassela (Table 10).

The best hybrid in term of grain yield was 5.943 t/ha with TZI1876/CML442 (Table 11).

4.5 Grain Yield for Fifteen (15 entries) Trial at Sotuba and Kassela

There was not difference among hybrids for trial15 entries at Sotuba and Kassela (Table 12).

The best grain yield was 5.120 t/ha with V481-73/S6 7-14 (Table 13).

4.6 Combining Ability at Differents Sites

4.6.1 Sotuba site twenty three (23) entries trial

There was significant difference among testers (Table 14). Tester 2 V481-73 had best General combining ability Fig. 1A. Line CML442 had the best general Combining Ability for both TZI1876 and V481-73 Fig. 1B. Hybrid V481-73/S6 1-6 had the best Specific Combining Ability Fig. 1C.

4.6.2 Sotuba site fifteen (15 entries) trial

There was significant difference among testers for General Combining Ability Table 15. Tester 1 TZ1876 had the best General Combining Ability Fig. 2. Hybrid V481-73/CML442 had the best Specific Combining Ability Fig. 3.

4.6.3 Kassela site twenty three (23) entries trial

There was significant differance among testers Table 16. Tester TZI 1876 had the best General Combining Ability Fig. 4A. Line EXP 124-1 had the best General Combining Ability for both tester Fig. 4B.

There was no difference among lines for Specific combining Ability Table 17.

4.6.4 Kassela Site Fifteen (15) entries trial

There was not difference among testers for General Combining Ability Table 18. Line S6 1-6 had the best General combining Ability Fig. 5A. It had the best Specific Combining Ability with V481-73 Fig. 5B.

Table N°18 gives cross rank per crosses and the best hybrid was (TZI1876/S6 1-6).

Table 2. Analysis of variance of observed traits

Source of variation	Df	Yield	Ear aspect	Plant aspect	Days to silking	Day to anthesis	Ear height	Leaf width	Plant height	Thousand kernels weight
Replication	2	40519271	2.26	12.2754	12.9	27.2	0.125	4.35E-06	0.1159	1149*
Hybrids	22	2548645	0.58	1.6311*	8.0	17.5	0.019	0.00008248*	0.0305	2757*
Residual	44	2664426	0.46	0.8208	5.4	18.9	0.015	0.0000392	0.0252	1567
Total	68									

Table 3. Mean of evaluated traits for Twenty-three (23) entries at Sotuba

Hybrids	Grain yield (kg/ha)	Plant aspect	Ear Aspect	50% day to silking	Day to 50% anthesis	Ear height (m)	Plant height (m)	leaf width (cm)	1000 kernels weight (g)
1TZI1876/CML538	3544	4	2.66	56	55	1.043	2.017	10	290
2-V481-73/CML538	3337	3.67	1.33	54	54	1.043	2.183	10	280
3-TZI1876/CML505	4812	2.33	1.66	55	55	0.957	1.983	10	296.7
4-V481-73/CML505	5767	2	2	54	54	0.823	1.867	9	383.3
5-TZI1876/EXP 124-1	3541	2.33	1.66	57	56	0.887	2.017	10	323.3
6-V481-73/EXP 124-1	3588	1.67	3	57	57	0.93	2.1	10.333	323.3
7-TZI1876/S6 1-6	4582	2	1.33	56	56	0.83	2.017	9.667	303.3
8-V481-73/S6 1-6	4351	2.33	2.33	54	48	0.9	2.05	10.667	290
09-TZI1876/CML 442	5564	1	1.33	56	56	0.99	2.117	9.667	326.7
10-V481-73/CML 442	4422	2.33	2	58	57	0.947	2.017	10.333	263.3
11-TZI1876/1368+PAC	4371	2.33	2	58	58	0.877	2.083	10	323.3
12-V481-73/1368+PAC	3628	2	2.66	57	56	0.8	1.867	9.333	286.7
13-TZI1876/CML502	4443	1.33	1.66	59	50	1.017	2.1	10	270
14-V481-73/CML502	5461	3	1.66	56	55	0.933	2.117	10.333	310
15-TZI1876/S6104-109	2693	2.33	2	54	54	0.91	2.217	9.667	380
16-V481-73/S6104-109	5002	3	2	54	54	1.063	2.05	10	326.7
17-TZI1876/J16-1	5711	1	1.66	59	58	1.053	2.217	9.667	336.7
18-V481-73/J16-1	4911	1.67	1.66	56	55	0.967	2.067	11.333	310
19-check	5329	1.67	1.66	57	57	0.94	1.85	11.333	273.3
20-TZI1876/9071	6003		1.66	56	56	1.033	2.15	9.667	300
21-V481-73/9071	5323	2.67	2	56	55	0.963	2.15	9	290
22-TZI1876/S6 7-14	4244	2	1.66	52	52	0.833	2.033	10	306.7
23-V481-73/ 7-14	3374	2	2.33	55	54	0.863	2.05	9.667	300
Mean	4522	2.19	1.91	56	55	0.939	2.057	9.913	308.4
Significance	-	*	-	-	-	-	-	*	*
LSD	2686	1.491	1.203	3.8	7.2	0.2022	0.2611	0.010302	65.15
CV%	36.1	41.4	38.3	4.2	7.9	13.1	7.7	6.3	12.8

Table 4. Mean square from analysis of variance for evaluated traits

Source of variation	Df	Grain yield	Ear aspect	Plant aspect	Day to 50% silking	Day to 50% anthesis	Ear height	Leaf width	Plant height	Thousand Kernel weight
Repetition	2	40003486	0.9556	0.5556*	40.56	46.82*	0.09891	0.9556	0.1623	4442
Entries	14	1854286	0.3746	1.1746*	18.78	21.99*	0.02211	0.6889	0.01605	1499
Residual	28	2436330	0.5508	0.627	15.1	10.13	0.01404	0.5032	0.01843	2021
Total	44									

Table 5. Mean of evaluated traits for fifteen 15 entries trial at sotuba

Hybrids	Grain yield (kg/ha)	Ear aspect	Plant aspect	Days to 50% silking	Days to 50% anthesis	Ear heigh (m)	Plant height (m)	Leaf width (cm)	Thousand kernels weight (g)
1-TZI1876/CML538	4907	2	2.33	57	57	1	2.017	10.3	283.3
2-V481-73/CML538	3178	2.33	1.33	55	55	0.87	1.967	10	303.3
3-TZI1876/CML505	5401	1	1.33	54	53	0.96	1.967	10	320
4-V481-73/CML505	4442	1.67	1	48	53	0.99	2.067	9.33	263.3
5-TZI1876/CML442	3292	1.67	1	59	58	1.14	2.217	10	280
6-V481-73/CML442	4144	1.67	1	57	57	1.09	2	9.67	320
7-TZI1876/S6 1-6	5111	1.33	1.33	55	46	0.88	2.1	10	303.3
8-V481-73/S6 1-6	4056	1.67	1.33	54	54	0.86	1.95	9.33	340
9-TZI11876/J16-1	5068	1	1	54	54	1.07	1.967	10.3	263.3
10-V481-73/J16-1	4413	2	1	57	56	0.88	2.033	10.6	300
11-TZI1876/9071	3835	1.67	1.33	56	56	1.02	2.017	10.6	293.3
12-V481-73/9071	4671	1.33	1.67	55	56	1.06	2	9.67	273.3
13-check	3119	1.67	2.33	56	55	1.01	2.087	10	310
14-TZI1876/S6 7-14	5253	1.67	2.67	55	54	0.95	2.133	9.67	320
15-V481-73/S6 7-14	5281	1.67	2.67	52	52	0.96	2.033	9	300
Mean	4411	1.62	1.56	55	54	0.98	2.037	9.91	298.2
Significance	-	-	*	-	*	-	-	-	-
LSD	2610.6	1.241	1.324	6.5	5.3	0.1981	0.2271	1.186	75.19
CV%	35.4	45.7	50.9	7.1	5.8	12	6.7	7.2	15.1

Table 6. Mean squares from analysis of variance of evaluated traits

Source of variation	Df	Grain yield	Ear aspect	Plant aspect	Day to 50% silking	Day to 50% anthesis	Ear height	Leaf width	Plant height	Thousand Kernel weight
Repetition	2	4825799	2.1449	9.841	2.797	8.014	37.34	0.0002261	0.01668	1149
Entries	22	3210561[*]	0.9829*	3.863	14.989**	15.827**	37.46	0.0001424	0.07729	2757[*]
Residual	44	1478739	0.4631	3.280	6.055	6.181	38.14	0.0002094	0.05436	1567
Total	68									

Table 7. Mean of evaluated traits at Kassela trial 23 entries

Hybrids	Grain yield (kg/ha)	Plant aspect	Ear aspect	Days to 50% silking	Days to 50% anthesis	Ear height	Leaf width (cm)	Plant height (cm)	Thousand kernels weight (g)
1- TZI1876/CML538	3255	2.33	1.00	57	57	1	9	2.2	286.7
2- V48173/CML538	2833	2.33	1.67	58	57	0.77	8.67	1.9	243.3
3- TZI1876/CML505	4561	1.67	1.00	56	55	1.08	9.67	2.27	350
4- V48173/CML505	3623	6.33	1.33	55	53	1.08	8.67	1.97	320
5- TZI1876/EXP124-1	4889	1.33	1.33	55	55	1.02	9.67	2.37	313.3
6.V481-73/EXP124-1	3526	2.67	2.00	60	59	0.77	9	2.18	293.3
7- TZI1876/S6 1-6	3886	2	1.00	55	55	0.77	8.67	2.2	316.7
8-V481-73/S6 1-6	4657	1.33	1.67	53	53	0.95	8	2.25	293.3
9- TZI1876/CML442	6320	2.33	1.33	59	59	17.82	9.67	2.18	330
10- V48173/CML442	4145	2.67	2.00	57	57	0.89	9.67	2.23	290
11- TZI1876/1368+PAC	3799	1.67	1.33	57	57	0.88	7.33	2.4	320
12- V48173/1368+PAC	4007	1.67	2.00	57	56	0.97	10	2.12	310
13-TZI1876/CML502	2017	2.33	2.33	59	59	0.85	9	2	270
14-V481-73/CML502	3721	2.67	2.33	55	54	0.94	9.33	2.27	253.3
15- TZI1876/S6 104-109	2016	3.33	2.67	59	59	0.78	8.67	2.02	256.7
16-V48173/S6104-109	3184	2.67	2.33	57	56	0.9	8.67	1.98	263.3
17-TZI1876/J16-1	3209	2.33	2.67	63	62	0.86	10	2.12	296.7
18-V481-73/J16-1	3321	2.67	2.00	55	55	0.9	9	2.23	286.7
19-check	2543	2.67	2.67	60	59	0.76	10	2.1	240
20-TZI1876/9071	3291	2.67	1.67	58	58	0.92	8.67	2.2	306.7
21-V481-73/9071	2609	3.33	2.33	58	57	0.82	8.67	1.97	250
22-TZI1876/ 7-14	2065	5	2.67	57	57	0.74	8	1.7	256.7
23-V481-73/ 7-14	2360	3.67	2.33	55	55	0.92	9	2.13	283.3
Mean	3471	2.68	1.90	57	57	1.62	9	2.13	288.3
Significance	*	-	*	**	**	-	-	-	-
LSD	2094.6	-	1.20	4	4.1	-	-	-	-
CV%	36.7	70.4	38.60	4.3	4.4	381.1	16.1	10.8	16.8

Table 8. Mean square from anlysis of variance for evaluated traits at Kassela

Source of variation	df	grain yield	Ear aspect	Plant aspect	Days to 50% silking	Days to 50% anthesis	Ear height	Leaf width	Plant height	Thousand kernels weight
Replication	2	9850869	4.4222	9.8000	16.956	15.622	0.21215	0.0001489	0.24156	4776
Entries	14	1054287.*	0.2603	0.3714	11.803*	12.232	0.02224	0.0002546	0.03232	546
Résidual	28	514668	0.2317	0.5143	5.741	6.717	0.03905	0.0002227	0.02019	1937
Total	44									

Table 9. Mean of evaluated traits for fifteen (15) entries at Kassela

Hybrids	Grain yield (kg/ha)	Ear aspect	Plant aspect	Days to 50% silking	Day to 50% anthesis	Ear height (m)	Plant height (m)	Leaves width	Thousand kernels weight (g)
1-TZI1876/CML538	2905	1.333	2.67	57	57	0.57	2.017	15	303.3
2-V481-73/CML538	2939	2	3	55	55	0.96	2.15	8.67	303.3
3-TZI1876/CML505	4094	2.333	3.33	54	53	0.83	2	6	293.3
4-V481-73/CML505	3263	1.667	3.33	51	52	0.787	2.2	9.33	316.7
5-TZI1876/CML442	2989	1.333	2.67	56	56	0.943	2.25	9.33	276.7
6-V481-73/CML442	3647	1.667	2.67	56	56	0.67	2.133	9.33	290
7-TZI1876/S6 1-6	3393	1.667	2.33	54	52	0.82	2.25	9.33	303.3
8-V481-73/S6 1-6	3331	1.667	3	50	50	0.833	2.167	9.33	310
9-TZI11876/J16-1	3074	1.333	3.33	54	54	0.857	2.083	9.33	293.3
10-V481-73/J16-1	3954	1.667	3	52	52	0.87	2.217	9.33	296.7
11-TZI1876/9071	3823	1.333	2.67	54	54	0.867	2	8.33	316.7
12-V481-73/9071	2725	1.667	2.67	54	54	0.917	2.05	8.67	283.3
13-check	3237	1.333	2.33	56	56	0.963	2.133	9.33	310
14-TZI1876/S6 7-14	2925	1.333	2.67	52	51	0.793	2.183	9.67	326.7
15-V481-73/S6 7-14	4960	1.333	2.33	55	55	0.983	2.067	9.67	293.3
Mean	3417	1.578	2.8	54	54	0.87	2.118	9.02	301.1
Significance	*	-	-	*	*	-	-	-	-
LSD	1199.9	-	-	4	4.3	-	-	-	-
CV%	21	30.5	25.6	4.4	4.8	22.7	6.7	16.5	14.6

5. DISCUSSION

In the current study, Tester V481-73 showed a good general combining ability at Sotuba. The same result has been found by [9]. The best grain yield was 6320 kg/ha with TZI1876/CML442. This yield was better than the one found by [9] using the same tester TZI1876 (4840kg/ha).

The Specific combining ability has been found with hybrid TZI1876/9071 (6003 kg/ha) Trial 2. The one found with [9] was hybrid TZI1876/87036 with 4640 kg/ha in term of grain yield. For trial 3   General Combining Ability was

obtenained with TZI1876. Specific Combining Ability was obtenained with V481-73/CML 442. Trial 1. General and Specific Combining Ability was obtenained with S6 1-6 for trial 1 at Kassela. However, for trial 2 General Combinig Ability and Specific Combining Ability were obtenained with TZI1876 and V481-73/ S6 1-6 respectively. Testers react to lines differently. In term of Grain yield mean from both sites namely Sotuba and Kassela the best hybrid for trial 1 was TZI1876/CML442 with 5943kg/ha. For trial two the best grain yield was 5120 /kg/ha with V481-73/S6 7-14. The two testers reacted differently according to sites and lines.

Table 10. Analysis of variance for grain yield for twenty three (23) entries trial at Sotuba and Kassela

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr
Site	1	12691353.	12691353.	16.99	
Entries	22	25810458.	1173203.	1.57	0.148
Résidual	22	16429546.	746798		
Total	45	54931357			

Table 11. Mean of grain yield twenty three (23) entries trial at Sotuba and Kassela

Hybrids	Grain yield (kg/ha)
1-TZI1876/CML538	3400
2-V48173/CML538	3085
3TZI1876/CML505	4686
4-V48173/CML505	4695
5-TZI1876/EXP124-1	4215
6-V481-73/EXP124-1	3557
7-TZI1876/S6 1-6	4234
8-V481-73/S6 1-6	4504
9-TZI1876/CML442	5943
10V48173/CML442	4284
11TZ1876/1368+PAC	4085
12V48173/1368+PAC	3818
13-TZI1876/CML502	3230
14-V481-73/CML502	4591
15TZI1876/S6 104-109	2355
16-V48173/S6104-109	4093
17-TZI1876/J16-1	4460
18-V481-73/J16-1	4116
19-check	3936
20-TZI1876/9071	4647
21-V481-73/9071	3966
22-TZI1876/S6 7-14	3155
23-V481-73/S6 7-14	2867
Mean	3997
Significance	-
LSD	1.792.2
CV%	2..1.6

Table 12. Analysis of variance for grain yield fifteen (15) entries trial at Sotuba and Kassela

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr
Sites	1	7415241.	7415241.	21.49	
Entries	14	8746806.	624772.	1.81	0.139
Residual	14	4830527.	345038		
Total	29	20992573.			

Grain yield found in both sites sotuba and kassela was low compared to the potential of hybrids 4370 kg/ha-8073 kg/ha [10]. Thousand kernels weight was from 263.3 grams to 380 grams at Sotuba and from 240 to 276.7g at Kassela. These weights were low compared to those found by [11] where the best weight was 511.25 grams. Kernel weight could influence grain yield. From two trials at Sotuba and Kassela mean of day to 50% anthesis and day to 50 % silking were 56 and 55 respectively for 23 entries trial. At Kassela, mean of day to 50% anthesis and days to 50 % silking were 57 for both traits for 23 entries trial and 54 for both traits for 15 entries trial. 55 and 54 for 15 entries trial. Plant aspect mean was better at Sotuba

2.19 and 1.56 for 23 and 15 entries trials respectively than Kassela trials. This difference is due to soil nature. However mean of ear aspect was better at kassela 1.8 and 1.5 for 23 and 15 entries trials respectively against 1.9 and 1.6 at Sotuba. This good ear aspect at kassela revealed good grain yield. The best grain yield was found at Kassela 6320 kg/ha with TZI1876/CML442. After investigation we realized that farmer used poultry organic manure. A part of ear height at kassela site where there was 1.62 m and 0.870 m for 23 entries trial and 15 entries trial, respectively plant height, ear height and leave width were almost the same in term of mean.
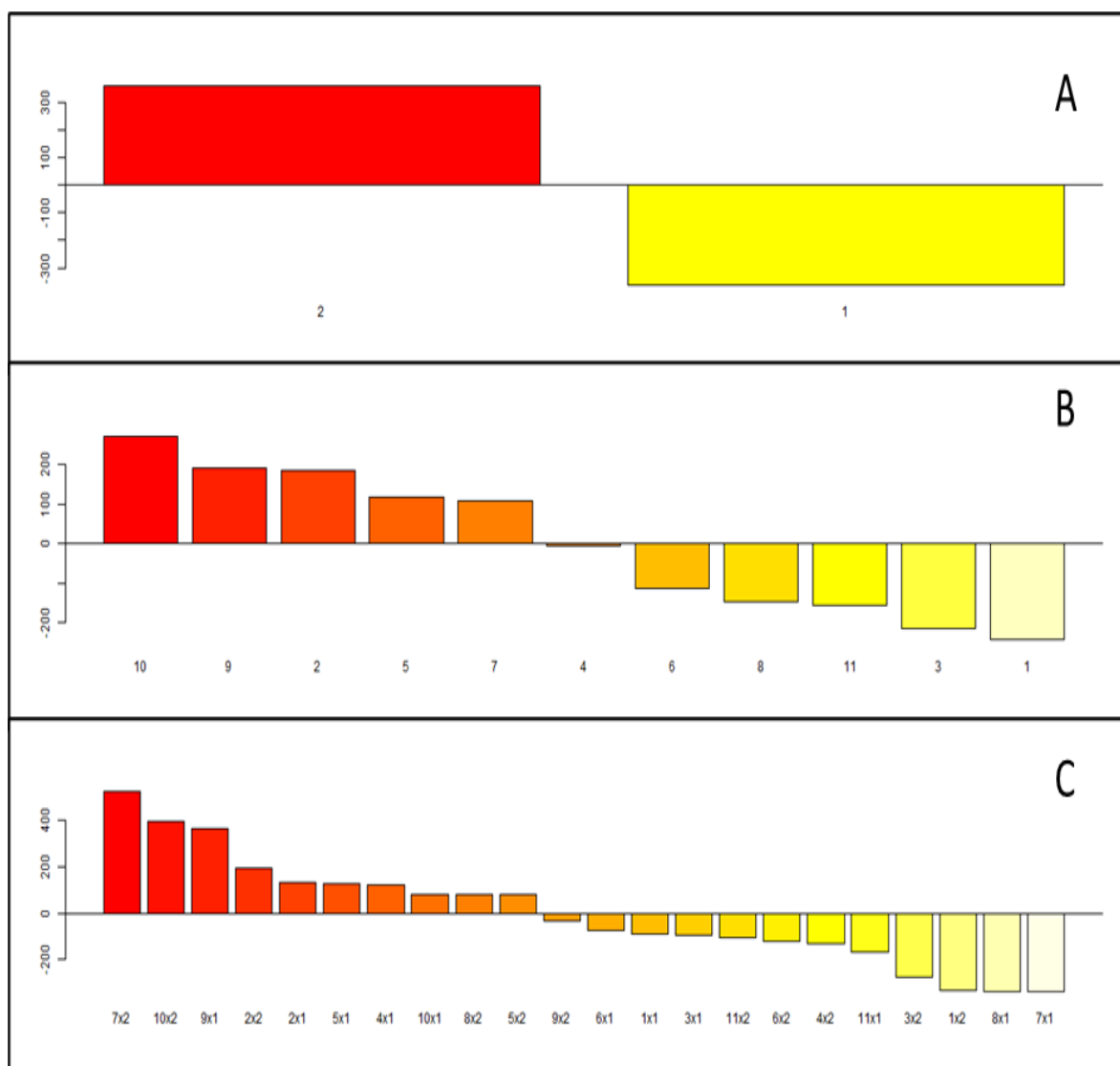

Fig. 1. General combining ability for the best tester (V481-73) (A), best lines (CML442) (B) and specific combining ability for the best line/tester (V481-73/S6 1-6) (C)

Fig. 2. General combining ability for the best tester (TZI1876)
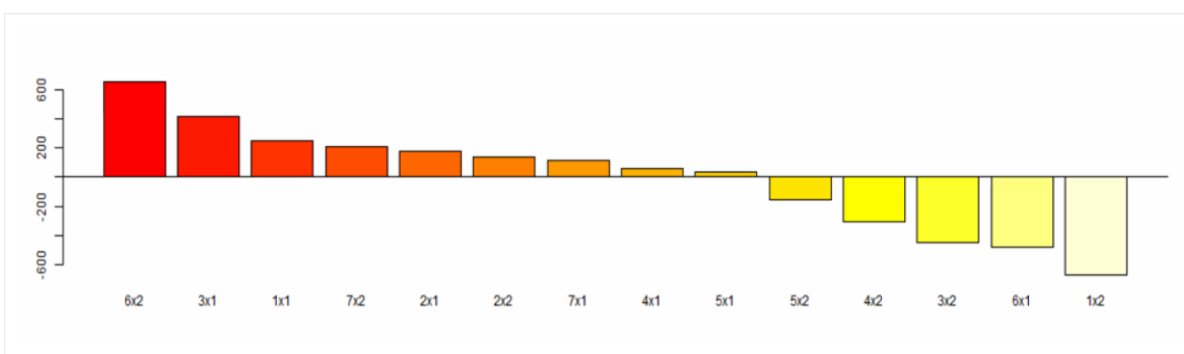

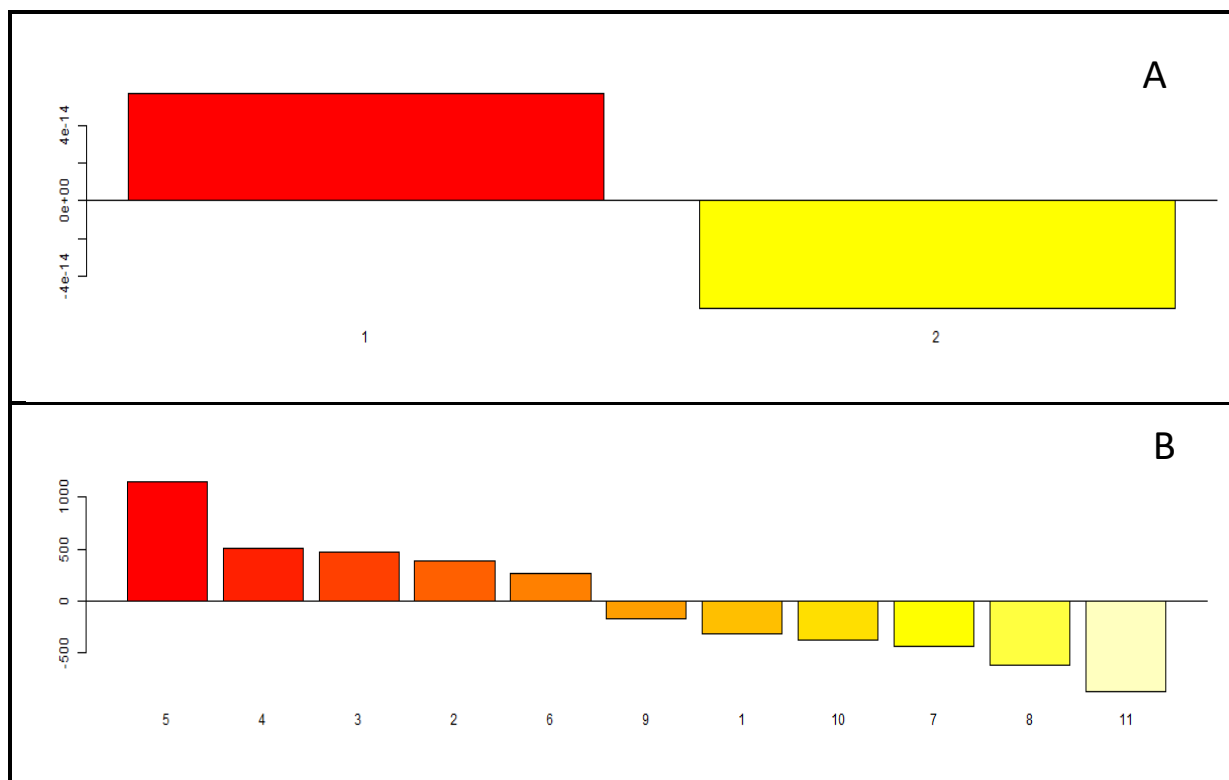**Fig. 3. Specific combining ability for the best hybrid (V481-73/CML442)**

Fig. 4. A. General combining ability for the best tester TZI1876 23 entries
B. General combining ability for the best lines 23 entries

Table 13. Mean of grain yield Fifteen (15) entries trial (Sotuba and Kassela)

Hybrids	Grain (kg/ha)
1-TZI1876/CML538	3906
2-V481-73/CML538	3058
3-TZI1876/CML505	4748
4-V481-73/CML505	3852
5-TZI1876/CML442	3139
6-V481-73/CML442	3896
7-TZI1876/S6 1-6	4252
8-V481-73/S6 1-6	3694
9-TZI11876/J16-1	4071
10-V481-73/J16-1	4184
11-TZI1876/9071	3829
12-V481-73/9071	3698
13-check	3178.
14-TZI1876/S6 7-14	4089.
15-V481-73/S6 7-14	5120.
Mean	3.914.
Significance	-
LSD	1.259.8
CV%	1.5.0

Table 14. Testers general combining ability trial 23 entries (Sotuba)

Testers	Mean	GCA	Standard_Error	T_Value	Prob_T	Rank
1. TZI1876	4485,084	-362,957	276,96	-1,3105	0,414955	2
2. V481-73	4485,084	362,9572	276,96	1,310504	0,414955	1

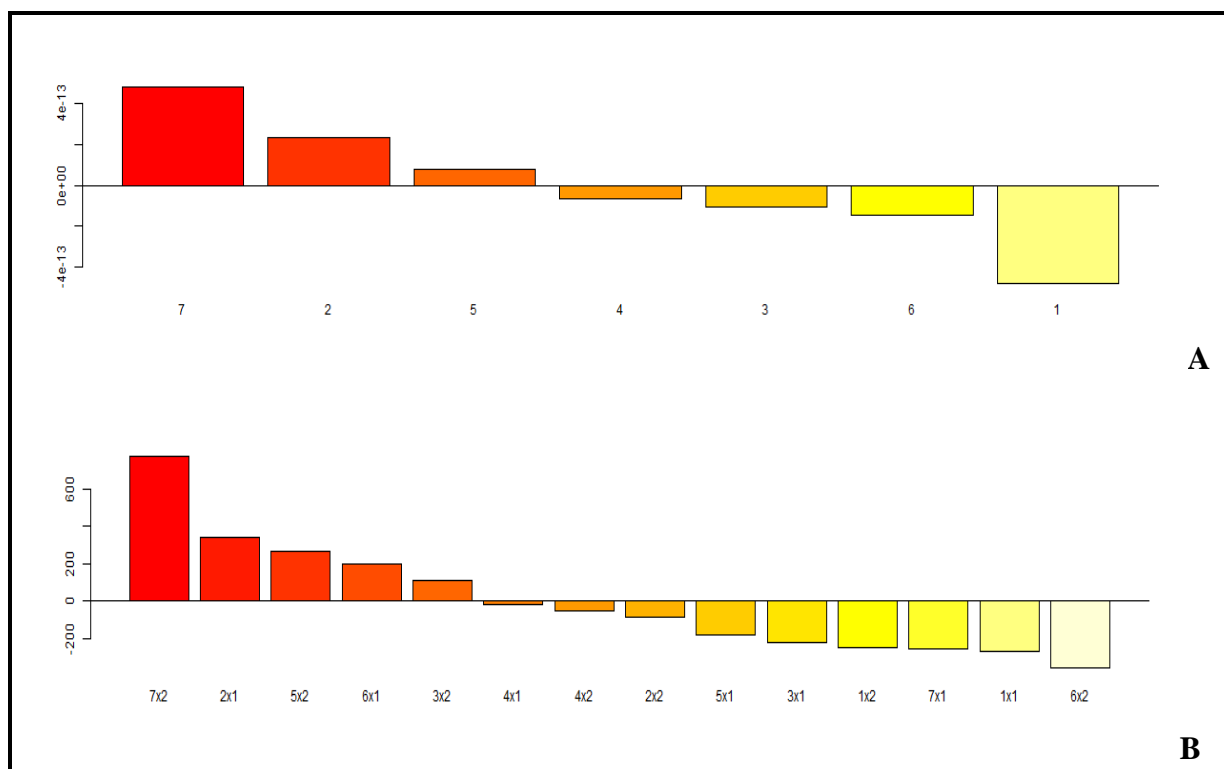*T Value=Test Value; Pro T=Probability Test*

Fig. 5. General combining ability for the best lines 15 entries A. Specific Combining Ability for the best hybrid 15 entries B

Table 15. Testers general combining ability trial 15 entries (Sotuba)

TESTER	GRAN_MEAN	GCA	Standard_Error	T_Value	Prob_T	GCA_RANK
1	4876,509	102,6885	198,6893	0,51683	0,696319	1
2	4876,509	-102,688	198,6893	-0,51683	0,696319	2

Table 16. Testers general combining ability trial 23 entries (Kassela)

TESTER	GRAN_MEAN	GCA	Standard_Error	T_Value	Prob_T	GCA_RANK
1	3513,41	5,7E-14	1,38E-05	4,13E-09	1	1
2	3513,41	-5,7E-14	1,38E-05	-4,1E-09	1	2

Table 17. Specific combinig ability 23 entries (Kassela)

Lines	Testers	Mean	SCA	Standard_Error	Rank
1. TZI1876/CML538	1. TZI1876	3513,41	0	0	11,5
1. TZI18976/CML538	2. V481-73	3513,41	0	0	11,5
10. V481-73/CML442	1. TZI1876	3513,41	0	0	11,5
10. V481-73/CML442	2. V481-73	3513,41	0	0	11,5
11. TZI1876/1368+PAC	1. TZI1876	3513,41	0	0	11,5
11. TZI1876/1368+PAC	2. V481-73	3513,41	0	0	11,5
2V481-73/CML538	1. TZI1876	3513,41	0	0	11,5
2. V481-73/538	2. V481-73	3513,41	0	0	11,5
3. TZI1876/CML505	1. TZI1876	3513,41	0	0	11,5
3TZI1876/CML505	2. V481-73	3513,41	0	0	11,5
4. V481-73/CML505	1. TZI1876	3513,41	0	0	11,5
4V481-73/CML505	2. V481-73	3513,41	0	0	11,5
5. TZI1876/EXP124-1	1TZI1876	3513,41	0	0	11,5
5. TZI1876/EXP124-1	2V481-73	3513,41	0	0	11,5
6. V481-73/EXP124-1	1. TZI1876	3513,41	0	0	11,5
6. V481-73/EXP124-1	2. V481-73	3513,41	0	0	11,5
7. TZI1876/S6 1-6	1. TZI1876	3513,41	0	0	11,5
7TZI1876/S6 1-6	2. V481-73	3513,41	0	0	11,5
8. V481-73/S6 1-6	1. TZI1876	3513,41	0	0	11,5
8. V481-73/S6 1-6	2. V481-73	3513,41	0	0	11,5
9. TZI1876/CML442	1. TZI1876	3513,41	0	0	11,5
9. TZI1876/CML442	2. V481-73	3513,41	0	0	11,5

T Value=Test Value ; Pro T=Probability Test ; N/A=Non Applicable

Table 18. General combining ability for testers 15 entries (Kassela)

Testers	Mean	GCA	Standard_Error	Rank
1. TZI1876	3429,989	0	0	1,5
2. V481-73	3429,989	0	0	1,5

T Value=Test Value; Pro T=Probability Test; N/A=Non Applicable

6. CONCLUSION

This work was to evaluate hybrids performance and combining ability of maize lines in Mali two sites. Two trials were conducted. The first was composed of 23 hybrids and the second was composed of 15 hybrids. All these hybrids had in common two testers.

At Sotuba with 23 hybridsTester 2 V481-73 had best General combining ability.

Line CML442 had the best general Combining Ability for both TZI1876 and V481-73.

Hybrid V481-73/S6 1-6 had the best Specific Combining Ability. However, with 15 hybrids Tester 1 TZ1876 had the best General Combining Ability. Hybrid V481-73/CML442 had the best Specific Combining Ability.

At kassela with 23 hybrids Tester TZI 1876 had the best General Combining Ability. Line EXP 124-1 had the best General Combining Ability for both testers. However, there was not difference among testers for General Combining Ability. Line S6 1-6 had the best General combining Ability. It had the best Specific Combining Ability

with V481-73. This line in six generation selfing will be include in our breeding programm.

Testers reacted to lines differently according to sites.

7. PERSPECTIVES

This work must be done second time to confirm results at the same time increase sites number. The best hybrid was 6320 kg/ha with TZI1876/CML442. This hybrid will be tested at on farm trial for farmers appreciation. This hybrid will be tested at area where rainfall is above 600 mm.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kassam AH, JM Kowal, Dagg, Harrison MN. 1975. Maize in West Africa: Its potiential in savanna area. World Crops cited by Baffour Badu-Apraku* and A.Fontem Lum. Agronomic Performance of *Striga* Resistant Early-Maturing Maize Varieties and Inbred Lines in the Savannas of West and Central Africa. Crop Science. 2007; 47,(17:75) :78.
2. Fakorede MAB, Badu-Apraku BB, Kamara AY, Menkir A, Ajala SO. Maize revolution in West and Central Africa: An overview. In Badu-Apraku et al. (ed) Proc. of a regional maize workshop IITA Cotonou, Benin Republic. WECAMAN/IITA. 2001;14-18: 3-15.
3. IITA: Research for development: Cereal and legume System. 2007.
4. EUCORD: Mali Development of Agriculture through Sorghum Hybrids 1050 Brussels, BELGIUM. 2008.
5. Sprague GF et Tatum, LA Général vs capacité combinée dans les croisements simples de maïs. Agronomie. 1942;34:923-932.
6. Rojas BA, Sprague GF, A comparison of variance components in corn yield trials. III. General and specific combining ability and their interaction with locations and years. Agron. J. 1952 ;44:462-466.
7. Sprague GF, Eberhart SA. Corn breeding. In: Sprague, G.F. (Ed.) corn and corn improvement. 2.ed. Madison: American society of agronomy cited by NASS, L.L et al: Combining ability of maize inbred lines evaluated in three environments in Brazil, Sci.agric. n.1 Piracicaba. 2000; 57 :305-363.
8. Kempthorne O. An Introduction to Genetic Statistics. John Wiley and Sons, Inc., New York; 1957.
9. Coulibaly Mamadou Mory, Essie Blay, Vernon Gracen, The Charles, Niaba Teme: Performance of Maize Inbred Lines and Their Hybrids Under Varying Drought Stress Conditions in Mali. International Journal of Material and Mechanical Engineering (IJMME); 2014 www.ijm-me.org 2014; 3(2).
DOI: 10.14355/ijmme.2014.0302.01
10. Menkir et al Estimation des gains génétiques pour la tolérance aux combinaisons de stress chez les hybrides de maïs tropicaux Article de recherche original
Devant. Genet., 08 décembre 2022
Sect. Génomique végétale
Volume 2022;13.
Available:| https://doi.org/10.3389/fgene.2022.1023318
11. Mieso Keweti Shengu Genetic Study of Some Maize (Zea Mays L) Genotypes in Humid Tropic of Ethiopia International Journal of Scientific and Research Publications. 2017;7(1):284
ISSN: 2250-3153.

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