Performance of Variety Cross Hybrids of Maize (*Zea Mays* L.) in the Mid-Altitude and Highland Transition Areas of Ethiopia

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Abstract: Improved open-pollinated varieties (OPVs) have been developed and released for commercial production in maize growing areas of Ethiopia. However, the dissemination of these improved varieties is limited because of a low level of interest of seed producers in the production and marketing of OPV seed. The dissemination of broad based improved varieties could be increased by the development and release of adapted commercial high yielding variety cross hybrids. This study was conducted in 2002 at seven locations in the mid-altitude (1000 – 1800 meter above sea level, masl) and highland transition areas (1800 – 2000 masl) of Ethiopia to evaluate the performance of variety cross hybrids. Twenty-nine variety cross hybrids and nine parental OPVs/populations along two checks were tested in randomized complete block design with three replications at each location. Analysis of variance revealed significant difference ($P<0.01$) among the entries. The mean grain yield ranged from 3.9 to 8.3 t ha^{-1}. Some variety cross hybrids gave a better performance than the improved OPVs. Kuleni (Pool-9A) x Abo-Bako outyielded the high parent (Kuleni) by 29.7% and Gibe-1 x Kuleni outyielded the best OPV and high parent (Gibe-1) by 14.7%. Gibe-1 x Kuleni also had a more stable performance across the testing locations than the parental OPVs. This implied that moving from OPVs to variety cross hybrids, particularly under small scale farmers' conditions, could increase the productivity of maize.

Keywords: Grain yield; Open Pollinated Variety; Variety Cross Hybrid; *Zea mays*

1. Introduction

In Ethiopia, maize production has increased over the years (Kebede *et al*., 1993; Mosisa *et al*., 2002; CSA, 2007). However, the demand for maize grain is expected to increase due to the high rate of population increase in the country. To fulfill the demand for maize grain in the future, maize production must be performed predominantly on the existing cultivated land. Expansion of cultivated land is decreasing more and more because of population increase, environmental concerns and urbanization.

Improved varieties play a great role in increasing maize productivity on currently cultivated land. The National Maize Research Project has developed a number of improved maize varieties through different breeding methodologies (Benti *et al*., 1993; Mosisa *et al*., 2002). The improved maize varieties include open-pollinated varieties (OPVs) and different types of hybrids (top cross, three-way cross and single cross hybrids). The superiority of the improved varieties over the local checks (farmers' variety) and superiority of the hybrids over the improved OPVs has been demonstrated on the farmers' fields (Ibrahim and Tamene, 2002; Chimdo *et al*., 2002). However, only about 20% of the maize area in Ethiopia is planted with improved maize varieties, mainly conventional hybrids (Adungna and Melaku, 2002; Yonas and Mulugeta, 2002), indicating that the majority of farmers still plant local varieties and/or recycled seed of improved varieties.

Paliwal *et al.* (2000) reported that variety cross hybrids (cross between two OPVs/populations) have 17% yield advantage over improved OPVs, but lower yield potential compared to conventional and top cross hybrids. The authors emphasized that the depression in the yield with the use of F_2 seed is lower in the variety cross hybrids than in the conventional hybrids. Research results in Ethiopia also showed that grain yield reduction in F_2 generation of top-cross hybrid (BH-140), three-way cross hybrid (BH-660) and single-cross hybrid (BH-540) is 11.7%, 18.9% and 23.0%, respectively (National Maize Research Project, 1996), showing less yield reduction in F_2 of the broad based hybrid (top-cross hybrid) compared to in the narrow based hybrids. This indicates the importance of variety cross hybrids (broad based hybrids) in small scale farmers' conditions where the continuous supply of improved seed is limited and use of F_2 grain as seed is common.

Benti *et al.* (1989) evaluated variety cross hybrids at Bako and reported 1.8 to 4.6% higher grain yield for the best variety cross hybrid than for the best OPV. They associated this low heterosis among the crosses of locally adapted old OPVs with the lack of distinct genetic difference among the OPVs included in the study. Since then, different improved OPVs and breeding populations have been developed. However, the cross performance of these improved materials has not been studied. Thus, this study assesses the performance of variety cross hybrids and their parents in the sub-humid mid-altitude (1000 – 1800) and highland transition (1800 – 2000) areas of Ethiopia.

2. Materials and Methods

Nine OPVs and breeding populations adapted to sub-humid areas (areas with sufficient rainfall) were used in the formation of the variety cross hybrids. The sources and adaptation areas of these materials are presented in Table 1. For each material, two seeds were planted in 10 rows of 5.0 m length, in 2001 main season at Bako Agricultural Research Center. Then, 200 plants were maintained in each plot after thinning. Twenty nine crosses were made among selected materials, previously selected for grain yield and other important agronomic traits, using bulk pollen for each material. At harvest, all the harvested ears were shelled and the seed was bulked for each cross.

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Table 1. Maize materials used for the formation of variety cross hybrids and their areas of adaptation (meter above sea level, masl).

Maize materials	Source	Status	Altitude (masl)	Adaptation
Kuleni	CIMMYT	OPV	1700 – 2200	Highland transition
Gibe-1	Ethiopia	OPV	1000 – 1700	Mid-altitude
Gambela Composite	IITA	OPV	300 – 1000	Low-altitude
Abo-Bako	IITA	OPV	300 – 1000	Low-altitude
Obatanpa	Gahana/IITA	BP	300 – 1000	Low-altitude
Pop-43	CIMMYT	BP	1000 – 1500	Mid-altitude
Gutto LMS5*	CIMMYT	BP	1000 – 1700	Mid-altitude
SC Group Pool	Ethiopia	BP	1000 – 1700	Mid-altitude
Gutto Group Pool	Ethiopia	BP	1000 – 1700	Mid-altitude

** Female parent of BH-140, OPV- Open-pollinated variety*
BP- Breeding population

In 2002, the 29 variety cross hybrids, along with the nine parental materials and two checks were planted under rain fed condition at seven locations in the mid-altitude and highland transition areas using randomized complete block design with three replications (Table 2). The experiments were planted according to the recommended fertilizer rate and other cultural practices for maize at each site. Plot size was 5.1 m x 1.5 m with two rows for each entry. The spacings were 0.75 m and 0.30 m between rows and plants, respectively, giving 44,444 plants per hectare.

Agronomic data were recorded for all the entries. Silking date was recorded when 50% of the plants in the plot were with emerged silk. Then days from emergence to silking (DFF) were calculated. Plant height (PH) was measured from ground level to the point where the tassel starts branching. Similarly, ear height was measured from ground level to the node bearing the top ear for the same plants. Gray leaf spot (*Cercospora zeae-maydis*), Turcicum leaf blight (*Exserohilum turcicum*) and common rust (*Puccinia sorghi*) were scored on a scale of 1 (clean, no infestation) to 5 (severely diseased). Grain yield was recorded from all ears in the harvest area at harvest. Then grain yield (t ha^{-1}) was calculated using average shelling percentage of 80% and adjusted to 12.5% moisture.

Analysis of variance was conducted for each location. After Bartlett's test for the homogeneity of the error variance, combined analysis was conducted. Finally, stability analysis was conducted using Additive Main effect and Multiplicative Interaction, AMMI2 Model (the most suitable model for the data) (Crossa *et al*., 1990; Purchase, 1997), Wricke's ecovalence analysis (Westcott, 1985; Purchase, 1997) and Shukla's stability variance analysis (Shukla, 1972). MSTAT-C software computer program (Fred *et al*., 1991) and AGROBASE software computer program (Agronomix software INC. and AGROBASE, 2000) were used for the analysis of the data.

Table 2. Testing locations in the mid-altitude and highland transition areas of Ethiopia.

Site	Altitude (masl)	Annual Rainfall (mm)	Catagory
Bako	1650	1200	Mid-altitude
Awasa	1700	1110	Mid-altitude
Jimma	1750	1595	Mid-altitude
Pawe	1100	1250	Mid-altitude
Areka	1800	1615	Highland transition
Finote-Selam	1800	1200	Highland transition
Arsi-negele	1960	900	Highland transition

3. Results and Discussion

3.1. Grain Yield and Some Related Traits

Analysis of variance for grain yield at each location showed significant difference (P<0.01) among the entries (Table 3). The mean grain yield ranged from 3.9 t ha^{-1} (for POP-43) to 8.3 t ha^{-1} (for Kuleni x Abo-Bako). Gibe-1 had the highest mean grain yield among the OPVs (Table 3). The lowland adapted OPVs, Abo-Bako and Gambela composite were the top yielding among the OPVs at Pawe whereas they were among the low yielding in the highland transition areas, Areka and Arsi-negele. Kuleni x Abo-Bako was among the top yielding hybrids across the testing locations except at Areka (Table 3). This indicated that crosses of lowland material and highland transition materials might adapt to mid-altitude and highland transition areas. The cross of mid-altitude material, Gibe-1 and highland transition material, Kuleni (Gibe-1 x Kuleni) was also among the high yielding hybrids across the testing locations. On the other hand, the top yielding hybrid at Pawe, Gibe-1 x Abo-Bako was relatively low yielding in the highland transition areas, Areka and Arsi-negele, compared to Kuleni x Abo-Bako and Gibe-1 x Kuleni. This may indicate that crosses of lowland and highland transition materials and crosses of mid-altitude and highland transition materials had better adaptation across mid-altitude and highland transition areas than the crosses of lowland and mid-altitude and crosses of lowland and lowland materials which had relatively specific adaptation (Table 3). In line with these findings, Eberhart (1989) found that highland transition materials performed relatively before in the low elevations than lowland materials in the high elevations.

The combined analysis for grain yield showed significant genotype by environment interaction (P<0.01) showing the inconsistency of the performance of the maize materials across the testing locations. IPCA1 was significant (P<0.01) and explained 34.6% of the genotype by environment interaction. IPCA2 was also significant (P<0.01) and explained 25.7% of the genotype by environment interaction. Thus, the two principal components explained 60.3% of the genotype by environment interaction (data not shown).

Stability parameters showed differences among the maize materials for their stability performance for grain yield across the testing locations (Table 4). The closer the IPCA scores (Interaction Principal Component Analysis scores, IPCA1 and IPCA2) to zero the more stable the maize materials are across the locations.

Table 3. Grain yield (t ha^{-1}) of maize variety cross hybrids and their parental OPVs/populations at seven different testing locations in the mid-altitude and highland transition areas in Ethiopia.

	Entry	Bako	Awasa	Areka	Arsi-negele	Pawe	Finote-Selam	Jimma	Mean
1	Gibe-1 x Gutto Group Pool	8.6	5.6	6.0	3.8	7.9	4.7	6.7	6.2
2	Gibe-1 x Kuleni	9.1	8.0	6.1	5.7	8.6	8.4	8.8	7.8
3	Gibe-1 x Gambela composite	8.4	7.2	3.0	5.5	9.8	6.3	8.6	7.0
4	Gibe-1 x Abo-Bako	10.0	8.9	4.7	4.7	10.2	7.0	8.9	7.8
5	Gibe-1 x Gutto LMS5	8.4	7.4	6.8	4.8	8.6	5.7	8.2	7.1
6	Kuleni x POP-43	9.4	8.1	5.6	5.8	8.2	5.9	9.8	7.5
7	Kuleni x Gutto Group Pool	8.9	8.1	6.1	5.1	7.1	5.9	8.5	7.1
8	Kuleni x Gambela composite	9.2	8.3	4.5	6.0	8.7	6.9	7.3	7.3
9	Kuleni x Gutto LMS5	8.8	8.4	6.0	5.9	8.4	6.0	9.6	7.6
10	Kuleni x Abo-Bako	10.0	9.9	5.4	6.0	10.0	6.5	10.4	8.3
11	Kuleni x SC Group Pool	9.7	8.0	7.1	6.3	7.8	6.0	9.6	7.8
12	Gibe-1 x SC Group Pool	9.1	7.1	8.5	6.0	8.7	6.5	8.5	7.8
13	SC Group Pool x Gambela composite	7.9	6.6	5.5	6.1	8.9	6.2	7.7	7.0
14	SC Group Pool x POP-43	9.3	8.2	6.5	4.8	8.6	6.2	7.7	7.3
15	SC Group Pool x Gutto Group Pool	8.6	7.2	6.0	4.5	8.4	6.3	8.3	7.0
16	SC Group Pool x Abo-Bako	9.8	7.4	6.0	4.7	10.2	6.1	8.0	7.5
17	SC Group Pool x Gutto LMS5	8.2	8.2	7.6	4.8	8.3	5.6	8.2	7.3
18	Gutto Group Pool x Abo-Bako	8.8	7.2	4.2	4.2	8.0	5.6	4.9	6.1
19	Gutto Group Pool x POP-43	5.8	6.2	4.7	4.5	7.0	4.7	5.6	5.5
20	Gutto Group Pool x Kuleni	6.8	7.8	4.9	5.6	7.6	5.3	6.9	6.4
21	Gutto Group Pool x Obatanpa	7.4	7.3	5.2	3.7	8.1	6.6	5.6	6.3
22	Gutto Group Pool x Gambela composite	8.0	6.0	4.1	4.4	6.2	5.4	6.2	5.8
23	Gutto Group Pool x Gutto LMS5	6.2	5.8	5.1	4.1	7.2	4.8	4.8	5.4
24	Gambela composite x Obatanpa	8.8	6.8	3.3	3.3	8.7	5.1	5.5	5.9
25	Gambela composite x Abo-Bako	7.1	6.1	2.9	3.6	9.1	5.1	5.7	5.6
26	Abo-Bako x Obatanpa	5.9	4.0	2.1	1.3	6.8	5.1	3.7	4.2
27	Abo-Bako x Gutto LMS5	8.5	7.8	5.1	4.0	8.7	5.1	5.9	6.4
28	POP-43 x Gibe-1	8.2	7.4	4.7	4.9	8.0	7.4	7.4	6.9
29	Gutto LMS5 x POP-43	7.2	5.6	4.9	4.4	7.0	5.5	4.4	5.6
30	Gibe-1	8.4	7.6	7.0	5.1	7.4	5.5	7.0	6.8
31	Gambela composite	6.5	5.6	3.2	2.9	8.3	5.1	5.8	5.3
32	Kuleni	8.1	7.0	3.9	5.3	5.7	6.9	8.2	6.4
33	Gutto LMS5	6.8	5.2	4.0	3.6	6.6	4.0	5.7	5.1
34	Abo-Bako	7.0	6.7	2.5	3.6	8.4	5.5	5.8	5.6
35	Obatanpa	7.8	7.1	4.7	3.3	7.0	6.0	5.5	5.9
36	POP-43	4.5	5.0	2.2	2.8	5.6	5.0	2.5	3.9
37	SC Group Pool	7.9	5.6	5.0	4.3	7.3	5.5	7.7	6.2
38	Gutto Group Pool	6.1	5.7	3.9	3.9	6.9	4.5	5.4	5.2
39	BH-140	8.7	8.3	6.0	4.5	7.4	5.3	7.0	6.8
40	BHQP-542	8.7	6.4	5.2	4.6	7.8	5.8	7.8	6.6
	Mean	8.1	7.0	5.0	4.6	8.0	5.8	7.0	6.5
	CV%	12.2	11.8	26.1	18.9	14.4	19.2	19.4	17.0
	F-test	**	**	**	**	**	*	**	**
	LSD 0.05	1.6	1.3	1.4	1.4	1.9	1.8	2.2	0.7

Similarly, the materials with the small ecovalence and stability variance are considered to be stable (Lin et al., 1986; Crossa *et al.*, 1990; Purchase, 1997). The hybrid with the high mean grain yield, Kuleni x Abo-Bako, was among the hybrids with high negative IPCA scores (IPCA1 and IPCA2). In addition, this hybrid had high stability variance and ecovalence, indicating that the performance of this hybrid was not stable across the testing locations. However, Gibe-1 x Kuleni had low stability variance, ecovalence and IPCA scores (negative) as compared to the parental OPVs. This indicates that some specific variety cross hybrids were more stable than the improved OPVs for grain yield performance across the testing locations.

The stable variety cross hybrid, Gibe-1 x Kuleni, outyielded the best OPV, Gibe-1 by 14.7%, indicating the superiority of variety cross hybrids over the improved OPVs in grain yield (Table 4). This hybrid had also good tolerance to major foliar diseases common at the testing locations and had less than 250 cm and 150 cm plant height and ear height, respectively (Table 5). This justified the feasibility of variety cross hybrids for commercial production, particularly on small scale farms of resource poor farmers who have limited access to input and output markets.

In this study, the best variety cross hybrids outyielded the commercial top cross hybrid, BH-140 (Table 3). However, these hybrids may not outyield the best available conventional hybrids in Ethiopia (Mosisa *et al.*, 2002). This may limit the production of variety cross hybrids in the large commercial maize farms. On the other hand, the simplicity of seed production and low seed price of variety cross hybrids may increase the demand for variety cross hybrids, particularly under small scale farmers' conditions. Thus, considering the interest of small scale farmers, who are the major maize grain producers in Ethiopia, development of variety cross hybrids is important for sustainable maize production. Paliwal (2000) also suggested the use of non-conventional hybrids in tropical environments where the field size is small, recycling of F_2 seed is common and maize is harvested by hand.

3.2. Heterosis for Mean Grain Yield

The percentage of high-parent heterosis for the mean grain yield showed considerable variation among the crosses (Table 4). It ranged from -28.8% (for Abo-Bako x Obatanpa) to 29.7% (for Kuleni x Abo-Bako). Out of all the crosses, 6.9% showed negative high-parent heterosis while 24.1% showed more than 15.0% positive high-parent heterosis. All the mid-altitude and lowland materials manifested positive high-parent heterosis when crossed to Kuleni, highland transition material. The hybrid, Kuleni x Abo-Bako manifested the highest positive percentage of high-parent heterosis, indicating genetic divergence between the two OPVs. Leta *et al.* (1999) reported high heterosis between the cross of Kitale composite B (KCB) and Abo-Bako. Since Kuleni was mainly synthesized from east African materials (Lothrop, 1989), the high heterosis between Kuleni and Abo-Bako in this study may indicate that Abo-Bako is heterotic to some of east African materials. On the other hand, most of the crosses among lowland materials showed low or negative high-parent heterosis, suggesting close affinity among these materials.

The cross of the two heterotic populations, SC Group Pool and Gutto Group Pool, showed 12.9% high-parent heterosis, indicating the success in the formation of the two heterotic populations (Mosisa *et al.*, 1996). However, the lower heterosis between the two populations compared to some specific combinations in this study indicated the need for improving the two heterotic populations. Eberhart (1989) also suggested that the best population cross performance could be expected from populations improved by recurrent selection, particularly through reciprocal recurrent selection.

In conclusion, the higher grain yield and the more stable the performance of specific variety cross hybrids compared to improved OPVs implies that moving from OPVs to variety cross hybrids, particularly under small scale farmers' conditions, will increase the productivity of maize. In addition, the positive high-parent heterosis observed between the improved OPVs, Kuleni and Abo-Bako and Gibe-1 and Kuleni, showed that Kuleni and Abo-Bako and/or Gibe-1 and Kuleni could be good alternative heterotic combinations in the development of hybrids adapted to the mid-altitude potential areas in Ethiopia.

Table 4. Stability parameters [Interaction Principal Component Analysis axes (IPCA1 and IPCA2) ecovalence and stability variance] and mean grain yield (GY, t ha^{-1}) for maize variety cross hybrids and their parental OPVs/populations tested at seven locations in Ethiopia.

	Entry	IPCA1	IPCA2	Ecovalence	Stability variance	GY t ha^{-1}	Percent of high parent
1	Gibe-1 x Gutto Group Pool	-0.34	0.10	4.0	2.0	6.2	91.2
2	Gibe-1 x Kuleni	-0.34	-0.06	2.6	1.3	7.8	114.7
3	Gibe-1 x Gambela composite	0.06	-0.73	4.7	2.4	7.0	102.9
4	Gibe-1 x Abo-Bako	0.35	-0.67	6.6	3.4	7.8	114.7
5	Gibe-1 x Gutto LMS5	-0.35	0.21	2.3	1.2	7.1	104.4
6	Kuleni x POP-43	-0.77	-0.43	6.2	3.2	7.5	117.2
7	Kuleni x Gutto Group Pool	-0.44	0.29	3.9	2.0	7.1	110.9
8	Kuleni x Gambela composite	0.36	-0.19	3.2	1.6	7.3	114.1
9	Kuleni x Gutto LMS5	-0.75	-0.30	5.3	2.7	7.6	118.8
10	Kuleni x Abo-Bako	-0.79	-1.22	17.1	8.9	8.3	129.7
11	Kuleni x SC Group Pool	-0.80	0.22	6.1	3.1	7.8	121.9
12	Gibe-1 x SC Group Pool	-0.61	0.51	6.5	3.4	7.8	114.7
13	SC Group Pool x Gambela composite	-0.12	-0.13	2.3	1.1	7.0	112.9
14	SC Group Pool x POP-43	-0.03	0.25	1.4	0.7	7.3	117.7
15	SC Group Pool x Gutto Group Pool	-0.25	-0.03	1.1	0.5	7.0	112.9
16	SC Group Pool x Abo-Bako	0.05	-0.34	3.4	1.7	7.5	121.0
17	SC Group Pool x Gutto LMS5	-0.38	0.60	5.6	2.9	7.3	117.7
18	Gutto Group Pool x Abo-Bako	0.63	0.12	5.1	2.6	6.1	108.9
19	Gutto Group Pool x POP-43	0.04	0.43	3.2	1.6	5.5	105.8
20	Gutto Group Pool x Kuleni	0.03	0.33	3.9	2.0	6.4	100.0
21	Gutto Group Pool x Obatanpa	0.54	0.33	3.7	1.9	6.3	106.8
22	Gutto Group Pool x Gambela composite	-0.10	0.06	2.1	1.0	5.8	109.4
23	Gutto Group Pool x Gutto LMS5	0.18	0.50	3.5	1.8	5.4	103.9
24	Gambela composite x Obatanpa	0.63	-0.43	6.6	3.4	5.9	100.0
25	Gambela composite x Abo-Bako	0.61	-0.57	5.9	3.0	5.6	100.0
26	Abo-Bako x Obatanpa	0.58	-0.15	6.1	3.2	4.2	71.2
27	Abo-Bako x Gutto LMS5	0.42	0.16	3.6	1.8	6.4	114.3
28	POP-43 x Gibe-1	0.23	-0.13	2.4	1.2	6.9	101.5
29	Gutto LMS5 x POP-43	0.31	0.46	4.6	2.4	5.6	109.8
30	Gibe-1	-0.27	0.70	4.1	2.1	6.8	-
31	Gambela composite	0.39	-0.41	3.2	1.6	5.3	-
32	Kuleni	-0.35	-0.10	9.5	5.0	6.4	-
33	Gutto LMS5	-0.15	0.07	0.5	0.2	5.1	-
34	Abo-Bako	0.66	-0.47	5.5	2.9	5.6	-
35	Obatanpa	0.38	0.35	3.1	1.6	5.9	-
36	POP-43	0.82	0.37	9.2	4.8	3.9	-
37	SC Group Pool	-0.45	-0.18	2.1	1.1	6.2	-
38	Gutto Group Pool	0.10	0.16	1.1	0.5	5.2	-
39	BH-140	-0.06	0.50	3.6	1.9	6.8	-
40	BHQP-542	-0.31	-0.18	1.2	0.6	6.6	-

Table 5. Mean days to silking (DFF), plant height (PHT), ear height (EHT), gray leaf spot (GLS), turcicum leaf blight (TLB) and common rust for maize variety cross hybrids and their parental OPVs/populations tested at seven locations in Ethiopia.

	Entry	DFF	PHT	EHT	GLS	TLB	Rust
1	Gibe-1 x Gutto Group Pool	77	229	124	2.0	1.8	1.9
2	Gibe-1 x Kuleni	76	237	128	2.2	1.6	1.7
3	Gibe-1 x Gambela composite	77	226	113	2.2	1.9	2.3
4	Gibe-1 x Abo-Bako	79	244	137	1.6	1.9	2.2
5	Gibe-1 x Gutto LMS5	78	230	120	1.6	2.0	1.9
6	Kuleni x POP-43	76	232	123	1.9	1.8	1.9
7	Kuleni x Gutto Group Pool	76	231	124	1.6	1.9	1.8
8	Kuleni x Gambela composite	76	233	124	1.9	1.9	1.9
9	Kuleni x Gutto LMS5	79	235	130	1.8	1.9	1.8
10	Kuleni x Abo-Bako	78	248	144	1.8	1.8	1.9
11	Kuleni x SC Group Pool	77	246	138	1.6	1.7	1.8
12	Gibe-1 x SC Group Pool	77	240	131	1.9	1.7	1.9
13	SC Group Pool x Gambela composite	76	223	119	2.2	1.9	2.1
14	SC Group Pool x POP-43	76	232	124	1.7	1.9	2.2
15	SC Group Pool x Gutto Group Pool	77	232	127	2.0	1.7	1.9
16	SC Group Pool x Abo-Bako	77	242	132	2.2	2.1	2.1
17	SC Group Pool x Gutto LMS5	79	231	126	1.9	1.9	2.1
18	Gutto Group Pool x Abo-Bako	78	229	129	1.5	1.9	2.3
19	Gutto Group Pool x POP-43	77	216	114	1.8	2.3	2.0
20	Gutto Group Pool x Kuleni	77	228	123	1.7	1.7	1.8
21	Gutto Group Pool x Obatanpa	77	221	122	1.9	1.9	2.2
22	Gutto Group Pool x Gambela composite	76	217	116	1.8	1.9	2.2
23	Gutto Group Pool x Gutto LMS5	79	207	111	1.8	1.9	2.0
24	Gambela composite x Obatanpa	77	215	114	2.0	2.1	2.5
25	Gambela composite x Abo-Bako	80	225	123	1.8	2.1	2.6
26	Abo-Bako x Obatanpa	76	209	110	1.6	2.1	2.5
27	Abo-Bako x Gutto LMS5	80	227	124	1.5	1.8	2.4
28	POP-43 x Gibe-1	76	228	116	2.0	1.9	2.1
29	Gutto LMS5 x POP-43	78	215	112	1.8	2.2	2.1
30	Gibe-1	78	236	124	2.1	2.0	2.0
31	Gambela composite	78	218	117	2.2	2.0	2.7
32	Kuleni	78	243	134	1.4	1.8	1.6
33	Gutto LMS5	80	209	110	1.7	2.1	2.1
34	Abo-Bako	80	239	134	2.2	2.2	2.5
35	Obatanpa	76	228	117	1.7	2.1	2.5
36	POP-43	78	204	100	1.4	2.4	2.6
37	SC Group Pool	77	234	129	2.0	1.9	2.0
38	Gutto Group Pool	75	222	114	1.6	2.0	2.1
39	BH-140	80	232	124	1.3	1.9	2.2
40	BHQP-542	77	224	109	1.5	1.9	2.5
	Mean	77	228	122	1.8	1.9	2.1
	CV%	2.6	6.6	11.7	21.1	25.1	17.1
	F-test	ns	**	ns	*	ns	**
	LSD 0.05	-	24.2	-	0.6	-	0.6

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