ISSN 1020-3362

Plant Genetic Resources Newsletter

Bulletin de Ressources Phytogénétiques

Noticiario de Recursos Fitogenéticos

No. 112, 1997

Food and Agriculture Organization of the United Nations and the International Plant Genetic Resources Institute
Organisation des Nations Unies pour l'alimentation et l'agriculture et l'institut international des ressources phytogénétiques
Organización de las Naciones Unidas para la Agricultura y la Alimentación y el Instituto Internacional de Recursos Fitogenéticos

ARTICLE Plant Genetic Resources Newsletter, 1997, No. 112: 90-92

Variability of maize landraces from northwest Spain

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Summary
The Escola Superior d'Agricultura de Barcelona, Spain conserves 300 flint maize landraces (*Zea mays* L.) collected in the northwest of Spain. Multiplication and elemental characterization were carried out as well as top-cross characterization with the tester dent inbred CM105. The results indicate that this germplasm, cycle 150 to 300 FAO, is a reserve of genetic variability of interest in improvement programmes, particularly as some top-cross hybrids yielded equal or higher grain production than commercial check hybrids.

Introduction
The introduction of maize hybrids in the northwest of Spain has been slow due to the specific climatic conditions of the region (cold springs and high rainfall), and the continued use of traditional farming techniques on small plots. This has meant that farmers have continued to cultivate and maintain open-pollinated varieties of maize. However, unless these landraces are conserved in genebanks, their gradual replacement by hybrids will result in the genetic erosion of the species (Moreno 1981; Ordás *et al.* 1987).

In 1493, the first maize from South America was introduced in the south of Spain, but it was not until the end of the 16th, beginning of the 17th centuries that the crop began to be cultivated in the coastal zones of northwest Spain. Gradually, cultivation spread to higher altitudes. Grown for both human and animal consumption, maize became the staple cereal, preferred even to wheat. During the 17th century it became the staple diet of the rural classes in Asturias (Fig. 1).

In Galicia during the 18th century, maize became second only to rye in importance. The first varieties cultivated probably came from the south of Spain and Portugal. During the 16th and especially the 17th and 18th centuries, new earlier American germplasm was introduced (Garcia 1991).

The photoperiod, temperature and humidity associated with the altitude where the maize was grown were basic factors in the differentiation and development of landraces in northwest Spain. Over the last four centuries new groups have originated from the original populations introduced, through adaptation to local conditions as well as the hybridization brought about by continuous exchange and trade (Trifunovic 1978; Garcia 1991).

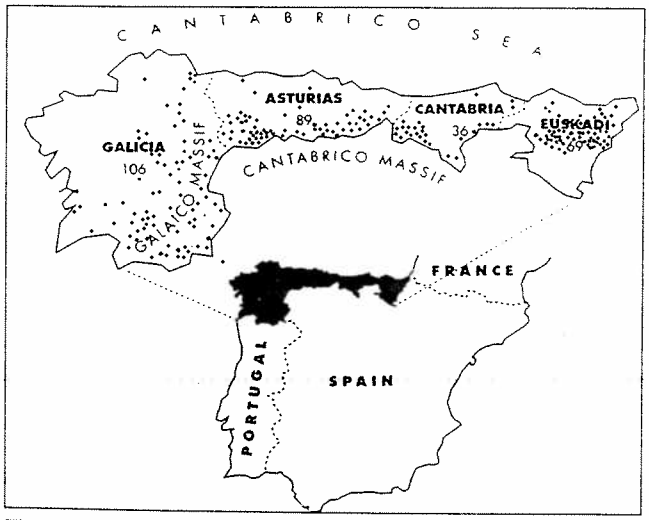

Fig. 1. Regions where maize landraces were collected. Dots indicate collecting locations, numbers indicate quantity of accessions collected in each region.

These landraces are adapted to altitudes from 0m to more than 1500m, in a region (northwest of Spain) of high rainfall, cold springs and mild summers, coupled to traditional farming techniques employing a low level of fertilizers and herbicides. Their habitat resilience, according to Moreno (1981), is characterized by: (a) early vigour to beat weeds, (b) good emergence in cold and wet soils, and (c) a short cycle which avoids excessive moisture at harvest time.

At the Escola Superior d'Agricultura de Barcelona (ESAB), 300 varieties of maize from the northwest of Spain have been collected and preserved to avoid loss of this germplasm. This paper concerns the collection of the material and analysis of the variation shown.

Collecting and multiplication
The landraces were collected from their traditional growing areas in the northwest of Spain (Fig. 1). This consists of a continuous strip running from Galicia to Euskadi, of considerable climatic and topographic diversity because of the Galaico, Cantabrico and Pirineo Massifs, and the Cantabrico Sea. In general, annual rainfall is evenly distributed throughout the year although it is slightly higher in the winter. Temperature oscillations are reduced as the climate is influenced by the sea; summers are cool (July average 16-20°C) and winters are warm (January averages 16-20°C).

Table 1. Number of locations (lc) and accessions (ac) collected in each region and in each interval of altitudes

Altitude (m)	Galicia		Asturias		Cantabria		Euskadi		Total	
	lc	ac	lc	ac	lc	ac	lc	ac	lc	ac
0-200	9	17	0	0	3	3	4	4	16	24
200-400	1	2	1	2	5	6	14	17	21	27
400-600	19	26	7	10	5	5	16	21	47	62
600-800	25	30	25	34	7	8	22	26	79	98
800-1000	14	21	20	31	5	12	1	1	40	65
1000-1200	7	8	8	10	2	2	0	0	17	20
1200-1400	1	1	2	2	0	0	0	0	3	3
1400-1500	1	1	0	0	0	0	0	0	1	1
Total	77	106	63	89	27	36	57	69	224	300

The 300 accessions maintained at ESAB are from locations situated at altitudes ranging from 0 m to 1500 m asl, although emphasis was put on collecting from mountainous zones (Table 1, Fig. 1). A minimum number of 11 ears per landrace was collected and in certain locations more than a single sample was gathered (Table 1). The landraces were multiplied with manual control of pollination, to ensure a minimum number of 40 plants so as to maintain population variability. Seeds are kept in cold store (0°C) at ESAB at 50% relative humidity.

Observed variability

In general terms, all the traits under study in the 300 landraces displayed a great deal of variability, with significant differences between accessions (Table 2). These are early materials with limited plant development and an average height of 143 cm. As a general rule, ears are attached to the lower half of the plant, a characteristic frequent in the early varieties (Paterniani 1981). Yield depends on cycle limitations, although this varies greatly between populations. The results match those found in other studies of landraces from the same zone (Alvarez and Lasa 1994).

Correlations for mean phenotypic values are high and particularly significant (Table 3). These correlations were found to be positive, as was expected, between days to flowering, total height, ear height, number of leaves per ear and yield (Hallauer and Miranda 1981). This, together with the significant negative correlation with the altitude of origin, indicate that the landraces have evolved by means of local adaptations, which is ascribed to a combination of temperature and latitude.

It could be interpreted that these local populations have adapted to the maximum cycle length which the local climate permits. The results indicate that each increase in altitude of 100 m reduces, on average, days to pollen shedding by 0.65 and production by 198 kg/ha. Hence, Euskadi varieties (Table 2), harvested at 800 m asl maximum and at an average of 470 m asl, show higher levels of plant development, days to pollen shedding and yield. Galician, Asturian and Cantabrian varieties presented similar behaviour, although average altitude of origin for the Asturian varieties (773 m asl) is superior to the Cantabrian (607 m asl) and Galician (624 m asl).

Subsequently, experimental top-cross hybrids obtained by crossing the 300 landraces with the tester CM105 were obtained, in order to provide breeders with not only a wide range of genetic variation, but also with data by which to select the most suitable accessions for incorporating into hybridization programmes. Populations which produced the best hybrids were then again tested *per se* and in top-cross combinations at three locations (Table 4).

For varieties as well as hybrids, the genotype factor displayed significant differences for all traits observed (Table 4). Bearing in mind material earliness and the fact that the tester CM105 is closer to the release era of INRSA260 and G350 than that of Adonis, we see that several populations such as 33, 220, 98, 123 and 64 gave excellent results in top-cross hybrid form. This gives an additional element of value to these populations since the top-cross results were consistent throughout 2 years, with evaluation in the second year being carried out at three experimental locations.

Table 2. Characterization, in one experimental location, of the 300 landraces from NW Spain at cultivation density of 50 000 plants/ha

Landraces from:	Mean	Range	CV (%)
Galicia (0 - 1500 m)			
Days to flowering	52.97	47.76-65.95	6.78
Ear height (cm)	52.63	23.15-100.95	26.29
Total height (cm)	133.63	94.21-176.68	11.24
No. leaves to ear	4.71	4.03-5.61	7.94
No. leaves	8.88	7.99-9.97	5.66
Yield (kg/ha)	4029	2970-6255	19.10
Asturias (300 - 1207 m)			
Days to flowering	51.76	46.19-63.08	6.63
Ear height (cm)	53.43	25.08-96.35	27.09
Total height (cm)	141.14	105.60-191.68	12.59
No. leaves to ear	4.77	3.68-6.67	13.54
No. leaves	9.15	7.93-11.74	7.95
Yield (kg/ha)	4251	2655-7290	24.81
Cantabria (50 - 1000 m)			
Days to flowering	52.10	43.34-58.42	7.26
Ear height (cm)	60.62	26.23-108.87	33.42
Total height (cm)	149.84	109.93-201.05	15.10
No. leaves to ear	5.26	3.87-7.61	18.12
No. leaves	9.50	8.11-11.94	11.31
Yield (kg/ha)	4570	3195-6930	23.84
Euskadi (100 - 800 m)			
Days to flowering	54.28	31.6-59.66	8.05
Ear height (cm)	69.87	27.15-104.17	22.08
Total height (cm)	151.39	76.69-180.15	12.21
No. leaves to ear	5.89	3.02-7.36	14.56
No. leaves	10.16	5.72-11.98	11.58
Yield (kg/ha)	6022	2205-8685	23.50
All landraces tested (0 - 1500 m)			
Days to flowering	52.74	31.6-65.95	7.31
Ear height (cm)	58.25	23.15-108.87	29.36
Total height (cm)	142.93	76.69-201.05	13.62
No. leaves to ear	5.12	3.02-7.61	16.82
No. leaves	9.40	5.72-11.98	10.61
Yield (kg/ha)	4691	2205-8685	28.52

Table 3. Pearson correlation coefficient for landrace mean phenotypic values and zone of origin altitude

	Ear ht.	Total ht.	No. leaves to ear	No. leaves	Prodn.	Alt.
Days to flowering	0.70	0.66	0.77	0.83	0.71	-0.45
Ear height (cm)		0.93	0.95	0.90	0.75	-0.53
Total height (cm)			0.84	0.85	0.71	-0.43
No. leaves to ear				0.95	0.77	-0.58
No. leaves					0.80	-0.49
Production (kg/ha)						-0.39

All correlation coefficients are significant ($P \leq 0.0001$).

Conclusions

The results presented in this paper indicate that the accessions of *Zea mays* L. collected in northwest Spain, and held in the germplasm collection at ESAB, are an important genetic reservoir of variability. Some of these landraces should provide interesting base material for inclusion in breeding programmes to obtain hybrids for use in similar local environments.

Table 4. Mean agronomical traits of the 37 landraces with best top-cross performance using CM105 as tester

Accn	Collecting location	Landrace *per se**				Top-cross hybrid		
		Altitude (m)	Days to flowering	Total ht. (cm)	Yield (kg/ha)	Yield (kg/ha)	Days to flowering	Total ht. (cm)
254	Selviejo (Cantabria)	750	52.5	113	1390	8447	54.0	175
126	San Andrés, Luena (Cantabria)	500	50.0	†	†	7610	54.7	174
65	Sta. Maria, Trepa (Galicia)	800	52.3	91	2464	6815	55.0	150
46	Caleao (Asturias)	700	55.5	123	2606	9022	55.0	176
444	Foz de Caso (Asturias)	730	51.2	125	2101	8569	55.5	176
98	El Pino, Lieres (Asturias)	650	52.7	123	2637	9569	55.5	169
144	Moreiras, Xinzo de Limia (Galicia)	450	54.2	87	1738	7896	55.5	164
279	Cardes, Cangas de Onís (Asturias)	642	52.5	117	1512	8076	56.0	173
6	Baleira (Galicia)	730	53.8	110	2659	9057	56.2	171
343	Villar de Rogueros (Asturias)	1100	52.8	100	2132	8138	56.3	166
249	Cangas de Narcea (Asturias)	800	54.0	103	1700	8292	56.5	174
220	Anero (Cantabria)	50	55.8	130	3398	9848	56.7	170
257	Arganzúa (Asturias)	700	53.7	†	†	8195	56.8	168
263	Ataun (Euskadi)	600	60.0	136	3656	9637	57.4	185
55	A Gudiña (Galicia)	800	56.2	123	3403	8641	57.5	161
227	A Gudiña (Euskadi)	-	56.2	122	2955	8673	57.5	176
177	A Gudiña (Euskadi)	350	57.0	†	†	9259	57.5	170
132	Oñate (Euskadi)	500	56.3	122	2998	9024	57.7	180
101	Amieva (Asturias)	650	55.0	125	2009	8816	57.7	176
123	Puentecastro (Asturias)	500	61.2	135	2753	9883	57.8	191
8	Vallado (Asturias)	1207	54.2	106	2248	8763	58.0	155
92	Beizama (Euskadi)	650	60.3	124	3391	8862	58.0	165
33	Caserio Madariaga (Euskadi)	780	57.7	136	3265	10890	58.0	178
260	Regil (Euskadi)	550	58.8	137	2955	9647	58.2	180
376	Flor de Acebos (Asturias)	800	53.2	113	1716	8686	58.7	153
64	A Gudiña (Galicia)	800	57.0	121	2478	10000	58.8	171
89	Azcoitia (Euskadi)	600	59.3	127	3786	8587	59.2	173
192	Azcoitia (Euskadi)	200	57.7	†	†	9277	59.2	177
131	Dima (Euskadi)	500	56.3	141	3169	9288	59.3	184
59	Parada do Sil (Galicia)	700	55.0	110	2276	8481	59.5	180
186	El Molino (Cantabria)	254	61.5	173	2707	10038	59.5	200
16	- (Euskadi)	800	56.3	121	3093	9164	59.7	143
187	Bustablado, Ramales (Cantabria)	250	63.3	167	3283	7602	60.2	181
152	Mier (Asturias)	400	58.8	152	3558	9014	60.2	192
372	Murias-Moreda de Aller (Asturias)	700	56.8	141	2054	8346	60.3	150
178	Murias-Moreda de Aller (Euskadi)	350	59.8	132	3832	8755	60.3	171
171	Ocejo (Cantabria)	300	60.5	173	2674	10137	60.7	199
Inra260‡			58.8	156	4949	7681	57.7	168
Adonis‡			59.3	162	5101	10317	57.9	176
G350‡			65.2	178	6601	9838	63.7	196
Furio‡			67.0	181	5868	-	-	-
LSD			1.9	10	534	1348	1.5	12

Control CM105 at cultivation density of 45 000 plants/ha, location of collecting and height above sea level. Respective top-cross hybrid results at cultivation density of 83 000 plants/ha. Comparison with the check commercial hybrids. **Per se* landrace trait characterization. † Landraces which presented cultivation difficulties and for which no results are available on height and yield. ‡ Commercial check hybrids.

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Résumé

Variabilité des cultivars traditionnels de maïs collectés dans le nord-ouest de l'Espagne

L'Ecole supérieure d'agriculture de Barcelone (Espagne) conserve 300 variétés traditionnelles de maïs vitreux (*Zea mays* L.) collectées dans le nord-ouest de l'Espagne. La multiplication et la caractérisation élémentaire ont été menées à bien ainsi qu'une caractérisation par sélection à testeur constant utilisant la lignée «inbred» dentée CM105. Les résultats indiquent que ce matériel génétique, du cycle 150 à 300 FAO, constitue une réserve de variabilité génétique intéressante pour les programmes d'amélioration, en particulier parce que certains des hybrides obtenus ont donné un rendement en grains égal ou supérieur à celui des hybrides témoins du commerce.

Resumen

Variabilidad de las variedades locales de maíz recogidas en el noreste de España

La Escola Superior d'Agricultura de Barcelona (Barcelona, Spain) mantiene 300 variedades locales de maíz (*Zea mays* L.) de grano liso recolectadas en el noroeste de España. Se ha realizado la multiplicación y caracterización elemental de estas poblaciones, así como su caracterización top-cross con la linea dentada probadora CM105. Los resultados indican que este germoplasma, de ciclo 150 a 300 FAO, es una reserva de variabilidad genética de interés para su uso en programas de mejora, más aún cuando algunos híbridos top-cross rindieron producciones de grano iguales o superiores a híbridos comerciales testigos.