Heterosis In Acid Soil-Tolerant Maize Germplasm

L.Narro[1], S. Pandey[1], C. De León[1], J.C.Pérez[1], F. Salazar[1], M.P.Arias[1], J. Celis[2], S. Reyes[3] and S. Mejia[4]

[1] CIMMYT, Programa Sudamericano de Maíz. A.A. 6713. Cali, Colombia.
[2] INIA, Programa de Maíz y Arroz. Apartado 169. Cajamarca, Perú.
[3] INIAP, Programa de Maíz. Casilla 13-01-100. Portoviejo, Ecuador
[4] CORPOICA, Regional 8. A.A. 602. Montería Córdoba, Colombia

CIMMYT
International Maize and Wheat Improvement Center, Lisboa 27, Apdo. Postal 6-641, Deleg. Cuauhtemoc, 06600 Mexico, D.F., Mexico

Introduction

Distribution of acid soils in the world.

Region	Millon ha	%
Africa	659	16.7
Australia/New Zealand	239	6.1
Europe	392	9.9
Asia 1044	26.4	
America	1616	40.9
North	(662)	(41.0)
Central	(37)	(2.2)
South	(917)	(56.8)
Total	3950	100

After H.R. von Uexkull and E. Mutert. 1995

Area under acid soils (Oxisols and Ultisols) and sown to maize by country, South America.

Country	Acid soils	Maize
Brazil	572.71	12.64
Colombia	67.45	0.79
Bolivia	39.54	0.26
Venezuela	51.64	0.45
Peru	56.01	0.31
Paraguay	9.55	0.34
Ecuador	8.61	0.45
Chile	1.37	0.1
Argentina	1.28	1.97
Uruguay	0.00	0.06
Other acid soils	108.84	-
Total	917.00	17.38

If maize and other crops can be produced sustainably on acid soil areas, many of which are underutilized savannas, this would provide more and cheaper food for South America's city dwellers (three-quarters of the continent's populace) and lessen pressure to raze the margins of tropical forests. Results of long-term studies on the effects of intensifying agricultural production on savannas have been favorable (work has been done by researchers from Brazil, Colombia, and the Centro Internacional de Agricultura Tropical, CIAT).

The Problem

Low fertility of acid soils due to:

Low pH
Al and Mn toxicities
P, Ca, and Mg deficiencies

Solutions

Soil treatments (e.g., lime applications)
Not easily available and too expensive for poor farmers

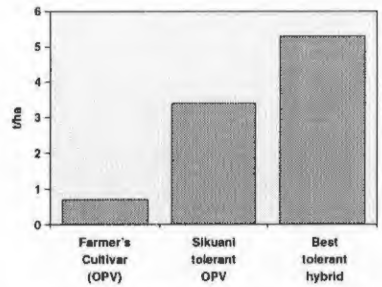
Acid soil tolerant cultivars
A permanent, ecologically clean, and energy conserving solution

The two alternatives are complementary

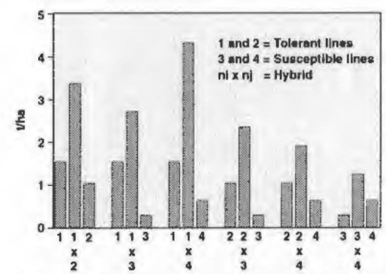
Nonconventional and conventional hybrids

Grain yield and rank of the best hybrids (pedigree in bold) evaluated under acid and nonacid soils during 1996.

Trial and pedigree	Number of entries evaluated	Acid soils Number of environments	Rank	Yield (t/ha)	Non-acid soils Number of environments	Rank	Yield (t/ha)
Yellow testers							
SA3-C4HC (19 x 25)-2-6-4-5 x (LASP2 x LASP3)	172	8	1	4.61	3	1	7.4
White testers							
SA8-C1HC(27x3)-1-1-4-8- x CML 16	100	4	1	5.68	2	10	7.15
SA8-C1HC(27x3)-1-1-2-7 x CML 16			2	5.14		61	5.66
SA8-C1HC(27x26)-1-1-4-3 B x (CML 247 x CML 254)			3	5		5	7.5
SA8-C1HC(27x3)-1-3-1-11 x (CML 247 x CML 254)			33	4.20		1	8.01
SA7-C2HC (13 x7)-1-1-1-5 x CML 16			77	3.50		2	7.82
Yellow Design II							
SA3-C4HC (19x25)-2-6-4-5B x SA4 HC7-1-5-1-3-4-7-B	275	7	1	5.36	3	197	5.44
SA3-C4HC (16x25)-2-4-8-7B x SA4 C2HC(7x15)2-3-5-1B			2	5.36		54	6.43
SA3-C4HC (16x25)-2-4-8-5B x SA4 C2HC(7x15)2-2-2-3B			3	5.26		85	6.12
SA3-C4HC (19x25)-2-6-5-6B x SA4 HC7-1-5-1-3-1-6B			4	5.08		1	7.57
SA5-C2HC(2x20)-2-7-3-8B x CML 304			115	3.86		1	7.57



Yield of a farmer's cultivar, OPVs (Tuxpeño and Sikuani) and hybrids, in acid soils.



Grain yield of crosses among two tolerant and two susceptible acid soil inbred lines.

Materials and Methods

Intervariety heterosis

Populations

Yellow	SA3	Flint
	SA4	Dent
	SA5	Flint
White	SA6	Dent
	SA7	Flint
	SA8	Flint

Intervarietal diallel
Gardner and Eberhart's analysis II and III

Non-conventional and conventional hybrids

Acid soil tolerant S_6 lines from yellow and white populations

Testers
Lines, OPVS, and hybrids
Acid soil tolerant and susceptible cultivars

Diallel among tolerant and susceptible lines
Line x tester
Design II among tolerant lines

Results

Intervariety heterosis

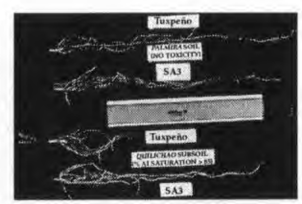
Average grain yield (t/ha) and high-parent heterosis for crosses between varieties of maize with different genetic background evaluated under acid soil conditions.

Pedigree	Yield (t/ha)	High-parent Heterosis (%)	Pedigree	Yield (t/ha)	High-parent Heterosis (%)
90 SA3 x 90 SA4	3.10	16.6*	92 SA3 x 92 SA4	4.07	16.3*
90 SA3 x SA5	2.72	2.4	92 SA3 x SA5	3.78	8.0
90 SA3[1] x SA6	2.83	6.4	92 SA3 x SA6	4.02	14.9*
90 SA4 x 90 SA5	2.65	13.4	92 SA4 x 92 SA5	3.56	11.2
90 SA6 x 90 SA7	2.40	18.8*	92 SA6 x 92 SA7	3.47	10.5

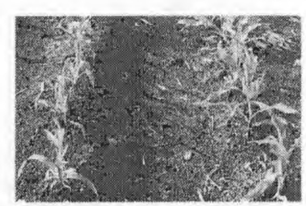
* Significant at $P < 0.05$

[1] Genetic background of population SA3 is similar to that of SA8.

SA3 was merged with SA5 to form the new SA3
SA7 was merged with SA8 to form the new SA7



Root development of susceptible and tolerant maize varieties under normal soil conditions (above) and acidic soils (below).



Susceptible (left) and tolerant (right) maize plantlets under acid soil conditions.

Conclusions

- It is possible to identify nonconventional [(SA3 - C4 HC (19 x 25) 2-6-4-5 x LASP2 X LASP3 and SA8 B C1 HC (27 x 26)-1-1-4-3 B x (CML 247 x CML 254)] and conventional SA3 B C4 HC (19 x25)-2-6-5-6 B x SA4 B HC 7-5-1-3-1-6 B hybrids with high yield at both acid and nonacid soil conditions.
- Grain yield of the experimental hybrid (Entry 15 = Pob SA8 C3 B HC49-3 x CIMCALI 93SA6) was 55% higher than of Sikuani, an acid soil tolerant OPV.
- Heterosis is a powerful tool to increase grain yield in acid soils.
- General and specific combining ability effects were highly significant.
- Positive effects are associated with acid-tolerant lines.

References

Pandey, S., H. Ceballos, R. Magnavaca, A.F.C. Bahia Filho, J. Duque-Vargas, and L.E. Vinasco. 1994. Genetics of tolerance to soil acidity in tropical maize. Crop Sci. 34:1511-1514.

Salazar, F.S., S. Pandey, L. Narro, J.C. Perez, H. Ceballos, S. Parentoni, and A.F.C. Bahia Filho. 1997. Diallel analysis of acid-soil tolerant and intolerant tropical maize populations. Crop Sci. 37 (Accepted).

Salinas, J.G., and C.E. Castilla. 1990. Estrategias para el uso y manejo de los suelos ácidos en América Tropical. *In* J.G. Salinas and L.M. Gourley (ed.). Sorgo para suelos ácidos. CIAT: Centro Internacional de Agricultura Tropical. Cali, Colombia.

Von Uexkulland, H.R., and E. Mutert. 1995. Global extent, development, and economic impact of acid soils. Plant and Soil. 171:1-15.