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PERFORMANCE OF SINGLE-CROSS MAIZE HYBRIDS FROM DIVERSE CROSS COMBINATION OF PARENTAL INBRED LINES IN ACID SOIL CONDITIONS

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ABSTRACT

Maize is one of the strategic commodities in Indonesia that receive special attention to be enhanced due to food security and sovereignty. Utilizing high yielding maize varieties along with sustainable agronomic practices offer an effective strategy for improving maize productivity in acid soils. Ten single cross hybrids derived from a diverse tropical inbred lines and two check varieties were evaluated in two locations with two acid soil conditions in order to obtain hybrids that produce high yield in acid soils. The evaluations were carried out in a randomized complete block design with three replications during 2014 – 2015. The locations were in Padang with two soil conditions, *i.e.* limed- and unlimed-acid soil with the order Ultisol and in West Pasaman with two soil conditions, *i.e.* a good soil with the order Andisol and natural acid soil with the order Ultisol. Data were subjected to the analysis of variance using the Proc GLM of the SAS software. Results showed that there was no hybrid that consistently produced high yield in all soil acidity conditions. The hybrids that produced high yields in acid soil conditions produced lower yields in a good soil compared to the commercial hybrid check variety.

Key words: maize, single-cross hybrid, inbred lines, acid soil tolerance

INTRODUCTION

Maize in an important commodity in the economy and national food security due to the high demand for it as human food, animal feed and raw materials for industrial products. The importation of grain maize kept increasing in the past one decade (Indonesia Investment, 2015). Hence, efforts to improve the productivity of maize become a necessity in order to attain national food security and sovereignty.

The extension of planting area and intensification efforts were needed to attain self-sufficiency of maize. However, the extension of planting area can only be practiced on marginal land such as acid soils. Acid soil which are classified as Ultisol are widespread in Indonesia (Subagyo *et al*, 2000), mainly in Sumatera and Kalimantan islands. This soil is highly weathered soil that have low pH, low cation exchange capacities, high soil solution aluminum (Al) concentration and low basic cations, mainly Ca and/or Mg (Shamshuddin and Ishak, 2010). Al toxicity is being a major constraint of maize production in acid soils if compared to other factors. Acid soil is being used extensively for oil palm and rubber plantations. However, maize as cash crop or intercrop during the early years of the crops, generally produces low yield in acid soil.

Although acid soil has potential in terms of the acreage, it also has low level soil fertility. Several management practices such as application of lime and organic matter are needed to make the soil become as productive as any other good soil (Shamshuddin dan Ishak *et al*, 2010). However, they also have several limitations in used as reported by Shamshuddin *et al* (1998) and Hede *et al* (2002). Planting maize hybrid varieties tolerant to acid soils along with the use of sustainable agronomic practices is one of the strategies for improving maize productivity in acid soils.

Hybrid is a first generation of cross between two parental inbred lines that have different genetic background. The hybrid variety produces high grain yield, possesses uniform plant and matures reasonably early as compared to the parental inbred lines and the open-pollinated varieties. Hybrids also perform high tolerance to environmental stress, including acid soil conditions (Dewi-Hayati *et al*, 2015).

A series of research which was an extensive maize breeding program have been done to obtain hybrids tolerant to acid soil. The program has been initiated by utilizing diverse tropical grain maize populations from open-pollinated and hybrid varieties, local cultivar and introduced lines as germplasm sources in the formation of base populations since 2008. Maize inbred lines obtained from the populations were screened for tolerance to acid soil to obtain inbred lines tolerant to acid soil (Dewi-Hayati dan Armansyah, 2011). The inbred lines then were crossed in a diallel mating scheme to produce single-cross hybrids (Dewi-Hayati *et al,* 2014). This research was the on-going program carried out to evaluate agronomic and yield performance of several single-cross hybrids in acid soil conditions and to obtain single-cross hybrids tolerant to acid soils.

MATERIALS AND METHODS

The research was carried out in two locations, namely Padang and West Pasaman during 2014 – 2015. Evaluation of the hybrids in Padang was conducted in two acid soil conditions, *i.e.* naturally acid soil with the order Ultisol and acid soil ameliorated by ground magnesium limestone at the rate of 2 t ha^{-1}. Meanwhile, the evaluations in West Pasaman were conducted in two different order of soil *i.e.* a good soil with the order Andisol and acid soil with the order Ultisol.

The genotypes evaluated were ten single-cross hybrids selected from 66 hybrids obtained from cross combinations of 12 maize parental inbred lines in the diallel mating scheme and the two check varieties, namely the composite variety Sukmaraga that was reported as acid soil-tolerant variety (ICERI, 2004) and one commercial hybrid variety (Table 1). The hybrids selected based on their good specific combining ability on grain yield evaluated in acid soil. The experiments were arranged in a randomized complete block design with three replications. Each genotype was planted as four 4-meter long rows with a spacing of 25 cm x 65 cm.

Table 1. The genotypes evaluated and their pedigree

No	Genotypes	Pedigree (Parental inbred lines)
1	H6	SgM9 x Gg4.1
2	H8	P1.2 x Gg4.1
3	H13	SgM6 x Lgu2
4	H16	SgM9 x Lgu2
5	H21	SgB3.3 x Lgu2
6	H31	SgB1 x SgM6
7	H34	BH 1 x SgM6
8	H35	P1.2 x SgM6
9	H45	SgB3.3 x SgB1
10	H51	SgB3.3 x Uq 3.1
11	Sukmaraga	
12	Commercial Hybrid	

Fertilizers were applied at the rate of 150 kg N ha^{-1}, 120 kg P_2O_5 ha^{-1} and 100 kg K_2O ha^{-1} in the form of urea, SP36 and KCl. Urea is applied in split at 14 and 30 days after planting, while SP36 and KCl fertilizers were totally given at 14 days after planting. The cultivation was conducted as standard cultural practices. The traits observed were plant height, ear height, 50% days of tasseling and silking and grain yield per hectare after being converted to 15% moisture content.

Data were analyzed using the variance F test, whereas the mean comparisons were performed using Duncan New Multiple Range test at 5% level. Various Selection indices were determined based on the formula suggested and calculated using Proc GLM of the Statistical Analysis System (SAS) computer software (SAS/STAT, 2003).

RESULTS AND DISCUSSION

Based on the chemical soil properties, there were four level of soil acidity conditions from both two locations *i.e.* high level soil acidity which was natural acid soil with the order Ultisol in each location and low level soil acidity which was limed Ultisol soil and a good soil as the order of Andisol (Table 2). Amelioration of acid soil with the ground magnesium limestone (GML) increased the soil pH and decreased the exchangeable aluminum in the soil solution, however, the application of GML at the rate 2 t/ha was not enough to alleviate total aluminum in the soil solution. Based on the criteria of the soil pH (Hardjowigeno, 2000), limed-acid soil is characterized as acidic with a higher pH than the initial soil pH that is characterized as very acidic. Meanwhile, the soil pH criteria for the Andisol order soil in the West Pasaman was less acidic eventhough the exchangeable aluminum was not detected in that soil.

Table 2. The chemical soil properties

Soil properties	Padang		West Pasaman	
	Limed Ultisol	Acid Ultisol	Andisol	Ultisol
pH $_{(H2O)(1:1)}$	5.30	4.50	5.83	4.90
CEC ($cmol_c kg^{-1}$)	20.30	20.03	37.53	20.01
P (ppm)	4.30	4.03	32.50	4.01
Ca ($cmol_c kg^{-1}$)	1.52	0.20	8.54	0.91
Mg ($cmol_c kg^{-1}$)	0.55	0.44	1.61	0.74
K ($cmol_c kg^{-1}$)	0.29	0.30	0.78	0.28
Na ($cmol_c kg^{-1}$)	0.43	0.41	0.21	0.49
Al ($cmol_c kg^{-1}$)	1.02	2.95	nd	1.37
Al sat. (%)	0.27	0.69	nd	0.36

nd: not detectable

The cation exhange capasity (CEC) of soil varied in each soil acidity. Amelioration of acid soil improved the CEC into 20.3 $cmol_c kg^{-1}$. However, the CEC of the Ultisol were in the criteria as moderate. Only Andisol showed high level of the CEC. Similar to the CEC, Andisol also contained higher phosporous and basic cation concentration in the soil. The phosporous criteria for Andisol was low, while another acid soils had very low of phosporous concentration. Calcium and magnesium concentrations were moderate which was better than low criteria for those in acid soil conditions. Meanwhile, the concentration of the aluminum in the soil solution was not detected, indicating that the soil has better chemical soil properties.

Results of the analysis of variance in each soil condition showed the effects of genotypes on yield, while the combined analysis showed the effects of soil acidity, genotype, and interaction between genotype and soil acidity. This indicated that the ranking of the hybrids varied with different soil acidity conditions. Since the error variance in each soil acidity conditions were not homogenous, the means of genotypes were performed in each soil condition (Table 3).

Table 3. Grain yields (tonnes/ha) of single-cross hybrid evaluated in two locations and two acid soil conditions

Genotypes	All location & condition	Limed Ultisol (Padang)		Acid Ultisol (Padang)		Andisol (WPasaman)		Acid Ultisol (WPasaman)	
	.... t/ha								
H6	4.91	5.74	ab	3.55	ab	7.06	d	3.31	d
H8	5.86	6.03	a	3.68	a	9.39	ab	4.38	abc
H13	5.34	5.88	ab	3.60	a	8.32	bcd	3.56	cd
H16	5.58	5.31	ab	3.59	a	9.44	ab	3.97	bcd
H21	5.63	6.10	a	3.49	ab	7.86	cd	5.09	a
H31	5.76	5.59	ab	3.20	abc	9.11	abc	5.15	a
H34	5.37	5.47	ab	3.30	abc	7.79	cd	4.93	ab
H35	5.61	5.65	ab	3.83	a	8.64	abc	4.32	abcd
H45	5.30	4.97	ab	2.46	c	8.75	abc	5.01	ab
H51	5.42	5.29	ab	3.38	abc	8.68	abc	4.33	abcd
Sukmaraga	5.14	5.16	b	2.62	c	7.85	cd	4.92	ab
Commercial Hybrid	5.75	6.05	a	2.47	c	9.89	a	4.59	abc
c.v.		7.70		14.90		8.20		12.80	

Grain yields of the hybrids varied greatly within acid soil conditions and locations, in which different hybrids were found to have high yield performance in the different acid soil conditions and locations. The grain yields of the hybrids on limed-soil condition and the Andisol generally higher than that on acidic soils. Grain yields of the hybrids in Andisol was the highest, indicating that the soil condition was considered optimum for growth and yield of maize.

The grain yield in each soil acidity condition decreased with the increasing amount of exchangeable aluminum. The reduction of grain yields in acid soil varied greatly within hybrids and acid soil conditions. The reduction of grain yield in Padang ranging from 32 to 51%, while that in West Pasaman ranging from 35 to 58%, indicating the high difference of soil acidity level in West Pasaman.

Hybrid H21, H31 and H45 produced higher yields around 5 t/ha in acid soil in Pasaman. However, their production was still similar to grain yield of the commercial hybrid and the composite variety Sukmaraga as the check varieties. On the contrary, even though several single-cross hybrids, namely H8, H16, H31 produced higher yields than those of other single-cross hybrids which exceeded 9 t/ha, there was no single-cross hybrids produced the highest yield in a good soil (Andisol). This indicated that the commercial hybrid produces high yield in a good soil.

Evaluation of hybrids in acid soil in Padang showed that several single-cross hybrids produced higher yields compared to the two check varieties, however only hybrid H21 that produced high yield consistently in acid soil in two locations. Meanwhile, only two hybrids, namely H8 and H21 produced high yields around 6 t/ha similar to yield of the commercial hybrid in limed-soil.

The good hybrids perform ear height in the middle of the plant height. The increasing of soil acidity reduced ear height and plant height (Table 4). The reduction of plant height in Padang ranging from 0 to 15 cm, while that of ear height ranging from 1 to 29 cm. Meanwhile, the reduction of plant height in West Pasaman ranging from 28 to 47 cm, while that of ear height ranging from 45 to 64 cm, indicating that the reduction of height in ear is higher than that in plant height. All hybrids and the two check varieties in acid soil in West Pasaman performed ear height was beneath the mid of ear height.

The anthesis-silking interval (ASI) is an important trait to ensure the synchronous of female and male flowering time, thus it is crucial to ensure the synchronous of pollination.

The increase of soil acidity prolonged the anthesis-silking interval that affected yields. Hybrids performed longer anthesis-silking interval in acid soil compared to that in a good soil.

Table 4. Plant and ear heights (cm) of single-cross hybrids evaluated in two locations and two acid soil conditions

Genotypes	Limed ultisol (Padang)		Acid ultisol (Padang)		Andisol (WPasaman)		Acid Ultisol (WPasaman)	
	PH	EH	PH	EH	PH	EH	PH	EH
	………………………….. cm ………………………………..							
H6	195.0	89.5	188.5	88.6	227.1	111.7	129.7	49.0
H8	171.0	72.0	156.2	66.6	217.9	104.6	121.1	43.5
H13	205.1	105.8	200.3	105.7	251.0	150.2	132.6	54.1
H16	188.6	86.5	168.2	72.4	226.3	115.4	145.1	59.1
H21	196.0	92.8	196.1	90.7	229.1	132.3	165.8	73.1
H31	203.0	102.9	176.0	79.9	230.1	126.3	151.7	66.7
H34	192.4	91.8	166.7	68.6	222.1	115.8	146.1	54.6
H35	198.6	94.2	194.9	88.8	222.4	122.4	146.8	60.7
H45	187.8	90.8	159.9	64.9	239.9	133.3	139.5	62.0
H51	183.5	87.5	172.0	75.8	235.5	130.2	148.3	62.6
Sukmaraga	187.2	82.8	157.2	56.2	237.3	133.1	155.6	71.9
Commercial Hybrids	175.5	71.4	175.4	58.2	226.6	123.7	123.8	54.3

PH = plant height and EH = Ear height

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Table 4. Days to tasseling and days to silking of single-cross hybrids evaluated in two soil locations and two soil acidity conditions

Genotypes	Limed ultisol (Padang)		Acid ultisol (Padang)		Andisol (WPasaman)		Acid Ultisol (WPasaman)	
	DT	DS	DT	DS	DT	DS	DT	DS
H6	59.3	60.7	59.7	61.3	58.3	59.7	59.3	63.7
H8	59.0	59.0	64.3	67.3	56.0	57.3	62.3	66.0
H13	60.0	62.3	60.7	62.7	57.7	60.3	60.0	63.7
H16	63.0	64.3	64.3	66.3	57.0	59.7	59.3	63.7
H21	56.3	56.3	61.0	62.7	55.3	56.3	58.0	59.7
H31	56.7	57.3	65.3	67.3	56.3	58.0	60.3	62.3
H34	59.3	59.7	59.3	61.7	55.7	56.7	57.0	59.7
H35	60.7	61.0	62.7	65.3	56.7	58.3	63.7	66.7
H45	64.3	67.0	67.0	70.0	62.0	64.0	64.7	67.0
H51	61.0	64.0	63.3	67.3	59.3	61.3	62.0	65.0
Sukmaraga	61.0	64.3	69.3	71.0	59.3	61.3	61.7	65.0
Commercial Hybrids	61.0	64.3	69.3	71.3	59.7	61.7	65.0	66.3

It can be concluded that there was no single-cross hybrid that consistently produced high yield in all soil acidity conditions. The hybrids that produced high yield in acid soil conditions, produced lower yield in a good soil compared to the commercial hybrid. Among the single-cross hybrids, hybrid H21was consistently produced high yield in acid soil conditions.

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