GENOTYPE X ENVIRONMENT INTERACTION OF INBRED LINES OF MAIZE (ZEA MAYS L.) AND STABILITY OF CROSSES IN KIAMBU AND EMBU COUNTIES, KENYA

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Abstract- Despite the fact that virtually all households in Kenya grow maize over 60% of them are net maize buyers because they do not produce enough for their consumption. Kenya's current food supply situation and outlook give cause for serious concern. Maize is the main staple food averaging over 80% of total cereals (rice, wheat, millet and sorghum) in Kenya. Maize stocks are estimated to be depleted at all levels throughout the country. Due to increasing temperatures as a result of global warming and consequent dropping of water table, there has been shortage leading to increased demand for maize and its products. This study was conducted to determine the stability of respective single crosses in different environments. The trials were conducted in 2012 at experimental stations of Kenya Agricultural and Livestock Research Organization (KALRO), Muguga South and KALRO Embu in Kiambu and Embu counties of Kenya respectively. The study was conducted with 36 crosses. The stability of crosses was determined and interaction between the genotypes and environment was also determined among the crosses.The experiment was laid out in a 6 x 6 lattice complete randomized block design (RBCD) with two replications. Data was subjected to analysis of variance (ANOVA) using Genstat 12 program for individual single crosses as well as for combined environments considering environments as random effects and crosses as fixed effects. Mean separation was done using Tukey's comparison method at 0.05% significance level. Data on grain yield showed no significant difference between the sites but there was significant difference on grain yield. Data on disease scores where natural infestation was visually scored showed majority of the crosses had a score of one confirming their near immunity status. Further research on stability of the crosses can be done not only in the research sites but also in other regions of Kenya. For grain yield improvement crosses MUL508 x MUL688(entry 9), POPA x MUL141(entry 19), MUL513 x MUL114 (entry 31) and MUL513 x CN244 (entry 33) can further be evaluated and eventually released to farmers as they indicated promising relationship with yield potential compared to other crosses. The results will be useful to breeders and farmers in selecting the potential parental materials for improvement in maize breeding programs.

Key words- genotype x environment, KALRO, genotypes, mean performance, significant.

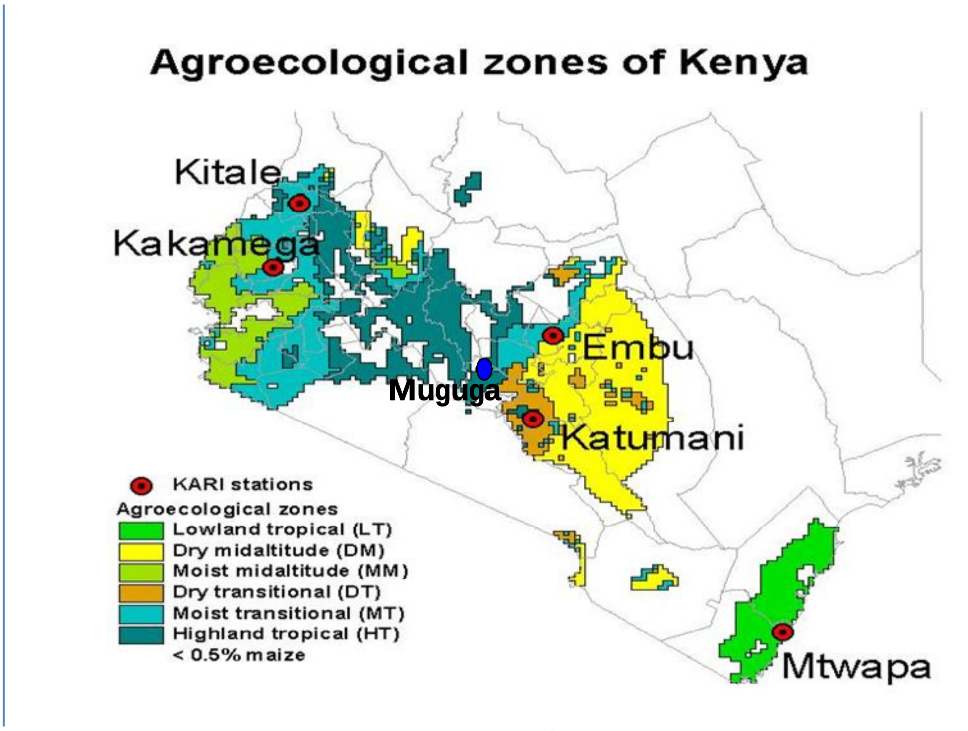
I. INTRODUCTION

Maize (Zea mays) also known as corn is an economically important crop worldwide and particularly in Africa where the annual production exceeds that of wheat and other important staple crops. Maize is the world's most widely grown cereal and is the primary staple food for majority of population in many developing countries (Ofori and Kyei – Baffour, 2006). Maize is a major source of food in Sub- Saharan Africa and its grown by both small and large scale farmers (Anami et al. 2009), and it is an important source of carbohydrate, protein, iron, vitamin B, minerals, livestock fodder and industrially for starch and oil extraction (Kenya Agricultural Livestock and Research Organization, 2009). In Kenya maize production is divided into six agro-ecological zones based on elevation and climate. These regions include: the lowland tropics comprising of the coastal strip and adjoining inland area, the dry mid attitude, the dry transitional zones in the South East, the highlands tropics, the moist transitional zone to the East and West of the highland tropics, the moist mid altitude zone around Lake Victoria (Corbett, 2005).The moist transitional zones are the most important maize production zones followed by the highland tropics. Maize yield variability is extremely high in Sub-Saharan Africa than other regions of the world, as maize production is primarily rain fed. Between 2005 and 2008, for example the average maize yield in SSA was estimated at 1.4 t/ha which is very low as compared to 2.5 to 3.9 in developing countries (Smale et al., 2011). Between 2003 and 2005 the World Food Program spent USS1.5 billion to alleviate food shortage due to drought and food failure in SSA alone (Edmeades, 2008). With maize occupying such central position in Kenya's diet and farm production activities, it's imperative that ways and means of improving maize productivity be sought (GOK, 2007).

II. MATERIALS AND METHODS

Study area

The experiment was undertaken in KALRO Muguga and KALRO Embu in Kiambu and Embu counties respectively.



Source: De Groote et al., 2005

Figure 1: Study sites KALRO Muguga and KALRO Embu

Study materials

The germplasm used in this study were 18 inbred lines and their respective single crosses derived from KALRO Muguga. The entries were used both as the maternal parents in one cross as well the paternal parents in the reciprocal cross. (Table 1)

Table 1: Inbred lines and their respective crosses used in the study

Entry	Single crosses	Entry	Reciprocal crosses
1	MUL 508 X MUL 516	2	MUL 516 X MUL 508
3	MUL 508 X MUL 521	4	MUL 521 X MUL 508
5	MUL 508 X MUL141	6	MUL 141 X MUL 508
7	MUL 508 X MUL 541	8	MUL 541 X MUL 508
9	MUL 508 X MUL 688	10	MUL 688 X MUL 508
11	MUL 508 X CN 244	12	CN 244 X MUL 508
13	POP A X MUL 511	14	MUL 511 X POP A
15	POP A X MUL 521	16	MUL 521 X POP A
17	POP A X MUL 114	18	MUL 114 X POP A
19	POP A X MUL 141	20	MUL 141 X POP A
21	POP A X MUL 536	22	MUL536 X POP A
23	POP A X MUL 541	24	MUL 541 X POP A
25	POP A X MUL 688	26	MUL 688 X POP A
27	MUL 513 X MUL 531	28	MUL 531 X MUL 513
29	MUL 513 X MUL 533	30	MUL 533 X MUL 513
31	MUL 513 X MUL 114	32	MUL 114 X MUL 513
33	MUL 513 X CN 244	34	CN244 X MUL 513
35	MUL 513 X MUL 516	36	MUL 516 X MUL 513

Data analyses

Data collected was subjected to analysis of variance (ANOVA) using Genstat 12 software. The data from the two environments, KALRO Muguga and KALRO Embu was analyzed separately. Basic two-way fixed effects linear model for genotype verses environment analyses was used: $\hat{y}_{ij} = \mu + \check{T}_i + \delta_j + (\check{T}\delta)_{ij} + \varepsilon_{ij}$ where

μ = grand mean overall genotypes and environment

$\check{T}_i$ is the main effect of the i^{th} genotype

δ_j is the main effect of the j^{th} environment

$\check{T}\delta_{ij}$ is the effect of the interaction (GE) of the i^{th} genotype and in the j^{th} environment

ε_{ij} is the average error

Stability was measured by combining Coefficient of Variation (CV), Mean Yield (MY) and Environmental Variance (EV). Genotypes with low CV, low EV and high Mean Yield (MY) were considered most desirable.

RESULTS

Mean performance of crosses on different morphological traits in KALRO Embu

The analysis of variance (ANOVA)(Table 2), showing the mean squares of plant height (PH), ear height (EH), disease scores of maize streak virus (MSV) disease, gray leaf spot (GLS), and grain yield (GY) for Embu are shown in Table 4.2. The crosses showed a highly significant difference ($p < 0.001$) for plant height and ear height. They also showed a significant difference ($p<0.05$) on grain yield.

Table 2: Performance of crosses for different morphological traits in KALRO Embu Mean sum of squares

Source of Variation	Df	PH(cm)	EH(cm)	MSV	GLS	GY(t/ha)
Replication	1	6290.7	660.1	10.889	27.5035	3.19
Genotype	35	2047.7**	1221.8**	2.2	0.5527	4.02*
Error	35	175.8	169	1.203	0.5035	1.74
Overall mean		185	99.5	1.00	1.44	2.68
CV%		7.1	4.3	5.5	49.4	7.2

*,** Significant at ($p<0.05$), and ($p<0.001$) respectively, PH-plant height, EH-ear height, MSV-maize streak virus, GLS-grey leaf spot, GY-grain yield, CV%-Coefficient of variation.

The data (Table 3) showed that the mean ear height for the crosses ranged between 53 cm for entry 31 (MUL533x MUL513) to 134 cm for entry 20 (MUL141 x POPA). Many of the crosses showed resistance to MSV with a score of 1. However crosses: MUL516 x MUL508, POPA x MUL141, MUL513 x MUL531, MUL513 x MUL516 (entry 2, 20, 28, 36) respectively had MSV score of 2, crosses MUL531 x MUL513 (entry 28) had a score of 3.5 which indicated some infestation. The mean plant height for the crosses in Embu was 185 cm, ear height 99.5 cm, disease scores for MSV and GLS were 1 and 1.77, respectively, while mean grain yield was 4.14 t/ha (Table 3).Test cross POPA x MUL 521 (entry 15) had the highest plant height (236 cm) in Embu while the lowest was 119cm for MUL533 x MUL513 (entry30) (Table 3).

Table 3: Mean performance of crosses on different morphological traits in Embu

Entry	CROSSES	PH(CM)	EH(CM)	MSV	GLS	GY(T/HA)
1	MUL508XMUL516	157±3.0	71±0.5	2.5±1.5	2.5±1.0	2.8±0.1
2	MUL516XMUL508	143±11.0	70±11.0	2±1.0	2.5±1.0	2.7±0.7
3	MUL508XMUL521	135±19.5	60±6.0	1±0.0	1.25±0.25	2.0±0.7
4	MUL521XMUL508	151±14.5	75±2.5	0.5±0.5	2.5±1.5	2.3±0.9
5	MUL508XMUL141	195±10.0	99±5.0	1.5±0.5	2±0.5	4.2±0.7
6	MUL141XMUL508	197±27.0	105±11.0	0.5±0.5	1.75±0.75	4.6±1.7
7	MUL508XMUL541	157±21.0	72±8.0	1±0.0	2±1.0	2.6±1.2
8	MUL541XMUL508	153±17.5	78±7.5	1±0.0	2.25±1.25	2.3±1.0
9	MUL508XMUL688	223±8.0	116±3.5	1.5±1.5	1±0.0	5.3±1.0
10	MUL688XMUL508	221±0.5	121±7.5	1±1.0	2±1.0	4.1±0.6
11	MUL508XCN244	162±15	71±4.0	1.5±1.5	1±0.0	3.2±0.8
12	CN244XMUL508	210±0.5	123±0.5	0.5±0.5	1±0.25	4.8±0.7
13	POPAXMUL511	209±12.0	121±11.5	1±0.0	1±0.0	3.2±0.0
14	MUL511XPOPA	198±5.0	102±3.0	1±0.0	2±0.5	5.1±0.6
15	POPAXMUL521	236±7.0	132±5.5	1±0.0	2.3±0.75	6.7±0.3
16	MUL521XPOPA	210±13.0	123±1.0	0.5±0.5	1±0.0	4.3±0.2
17	POPAXMUL114	186±2.5	94±6.0	1±1.0	2.25±0.75	5.3±0.3
18	MUL114XPOPA	221±8.0	134±3.5	1±1.0	2.25±0.75	5.8±0.1
19	POPAXMUL141	192±24.5	123±15.5	2±0.0	1±0.0	3.6±0.9
20	MUL141XPOPA	212±2.5	131±5.0	0.5±0.5	1.25±0.25	5.6±0.8
21	POPAXMUL536	219±23.5	124±20.5	0.5±0.5	1.75±0.75	4.5±2.4
22	MUL536XPOPA	186±17.0	101±6.0	1±0.0	1.75±0.75	5.4±1.2
23	POPAXMUL541	214±4.0	125±1.5	1±0.0	1.25±0.25	6.8±0.2
24	MUL541XPOPA	223±4.0	129±2.5	1±1.0	2.25±0.75	6.9±0.5
25	MUL688XPOPA	223±12.0	132±8.5	1±0.0	2.25±1.25	5.0±0.3
26	POPAXMUL688	195±7.0	122±4.5	1±0.0	2.25±1.25	3.6±0.9
27	MUL513XMUL531	151±22.0	83±8.5	2±2.0	1.75±0.75	2.3±1.0
28	MUL531XMUL513	153±1.5	73±2.0	4±1.0	2±1.0	4.0±1.3
29	MUL513XMUL533	140±5.5	66±6.0	1±1.0	1±0.0	2.3±0.3
30	MUL533XMUL513	119±10.0	53±5.5	0.5±0.5	2.5±1.5	1.7±0.8
31	MUL513XMUL114	192±5.0	126±3.6	2±2.0	1±0.0	4.2±1.4
32	MUL114XMUL513	200±17.5	100±10.5	1±0.0	1.5±0.5	5.6±0.9
33	MUL513XCN244	207±3.0	111±0.0	3.5±0.5	1.25±0.25	4.6±0.7
34	CN244XMUL513	186±5.5	90±3.5	0.5±0.5	1.5±0.5	3.6±1.4
35	MUL516XMUL513	146±22.5	76±13.0	2.5±1.5	2±1.0	3.1±0.8
36	MUL513XMUL516	144±3.5	76±0.5	2±0.0	2.25±1.25	4.9±1.7
	MEAN	**185±13.26**	**99.5±13**	**1±1.097**	**1.77±0.7096**	**4.14±1.319**
	L.S.D 5%	**26.92**	**26.39**	**2.2**	**1.4405**	**2.678**

PH-plant height, EH-ear height, MSV-maize streak virus, GLS-grey leave spot, GY-grain yield, L.S.D % –Least Significant Difference (5%)

Mean performance of crosses in KALRO Muguga

The analysis of variance (ANOVA) for plant height, ear height, disease scores for MSV and GLS and grain yield for Muguga are shown in Table 4.The crosses showed significant ($p<0.05$) difference for plant height, ear height and GLS, while there was no significant difference on MSV and grain yield on the crosses in Muguga (Table 4).

Table 4: Performance of crosses for different morphological traits in Muguga. MEAN SUM OF SQUARES

SV	Df	PH(cm)	EH(cm)	MSV	GLS	GY(t/ha)
Replication	1	19	32	0.0868	0	1.488
Genotype	35	2175.9**	796.8**	0.1725	0.2865**	11.536
Error	35	362.4	115.7	0.2225	0	8.215
Overall mean		214	79.9	1.16	1.94	4.84
CV%		0.3	1.2	4.2	0	4.2

** Significant at ($p<0.05$), PH- Plant height, EH- Ear height, MSV-Maize streak virus, GLS- Grey leaf spot, GY- Grain yield, CV%-Coefficient of variation.

Data on the mean plant height in Muguga ranged between 148±4.00 cm for MUL 533 x MUL 513 (entry 30) to 278±3.00 cm for POPA x MUL541 (entry 23) (Table 5). The cross which had the lowest mean plant height MUL533 x MUL 513 (entry 30) also had the lowest mean grain yield of 1.01±0.4742 t/ha, the cross also had low mean ear height (45±6cm) and a GLS score of 3.25±0.25 (Table 5). Cross MUL516 x MUL508 (entry 2) had a mean plant height of 178±1.5cm, mean ear height of 55±2cm and the highest grain yield of 11.9±10.84 t/ha (Table 5). The second best cross in grain yield was POPA x MUL541 (entry 23) which had grain yield of 10.08±0.83 t/ha; this test cross also had the second highest mean ear height of 123±1.00cm (Table 5). Cross POPA x MUL 141(entry 19) had the highest mean ear height of 125±2.5cm and was the third best in mean grain yield of 8.65±0.33 t/ha. Crosses CN244 x MUL508 (entry 12) and POPA x MUL511 (entry 13) had equal mean plant heights but different mean ear heights and different mean grain yields (Table 5).

Table 5: Mean Performance of crosses for different morphological traits in KALRO Muguga

Entry	CROSSES	PH(CM)	EH(CM)	MSV	GLS	GY(T/HA^{-1})
1	MUL508XMUL516	156±16.0	42±5.5	1±0.00	3.5±0.50	1.78±0.1901
2	MUL516XMUL508	178±1.5	55±2.0	1±0.00	3±0.00	11.9±10.8447
3	MUL508XMUL521	181±1.5	58±5.5	1±0.00	3±0.00	1.95±0.3049
4	MUL521XMUL508	160±7.5	54±6.0	2±1.00	3.25±0.25	1.84±0.0886
5	MUL508XMUL141	221±14.5	79±5.5	1.25±0.25	2.25±0.25	3.49±1.1328
6	MUL141XMUL508	242±6.0	92±0.5	1.25±0.25	2.75±0.25	5.17±0.0279
7	MUL508XMUL541	212±6.5	78±12.5	1.25±0.5	2.5±0.50	3.24±0.0854
8	MUL541XMUL508	220±10.5	76±3.5	1±0.00	2.5±0.50	5.71±1.0585
9	MUL508XMUL688	274±2.5	87±4.5	1±0.00	2±0.00	5.64±0.3859
10	MUL688XMUL508	233±15.5	87±3.5	1±0.00	2.75±0.25	4.66±0.8067
11	MUL508XCN244	211±5.0	68±10.0	2±0.00	2.25±0.25	3.84±02879
12	CN244XMUL508	238±17.5	84±10.5	1±1.00	2.25±0.25	3.99±0.7511
13	POPAXMUL511	238±21.5	101±6.0	1±0.00	1.5±0.00	7.01±0.9207
14	MUL511XPOPA	220±4	81±5.0	1±0.00	2±0.00	5.7±0.0413
15	POPAXMUL521	234±13.0	83±3.5	1±0.00	2.5±0.50	5.64±0.8723
16	MUL521XPOPA	233±28.5	95±2.8	1±0.00	2±0.00	5.07±1.6994
17	POPAXMUL114	180±6.0	66±12.0	1.75±0.75	2.5±0.00	3.94±0.2226
18	MUL114XPOPA	227±17.5	95±3.0	1±0.00	2.75±0.25	5.38±1.0128
19	POPAXMUL141	260±3.5	125±7.0	1±0.00	1.75±0.25	8.65±0.3338
20	MUL141XPOPA	250±18.5	117±8.5	1±0.00	1.75±0.25	6.75±2.6645
21	POPAXMUL536	249±34.0	108±23.5	1±0.00	2±0.50	7.79±1.9045
22	MUL536XPOPA	189±9.5	74±5.5	1.75±0.75	2.5±0.00	3.42±0.6465
23	POPAXMUL541	278±3.0	123±1.0	1±0.00	1.5±0.00	10.08±0.8281
24	MUL541XPOPA	232±11.0	96±5.5	1±0.00	1.5±0.00	6.23±0.6035
25	MUL688XPOPA	227±15.5	86±3.5	1±0.00	2.25±0.25	5.77±1.039
26	POPAXMUL688	209±4.5	86±1.0	1±0.00	2.5±0.00	4.75±0.472
27	MUL513XMUL531	197±15.5	67±9.0	1±0.00	2.5±0.50	2.95±0.1149
28	MUL531XMUL513	182±1.5	72±2.0	1±0.00	3±0.50	1.82±0.1047
29	MUL513XMUL533	197±7.5	65±1.5	1.5±0.50	2.5±0.00	3.42±0.5265
30	MUL533XMUL513	148±4.00	45±6.0	1±0.00	3.25±0.25	1.01±0.4742
31	MUL513XMUL114	241±20.5	86±12.0	1.5±0.5	1.75±0.25	6.05±0.8808
32	MUL114XMUL513	240±6.5	84±1.0	1.25±0.25	2±0.50	5.75±0.6533
33	MUL513XCN244	217±8.0	80±2.5	1±0.00	2.5±0.00	4.28±0.712
34	CN244XMUL513	186±10.5	70±11.0	1.25±0.25	2.5±0.50	4±0.8857
35	MUL516XMUL513	163±12.0	49±1.0	1±0.00	3.25±0.70	2.82±0.5103
36	MUL513XMUL516	187±13.0	71±11.0	1±0.00	2.5±1.00	2.83±0.6653
	MEAN	**214**±19.04	**79.9**±10.76	**1.16**±0.4	**1.944**±0.32	**4.84**±2.866
	L.S.D 5%	**38.64**	**21.84**	**0.9576**	**0.6645**	**5.819**

PH-plant height, EH-ear height, MSV-maize streak virus disease, GLS-grey leaf spot, GY-grain yield, L.S.D- Least Significant Difference (5%)

DISCUSSIONS

The study revealed that crosses from inbred line POPA had the highest plant height, ear height and also the highest grain yield in Embu (Table 3). Maize displays an orderly sequence of development of yield components namely: ear height, plant height, ears per plant and grain weight (Viola et al., 2003). This explains why indirect selection can be used by searching for improved yield components. The crosses in Embu and Muguga showed significant difference on plant height, ear height and grain yield ($P \leq 0.05$). The results revealed that entry 23 in Muguga (POPA X MUL 541) had the highest plant height (278±3.00 cm) (Table 5). The contrast was observed with entry 30 (MUL 533 X MUL 513) having plant height of (119±4.00cm) in Embu which was the lowest and also recorded the lowest grain yield of (1.675±0.47 t/h) (Table 4.6). The possible reason for the observed differences among the crosses on yield and yield components was variation in genetic makeup. Different hybrids have also been evaluated for morphological and agronomic traits, showing significant variation (Ihsan et al., 2005). The height of the main ear is a very important characteristic for breeding maize, the higher it is the more ears can develop from the nodes below, however if it is too high the weight of the ear may bend the stalk or even break it. Although low ear height is unfavorable for yield and makes harvesting difficult, it does protect the stalk from excessive weight (Zsubori et al., 2002).

The best crosses in Muguga were also the best in Embu on grain yield production with exception of cross MUL 516 x MUL508 which had a mean grain yield of 11.9 ±10.84t/ha in Muguga but produced 2.7 ±0.73 t/ha in Embu which was attributed to other factors other than genetic makeup. Grain yield being a complex trait, it is influenced by various environmental factors including biotic and abiotic factors. There is also interplay of various morphological characteristics that influence final yield. Variation in yield shows a diverse genetic background of genotypes studied under these conditions. The grain yield ranged between 1.01±0.47 t/ha entry 30 (MUL533 x MUL513) to 11.9±10.84 t/ha entry 2 (MUL 516 x MUL 508) both in Muguga (Table 5). The best cross for grain yield in Muguga was MUL 516 x MUL 508 (entry 2) (Table 5) while in Embu the best cross for grain yield was MUL541 x POPA (entry 24) (Table 3) indicating the crosses were unstable attributed to environmental factors.

The analysis of genotype x environment interaction showed significant difference in the traits studied namely: plant height, ear height, MSV disease, GLS and grain yield hence the crosses were unstable on both environments (Table 3 & 5) respectively. Data on disease scores where natural infestation was visually scored on a scale of 1-5 showed that among the evaluated crosses majority showed an MSV average score of 1.16 in KALRO Muguga while in KALRO Embu the highest MSV average scores of 4.00 were recorded. These observations could be attributed to high incidence of leaf hoppers (Cicadulina spp.) which transmit maize streak disease in Embu. Crosses MUL531xMUL513 and MUL513 x CN244 had the highest mean MSV scores 4.0 and 3.5 respectively.

CONCLUSIONS AND RECOMMENDATIONS

In Embu inbred line POPA produced the best grain yields when crossed with MUL541 and MUL521. Its high grain yield was also witnessed in Muguga where on average its performance was superior to other inbred lines. Cross MUL 516 x MUL 508 had the highest overall mean grain yield (11.9 t/ha) but had a GLS score of 3 compared to the second best in mean grain yield POPA x MUL541 10.1t/ha. These findings showed that POPAX MUL541 though a good yielding cross was affected by GLS disease though at a late stage when the ears had already developed. Crosses with high plant height had higher mean grain yield than those with low plant height, while crosses with low ear height had low mean grain yield and vice versa. In order to develop promising genotypes, it is essential to know the different traits particularly those associated with grain yield which is the ultimate objective in any breeding program.

The present findings are useful to breeders in selecting the potential parental materials for maize improvement programs in mid altitude agro-ecological zones in Kenya. For grain yield improvement crosses MUL508 x MUL688, POPA x MUL141, MUL513 x MUL114 and MUL513 x CN244 can further be evaluated and eventually released to farmers as they indicated promising relationship with yield potential compared to other crosses. Inbred line MUL 513 can further be evaluated for grain yield improvement with all the other inbred lines which had high grain yields.

Inbred lines MUL 508, POP A and MUL513 can be used in improving other genotypes on disease resistant trait. There is also need for further study of the inbred lines used in this study for stability and adaptability in other counties in Kenya.

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