



## Characterization of a flint maize (*Zea mays* L. convar. *mays*) Italian landrace: I. Morpho-phenological and agronomic traits

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### Abstract

Maize (*Zea mays* L.) landraces have the highest genetic variation and adaptation to the natural and anthropological environment where they have evolved. Surveying both qualitative and quantitative morphological traits of existing landraces may be useful in maintaining their genetic diversity and preserving them from genetic erosion. Our research deals with the morpho-phenological and agronomic characterization of a flint maize landrace, named 'Nostrano di Storo', still grown in an inland hilly environment in the low valley of Chiese River in Trentino, North-Eastern Italy. The majority of plants from twenty field populations proved to belong, with few exceptions (NSt2, NSt9, NSt11), to a single population. It means that the plant material long grown in this area and maintained by local farmers through yearly selection forms a single landrace within which some populations (i.e. NSt1, NSt3, NSt4, NSt7, NSt10, NSt18, NSt19, NSt20) could be considered as most representative and taken as 'core'. This is supported by the fact that the genetic variability was much higher within than between field populations: half of the plant and ear traits investigated did not show any significant difference between populations whereas all traits but two showed highly significant differences within populations. Selection carried out over the years by each farmer according to his own criteria produced little genetic differentiation within the original population. Gene flow among farmer populations, most likely occurred through both pollen dispersion to neighboring cultivated fields and seed exchange among farmers, may help to explain the low genetic differentiation. This information is useful for both planning conservation and recognizing the landrace as a unique germplasm source of specific geographic origin.

### Introduction

Maize (*Zea mays* L.) is one of the most important crops in Italian agriculture. The species was introduced in the national cultivation system approximately four centuries ago and grown mainly for human consumption.

Since then, a number of landraces have been developed in order to meet specific needs of cultivation and utilization and to overcome environmental constraints of different areas. Photoperiod, temperature and humidity associated with altitude where the maize was grown have been the basic factors in the differentiation and development of always new landraces as well as hybridization brought about by continuous

exchange and trade (Trifunovic 1978; Bosch et al. 1997). These landraces were maintained by farmers as open-pollinated populations and thus each of them represented a collection of highly heterozygous and heterogeneous plants. Although a considerable range of variation within each population was present, a between population differentiation was detectable for several distinctive traits as a consequence of both natural and human selection pressure.

Within the last few decades, the Italian agricultural scenery has profoundly changed and the subsistence mixed farming unit is now transformed into an intensive monoculture (Bertolini et al. 1998).

At present, a small number of populations of flint maize (*Z. mays* L. convar. *mays*) can be found under

very particular agricultural situations or in marginal areas, such as alpine valleys, on small fields traditionally managed according to low-input agronomic practices, and with production exclusively addressed to human consumption. The agricultural environment, together with the traditional diet of these regions, ensures preservation of some landraces and limits diffusion of modern hybrids. Unfortunately, many populations were lost before it was realized that they were important sources of germplasm.

Many maize breeders are concerned that genetic diversity within this species has been decreasing at an alarming rate as a consequence of modern hybrids and agricultural systems. The use of a limited number of elite lines and synthetics heightens the risk of genetic uniformity in commercial maize production fields (Hallauer et al. 1988). Thus, maize breeders have recently become more aware of the need for both maintaining genetic diversity among hybrid varieties and improving the management of genetic resources through the conservation of landraces (Goodman 1994). From this comes the renewed interest for *in situ* conservation of the landraces (Brush 1995; Louette et al. 1997) not only in order to preserve important sources of genetic material for breeding, but also to allow their valorization as essential components of sustainable agriculture, as Agenda 21 has stressed.

Landraces are the cultivated maize material with the highest genetic variation as well as with the best adaptation to the natural and anthropological environment where they have evolved (Maxted et al. 1997). They contain locally adapted alleles and represent an irreplaceable bank of highly co-adapted genotypes (Qualset et al. 1997). Information on both qualitative and quantitative morphological traits of existing maize landraces may be useful in maintaining their genetic variability and preserving them from genetic erosion.

A survey of Italian maize landraces from Northern, Central and Southern regions cultivated up to 1960s has been reported by Lanza (1961) and Brandolini et al. (1967). Despite their potentiality for maize breeding, genetic characterization of landraces has been ignored. In the past some comparative studies have however been conducted at the morpho-agronomic level (Bonciarelli 1961; Lorenzoni et al. 1965; Brandolini 1970; Camussi 1979; Camussi et al. 1980). Nowadays, after years of lack of interest towards the so-called old local varieties, this valuable source of maize germplasm has been rediscovered and ex-

ploited as a niche crop suitable for the cultivation of marginal lands.

Agronomic evaluation and genetic characterization are essential to the effective use of maize resources (Lucchin et al. 1998; Barcaccia et al. 1999). When *in situ* conservation is pursued, this information should also be related to the need of monitoring changes which might occur in the landrace in relation to population dynamics, genetic erosion, and gene flow.

Our research deals with the morpho-phenological and agronomic characterization of an old flint maize local variety, named 'Nostrano di Storo', still grown in an inland hilly environment in the low valley of Chiese River in Trentino, North-Eastern Italy. The purpose of the work was to determine whether this maize material represents a single landrace or if the selection made by each farmer according to his own criteria has caused a differentiation within the original population bearing to a composite with highly distinct sub-populations. This information will be useful for both planning *in situ* or *ex situ* conservation and recognizing the landrace as a unique germplasm source with specific geographic origin.

## Materials and methods

### *Plant material*

The object of this study is a flint maize landrace named 'Nostrano di Storo' (in short NSt) grown at Storo (409 m above sea level) in the low Chiese Valley (Province of Trento, in North-Eastern Italy) over an area of 200–250 ha.

The whole landrace population was sampled taking four ears at random among those that each of twenty farmers had previously singled out for seed according to his own criteria of correspondence to the 'Nostrano di Storo' standard phenotype for a total of 80 ears.

The 20 field populations were sown in May 1997 according to a randomized complete-block experimental design with three replications. Four commercial hybrids of maturity class from 200 to 500 were also included as check for earliness and morpho-agronomic traits. Plot size was 22.4 m<sup>2</sup> and every plot consisted of 4 ear-to-row progenies 70 cm apart and 8 m long. The density was 6 plants per m<sup>2</sup>. Fertilizer, equivalent to 50–120–150 kg ha<sup>-1</sup> of N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O, was applied according to standard local practices before hand-sowing. Weed control was performed by isoxaflutole 75 g ha<sup>-1</sup> and pendimethalin

330 g ha<sup>-1</sup> in pre-emergence. Escaped weeds were controlled by hand hoeing.

During the growing season observations were made as follows:

- a) on a row basis: number of days from sowing to tasselling and to male flowering (50% of plants showing tassel exertion and anther shed, respectively); number of days to female flowering (50% of primary ears having 1 cm of exposed silks); silk colour, recorded as red or white (%); number of ear shoots per plant; plants with no ear (%); grain yield (t ha<sup>-1</sup>) and cob weight (g m<sup>-2</sup>); European corn borer (*Ostrinia nubilalis* Hubn.) resistance and smut (*Ustilago maydis* (DC.) Cda.) resistance, recorded at physiological maturity as percentage of plants showing damages or infection, respectively; number of broken and lodged plants at harvesting; meal quality as protein (nitrogen × 6.25), crude fibre, fat, ash and carbohydrate content (% on a dry weight basis);
- b) on three plants taken at random within each row, excluding plants at each end of the row: tassel length and apex length (cm); number of branches per tassel; insertion angle of tassel branches (score 1 to 9, 1 = narrow angle, ±5°, 9 = wide angle, >90°); primary branch habit (score 1 to 9, 1 = straight branches, 9 = very crooked branches); leaf insertion angle (score 1 to 9, 1 = narrow angle, ±5°, 9 = wide angle, >90°) and growth habit of leaves above the ear (score 1 to 9, 1 = straight leaves, 9 = patent leaves) at flowering;
- c) at milk stage, on ten consecutive plants in each row: plant height (cm) to the flag leaf insertion; culm diameter (mm) at the second internode; apical ear height (cm) at the ear insertion node;
- d) after harvest, on five ears taken at random from each progeny row: ear length (cm); ear diameter (mm); cob diameter (mm); cob colour (0 = red, 1 = white); apical ear sterility (mm); number of rows per ear; 100 kernel weight (g).

For hybrids all observations were made on a plot basis.

#### Data analysis

Statistical analysis has been performed according to a nested multiway analysis of variance (ANOVA) procedure based on random effects (Steel and Torrie 1980), using the CoStat software (CoHort Software, Minneapolis, MN).

The assessed sources of variation were blocks (2 df), field populations (19 df), rows within populations (60 df), blocks per populations interaction (38 df), experimental error (120 df). For traits with multiple observations within each row, the sampling error sum of squares was estimated (320 df for ears, 160 or 720 df for plants). When the experimental error was not significant at the F test, a pooled error mean square was used for testing the rows within-population effects.

Variation within populations for the descriptive traits was assessed by the Shannon-Weaver Diversity Index (SDI) computed using the formula:

$$SDI = - \sum_{i=1}^s p_i \log_e (p_i)$$

where  $s$  is the number of phenotypic classes for a given trait, obtained by subdividing the range of variation into three classes with the same width or by using the two alternative descriptor states, and  $p_i$  is the proportion of the total number of data in the  $i^{\text{th}}$  class (Jain et al. 1975). The index was standardized to keeps its value in the range 0 to 1, by dividing the value by  $\log_e s$  (Yu et al. 1996).

Narrow-sense heritability ( $h_N^2$ ) of some plant and ear traits was estimated on the basis of linear correlation coefficients between mother plant and offspring for the measured trait. For each ear trait, individual measurements taken at the single plant level were used, while mean row values over all replicates were adopted for the plant traits. Observations of the quantitative traits were carried out during 1998 on a total of 80 offsprings originated by as ears taken at random from the ear-to-row progenies grown in 1997.

Genetic distance estimates between landrace populations were calculated in all possible pair-wise comparisons using the Euclidean coefficient for quantitative traits:

$$E_{ij} = [\sum_k (x_{ki} + x_{kj})^2]^{1/2}$$

where  $x_{ki}$  and  $x_{kj}$  represent the quantitative trait values of the pair of objects ( $i$  and  $j$ ) considered. Thus,  $E_{ij} = 0$  indicates complete identity, whereas  $E_{ij} > 0$  indicates diversity. The mean genetic distances of each population from the landrace as a whole were obtained by averaging between-population estimates using the whole set of populations belonging to the landrace. Interval measurement data were standardized according to the following linear transformation:  $y' = (y - \bar{y})/sd$ , i.e. the mean value of each

variable was subtracted and the difference divided by the standard deviation. Cluster analysis was performed using the unweighted pair-group arithmetic average method (UPGMA), and dendrograms of all populations were constructed from the standardized symmetrical mean genetic distance matrix.

Standardized quantitative trait values were subjected to principal components analysis (PCA) to obtain information on the traits most effective in discriminating the farmer populations. Common components coefficients, eigenvalues, and relative and cumulative proportions of the total variance expressed by single traits were calculated. The first two components having maximum variance were selected for the ordination analysis: eigenvectors from the matrix of correlation among variables were extracted and used for the projection of population centroids into a 2-dimensional plot.

All calculations were made using the appropriate options of the Numerical Taxonomy and Multivariate Analysis System (NTSYS-pc) Version 1.80 (Rohlf 1993).

## Results

### *Morpho-phenological and agronomic traits*

Information on the variables analyzed in the 20 populations of the landrace 'Nostrano di Storo' including mean values, coefficients of variability and among populations least significant differences are reported in Table 1.

All the landrace populations supplied by local farmers showed considerable variability for the examined morpho-phenological and agronomic traits. Marked differences among populations were related to a single or a few populations clearly distinguishable for some of the traits investigated.

On the basis of male and female flowering, the landrace populations showed a vegetative cycle length comparable to 300 (79.4 days) and intermediate between 400 and 500 (81.7 and 86.7 days) class hybrids, respectively. Pollen dispersion and silk emission required on average  $80.3 \pm 0.4$  and  $84.6 \pm 0.4$  days, respectively, and so a marked proterandry (4 days) was observed over the landrace as a whole (Table 1). This behavior was not observed for commercial hybrids used as standards.

The landrace showed to be characterized by an average plant height of  $241 \pm 1.7$  cm and by an ear

insertion height of  $151 \pm 1.8$  cm on average (Table 1). The maximum and minimum values for these traits were scored by NSt1 (258 cm and 165 cm) and NSt21 (229 cm and 135 cm), respectively. The stalk diameter was, on average,  $17.4 \pm 0.2$  mm varying from 16.0 mm (NSt13) and 18.7 (NSt12). As far as the 300 class hybrid used as standard, the plant height was similar (240 cm), the ear insertion height was much lower (98 cm), while the stalk diameter was a little bigger (18.7 mm).

The primary branch habit of the tassel was scored as moderately crooked ( $6.14 \pm 0.13$ ) while the leaf insertion showed a quite narrow angle (score =  $4.32 \pm 0.10$ ).

The kernel yield was on average equal to  $3.96 \pm 0.06$  t/ha, ranging from 3.38 t/ha of NSt14 and 4.51 t/ha of NSt1 (Table 1) and was always lower than that of hybrids ranging from 5.79 t/ha (200 class) to 8.94 t/ha (500 class). Moreover, the 100 kernel weight of landrace populations was much lower than that of hybrids ( $15.9 \pm 0.3$  g vs.  $27.4 \pm 1.0$  g, respectively).

Concerning kernel yield components and yield influencing factors, the ear length of landrace populations was similar to those of hybrids ( $17.3 \pm 0.2$  cm vs.  $16.4 \pm 0.4$  cm), whereas the number of rows per ear was lower ( $13.8 \pm 0.2$  vs.  $15.3 \pm 0.6$ ), and the length of apical sterility of landrace populations was higher than that of hybrids ( $7.9 \pm 0.4$  mm vs.  $4.8 \pm 1.8$  mm). Average values of ear thickness were  $34.0 \pm 0.2$  mm for landrace populations and  $44.7 \pm 1.8$  mm for hybrids while those of cob thickness were  $23.5 \pm 0.3$  mm and  $26.7 \pm 0.7$  mm, respectively.

Silk and tassel variability as well as ear morphological variants of the landrace 'Nostrano di Storo' are shown in Figure 1.

As much as 4.71% of plants yielded no ears, ranging from 2.62% of NSt10 to 8.04% of NSt15. Despite this, the average number of ears per plant was 1.02 due to the presence of plants with two ears. The number of ears per plant scored by hybrids was 0.99.

It is interesting to note that over all landrace populations a proportion of plants varying between 5.39% of NSt17 to 20.61% of NSt8 showed red silks, with an average value of 13.26%.

The incidence of the European corn borer attack in the landrace populations was as high as  $3.59 \pm 0.42\%$  and  $1.18 \pm 0.41\%$  in the hybrids. A high susceptibility to corn smut was recorded with an average proportion of infected plants of  $55.2 \pm 4.3\%$ , ranging from 25.0% (NSt21) to 91.7% (NSt19), whereas only

Table 1. Information on the morpho-phenological and agronomic characters observed in 20 maize field populations of 'Nostrano di Storo'.

Trait	Landrace populations																				Mean	CV	LSD*	
	NS1	NS2	NS3	NS4	NS5	NS6	NS7	NS8	NS9	NS10	NS11	NS12	NS13	NS14	NS15	NS17	NS18	NS19	NS20	NS21				
Tassel emission (d)	80.8	76.8	80.7	78.9	80.8	78.8	79.2	79.3	74.8	78.9	81.8	78.0	76.8	78.6	76.9	75.6	80.8	78.3	78.3	77.3	78.6	78.6	2.36	2.3
Tassel length (cm)	48.8	49.9	47.9	48.6	51.9	51.6	47.1	44.7	47.6	46.6	49.4	48.0	45.9	47.2	49.0	48.1	50.0	50.1	49.8	50.3	48.6	48.6	3.77	2.7
Apex length (cm)	21.3	21.5	20.0	20.7	23.7	22.5	21.0	21.3	18.7	22.6	23.1	21.1	20.8	23.2	20.7	23.2	21.9	22.8	22.5	23.0	21.8	21.8	5.86	1.9
No. of branches per tassel	14.8	16.5	16.7	16.8	16.1	15.5	15.0	16.6	15.1	14.5	13.9	15.3	16.3	16.0	15.9	14.7	15.7	14.8	15.7	14.4	15.5	15.5	5.45	1.5
Branch insertion angle (1-9)	5.72	5.22	5.83	6.00	5.06	5.56	5.61	5.67	5.61	5.83	5.78	5.67	5.94	5.78	5.89	6.28	5.72	6.22	6.17	5.67	5.76	5.76	5.13	-
Primary branch habit (1-9)	6.28	4.56	6.67	6.67	5.51	6.50	6.50	5.72	5.28	6.39	5.56	6.06	6.72	6.67	6.22	6.56	6.39	6.22	6.44	5.94	6.14	6.14	9.19	-
Pollen dispersion (d)	82.5	78.9	82.1	80.8	82.3	80.8	80.9	81.3	76.3	80.8	83.3	79.4	78.9	80.7	78.3	77.7	82.1	80.1	80.1	79.4	80.3	80.3	2.19	1.5
Silk emission (d)	85.4	83.0	85.9	85.8	87.4	84.6	85.8	85.5	80.8	84.7	87.3	84.5	83.9	85.1	84.3	81.1	86.8	83.8	83.3	83.3	84.6	84.6	2.11	2.4
Silk colour (% red)	12.8	12.0	13.7	12.8	20.4	15.9	14.3	20.6	6.9	15.2	11.0	18.9	9.5	15.9	13.9	5.4	11.6	14.5	11.3	8.6	13.3	30.4	3.7	-
Plant height (cm)	258	233	237	243	246	240	231	241	243	244	253	239	230	236	242	240	255	247	241	229	241	229	3.22	-
Stalk diameter (mm)	17.8	17.7	17.7	16.4	18.3	17.0	17.7	17.1	16.8	17.0	17.1	18.7	16.0	16.6	18.0	16.5	18.3	16.9	18.3	17.1	17.4	17.4	4.27	-
Leaf insertion (1-9)	3.72	4.22	3.72	4.67	4.06	3.89	4.28	4.00	5.39	4.28	3.67	4.67	4.44	4.61	4.39	5.06	4.00	4.44	4.67	4.28	4.32	10.3	-	-
Leaf growth habit (1-9)	4.72	5.83	4.72	5.06	5.17	4.89	5.00	4.33	5.06	4.28	4.67	4.39	4.56	5.50	5.39	5.06	4.50	5.06	4.67	5.33	4.91	8.42	-	-
Plants with no ear (%)	3.85	5.08	5.43	4.57	4.21	5.51	4.85	4.27	2.85	2.62	7.27	6.16	3.96	6.19	8.04	3.66	4.42	2.67	3.00	5.41	4.71	31.5	-	-
Ear insertion height (cm)	165	147	152	154	165	158	142	153	144	146	155	152	146	144	154	145	160	152	141	135	151	5.33	5	-
No. of ears per plant	1.03	1.07	0.99	1.01	1.02	1.05	1.00	0.98	1.03	1.05	1.10	1.04	1.05	1.00	0.96	0.98	0.99	1.01	0.99	1.02	1.02	1.02	3.39	-
Apical sterility (mm)	8.47	10.20	9.70	8.00	5.15	9.35	7.85	7.95	6.07	9.70	7.53	9.45	4.33	6.63	10.43	7.72	7.05	7.37	7.92	7.17	7.90	20.5	-	-
Ear length (cm)	18.8	15.9	16.9	17.0	18.0	18.4	16.3	18.2	15.8	17.1	17.9	17.7	17.7	17.2	16.4	16.1	18.4	17.9	16.9	16.3	17.3	5.28	0.8	-
Ear thickness (mm)	33.8	36.0	34.9	35.0	33.8	33.2	34.0	33.8	33.6	34.1	34.3	33.7	32.7	32.1	36.4	34.0	34.6	33.6	33.9	33.2	34.0	2.93	1.0	-
No. of rows per ear	13.9	14.3	13.9	13.7	14.3	14.6	13.8	13.4	12.0	13.5	13.6	13.1	14.6	15.2	14.0	13.4	13.7	13.9	14.0	13.0	13.8	4.88	0.6	-
Cob thickness (mm)	23.6	24.4	23.7	23.6	23.2	22.8	23.6	23.5	22.0	23.2	23.2	27.8	22.8	22.4	24.4	24.4	22.5	23.6	23.1	22.8	23.5	5.05	-	-
Cob weight (g/m <sup>3</sup> )	74.9	57.8	60.9	66.1	70.2	62.9	59.0	56.4	54.2	69.0	61.0	72.5	69.2	56.4	52.7	65.7	65.3	70.9	66.2	60.8	63.6	10.0	-	-
Cob colour (1 = white 0 = red)	0.97	0.85	0.93	0.92	0.98	0.95	0.93	0.97	0.90	0.87	0.95	0.97	1.00	0.93	0.97	0.93	0.83	0.83	0.78	1.00	0.92	6.57	0.16	-
Kernel yield (t/ha)	4.51	3.86	3.81	4.32	3.95	3.79	3.56	3.93	4.01	4.26	4.37	4.03	3.96	3.38	3.70	3.89	4.19	3.94	4.04	3.75	3.96	6.92	-	-
100 Kernel weight (g)	15.9	15.7	16.3	17.0	15.1	14.0	15.5	16.8	18.6	15.9	16.5	16.4	14.3	12.6	17.5	16.6	17.6	14.9	15.5	16.1	15.9	8.52	1.2	-
Plants with borer (%)	2.26	0.88	3.04	1.09	2.22	2.20	2.54	3.63	4.17	5.90	5.73	2.00	7.93	5.75	3.69	4.95	5.90	2.00	3.76	2.25	3.59	52.8	-	-
Plants with smut (%)	83.3	50.0	58.3	83.3	75.0	50.0	41.7	66.7	50.0	50.0	33.3	41.7	33.3	50.0	83.3	45.5	41.7	91.7	50.0	25.0	55.2	34.6	-	-
Plants broken (No./m <sup>2</sup> )	1.37	1.67	0.77	0.98	1.80	3.12	1.18	2.75	1.40	1.34	3.13	1.32	1.58	2.34	1.46	1.59	1.32	1.13	1.01	1.95	1.66	40.9	0.89	-
Plants landed (No./m <sup>2</sup> )	0.49	0.79	0.37	0.12	0.63	0.91	0.39	0.82	0.19	0.42	0.24	0.42	0.00	0.57	0.10	0.30	0.16	0.51	0.15	0.64	0.41	63.0	-	-
Protein (% = nitrogen × 6.25)	10.60	9.36	10.18	10.12	10.90	10.31	9.77	9.96	10.91	10.65	10.46	10.87	11.03	9.84	10.86	10.67	10.13	10.52	10.67	10.82	10.43	3.43	-	-
Crude fibre (%)	2.32	2.10	2.17	2.00	2.04	2.09	1.84	2.00	1.97	2.36	2.10	1.93	2.20	2.14	2.18	2.18	2.60	2.31	2.03	2.13	1.88	-	-	
Fat (%)	5.39	4.64	4.84	5.43	5.57	4.73	4.75	4.91	5.30	4.84	4.63	4.94	4.82	4.64	5.08	5.03	4.73	4.94	4.64	5.29	4.96	6.87	-	-
Ash (%)	1.49	1.49	1.50	1.48	1.58	1.51	1.62	1.73	1.53	1.49	1.49	1.61	1.61	1.60	1.81	1.56	1.46	1.59	1.51	1.48	1.56	19.8	-	-
Carbohydrates (%)	80.20	82.41	81.30	80.98	79.91	81.36	82.02	81.40	80.26	81.05	81.08	80.47	80.62	81.72	80.11	80.57	81.08	80.64	81.15	80.28	80.93	0.59	-	-

\* Significant at  $P = 0.05$

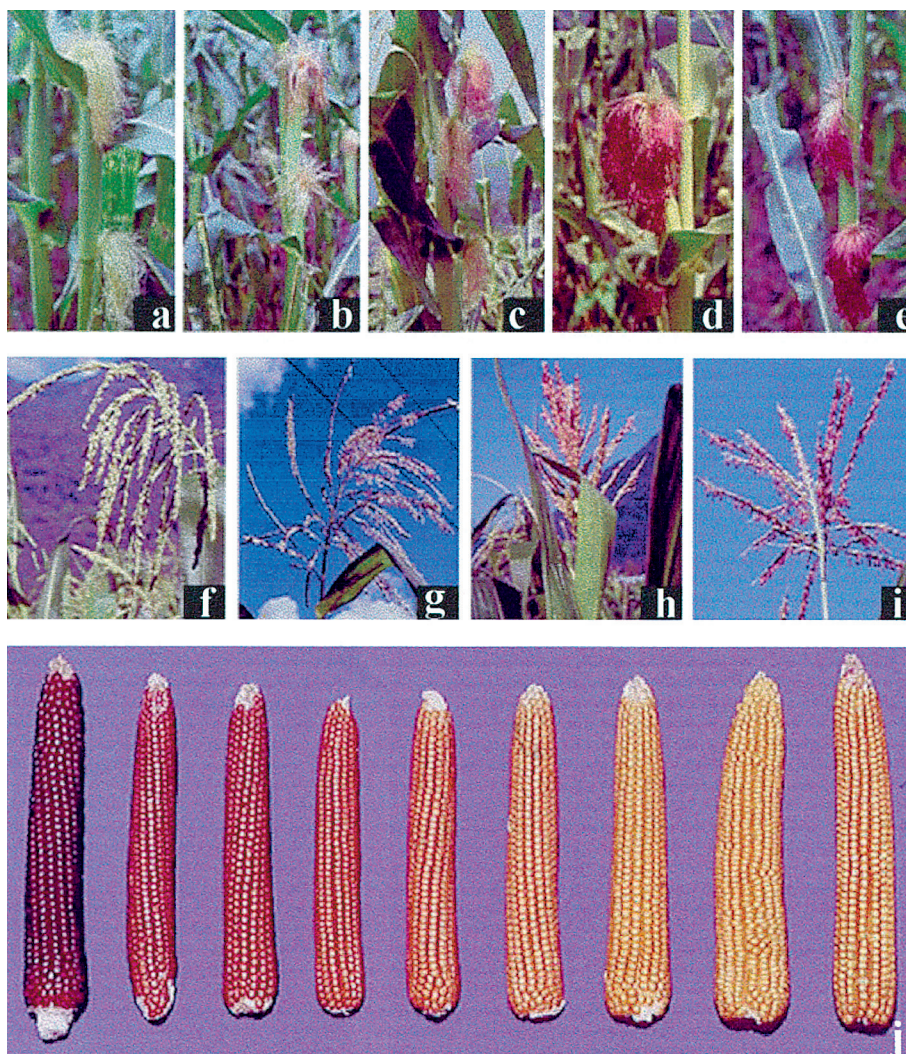


Figure 1. Examples of the phenotypic variability of silks (a–e), tassels (f–i), and ears (j) of the maize landrace ‘Nostrano di Storo’.

the 400 class hybrid showed some infected plants (16.7%).

#### *Heritability of distinctive landrace traits*

High narrow-sense heritability ( $h_N^2$ ) estimates were calculated for distinctive plant and ear traits such as ear insertion height (1.10), cob colour (0.76) and thickness (0.70), number of rows per ear (0.70), anther and silk colour (0.94 and 1.76, respectively) and kernel colour (0.52). Although important yield components like ear length and thickness, and 100 kernel weight gave heritability estimates of 0.62, 0.52 and 0.42, respectively, kernel yield had a virtually null heritability (0.03). Heritability of pollen disper-

sion and silk emission were 0.44 and 0.52, respectively, suggesting that proterandry is a distinctive reproductive behaviour of the ‘Nostrano di Storo’ landrace populations.

#### *Qualitative traits: meal composition*

The protein content was on average equal to 10.43%, varying from 11.03% of NSt13 to 9.36% of NSt2 (Table 1). The crude fibre (2.13%, on average) and ashes (1.56%, on average) showed the highest relative variation (CVs were 18.8% and 19.8%, respectively): the highest and lowest contents of crude fibre were observed for NSt7 (1.84%) and NSt18 (2.60%) while the same figures for ash were scored by NSt4 (1.48%)

Table 2. Shannon-Weaver Diversity Index for morpho-phenological and agronomic characters in 20 maize populations of 'Nostrano di Storo'.

Trait	NS1	NS2	NS3	NS4	NS5	NS6	NS7	NS8	NS9	NS10	NS11	NS12	NS13	NS14	NS15	NS17	NS18	NS19	NS20	NS21	Mean
Tassel emission (d)	0.936	0.981	0.981	0.921	1.000	0.873	0.981	0.836	0.657	0.836	0.981	0.921	1.000	0.981	0.921	0.873	0.921	0.921	0.836	0.946	0.915
Tassel length (cm)	0.921	0.873	0.957	0.906	0.962	0.713	0.935	0.927	0.921	0.750	0.834	0.785	0.981	0.808	0.994	0.773	0.880	0.956	0.906	0.808	0.879
Apex length (cm)	0.909	0.877	0.860	0.853	0.962	0.877	0.666	0.957	0.927	0.921	0.839	0.994	0.903	0.864	0.992	0.993	0.785	0.752	0.903	0.864	0.885
No. of branches per tassel	0.850	0.860	0.890	0.792	0.878	0.957	0.890	0.909	0.985	0.798	0.944	0.839	0.985	0.839	0.713	0.962	0.946	0.822	0.798	0.976	0.882
Branch insertion angle (1-9)	0.946	0.985	0.814	0.507	0.973	0.657	0.792	0.830	0.830	0.839	0.752	0.596	0.807	0.452	0.515	0.478	0.569	0.388	0.515	0.374	0.666
Primary branch habit (1-9)	0.785	0.992	0.752	0.773	0.981	0.814	0.921	0.962	0.986	0.657	0.877	0.873	0.750	0.798	0.798	0.839	0.820	0.880	0.792	0.944	0.850
Pollen dispersion (d)	0.790	0.836	0.921	0.836	0.946	0.946	0.808	0.808	0.657	0.836	0.981	0.981	0.981	0.981	0.936	0.936	0.936	0.936	0.946	0.946	0.897
Silk emission(d)	0.657	0.946	0.936	0.921	0.981	0.808	0.921	1.000	0.657	0.873	0.936	0.981	0.921	0.981	0.981	0.873	0.873	0.981	0.946	0.981	0.908
Silk colour (% red)	0.921	0.981	0.808	0.836	0.873	0.946	0.936	1.000	0.981	0.981	0.936	0.981	0.921	0.750	0.981	0.657	0.981	0.836	0.873	0.921	0.905
Plant height (cm)	0.860	0.906	0.906	0.791	0.962	0.798	0.820	0.998	0.864	0.893	0.909	0.822	0.962	0.946	0.872	0.903	0.814	0.909	0.822	0.921	0.884
Stalk diameter (mm)	0.793	0.720	0.819	0.807	0.819	0.588	0.839	0.846	0.975	0.720	0.919	0.888	0.856	0.947	0.892	0.720	0.896	0.809	0.745	0.769	0.818
Leaf insertion (1-9)	0.569	0.906	0.388	0.981	0.388	0.853	0.452	0.309	0.521	0.430	0.622	0.726	0.753	0.890	0.910	0.716	0.569	0.910	0.591	0.921	0.670
Leaf growth habit (1-9)	0.966	0.935	0.753	0.962	0.981	0.936	0.620	0.750	0.992	0.554	0.921	0.944	0.921	0.692	0.981	0.753	0.953	0.962	0.976	0.664	0.861
Plants with no ear (%)	0.808	0.750	0.750	0.750	0.921	0.750	0.946	0.750	0.650	0.946	0.946	0.750	0.515	0.750	0.936	0.981	0.921	0.657	0.836	0.750	0.803
Ear insertion height (cm)	0.979	0.971	0.945	0.769	0.987	0.948	0.870	0.872	0.765	0.773	0.920	0.922	0.944	0.894	0.910	0.838	0.914	0.937	0.878	0.701	0.889
No. of ears per plant	0.981	0.836	0.836	0.921	0.750	0.981	0.873	0.873	0.936	0.790	0.873	0.946	1.000	0.790	0.936	0.946	0.946	0.873	0.750	0.946	0.887
Apical sterility (mm)	0.619	0.884	0.645	0.699	0.663	0.571	0.710	0.750	0.154	0.799	0.644	0.914	0.701	0.710	0.784	0.896	0.717	0.855	0.909	0.538	0.708
Ear length (mm)	0.945	0.984	0.929	0.864	0.850	0.864	0.895	0.922	0.679	0.866	0.843	0.965	0.958	0.914	0.941	0.717	0.817	0.921	0.784	0.817	0.874
Ear thickness (mm)	0.694	0.955	0.636	0.884	0.717	0.973	0.843	0.798	0.828	0.909	0.874	0.833	0.777	0.739	0.892	0.941	0.973	0.668	0.906	0.741	0.829
No. of rows per ear	0.690	0.817	0.850	0.962	0.817	0.817	0.941	0.694	0.582	0.531	0.785	0.582	0.579	0.920	0.636	0.933	0.930	0.976	0.651	0.875	0.778
Cob thickness (mm)	0.777	0.845	0.337	0.957	0.895	0.937	0.933	0.935	0.678	0.701	0.122	0.626	0.636	0.745	0.811	0.776	0.914	0.789	0.922	0.978	0.766
Cob colour (1 = white 0 = red)	0.211	0.610	0.353	0.414	0.122	0.286	0.353	0.211	0.469	0.567	0.286	0.211	0.000	0.353	0.211	0.353	0.650	0.520	0.754	0.000	0.347
Kernel yield (t/ha)	1.000	0.921	0.981	0.750	0.981	0.936	0.836	0.981	0.750	0.981	0.873	0.750	0.921	0.981	0.981	0.836	0.946	0.946	0.946	0.981	0.914
100 Kernel weight (g)	0.980	0.855	0.960	0.884	0.904	0.895	0.990	0.962	0.933	0.908	0.962	0.839	0.899	0.899	0.844	0.956	0.919	0.843	0.757	0.750	0.897
Plants with borer (%)	0.657	0.657	0.873	0.750	0.657	0.946	0.873	0.414	0.936	0.981	0.750	0.515	0.873	0.515	0.873	0.946	0.921	0.650	0.873	0.657	0.766
Plants with smut (%)	0.650	1.000	0.980	0.650	0.811	1.000	0.980	0.918	1.000	1.000	0.918	0.980	0.918	1.000	0.650	1.000	0.980	0.414	1.000	0.811	0.883
Plants broken (No./m <sup>2</sup> )	0.873	0.790	0.981	0.921	0.750	0.921	0.836	0.808	0.981	0.981	0.921	0.873	0.981	0.836	0.921	0.946	0.790	0.946	0.946	0.921	0.898
Plants landed (No./m <sup>2</sup> )	0.790	0.946	0.657	0.650	0.921	1.000	0.750	0.946	0.808	0.790	0.657	0.657	0.000	0.657	0.750	0.657	0.657	0.946	0.657	0.946	0.742
Protein (% = nitrogen × 6.25)	0.985	0.819	0.887	0.954	0.932	0.887	0.946	0.887	0.887	0.548	0.895	0.976	0.757	0.819	0.946	0.946	0.997	0.422	0.896	0.887	0.864
Crude fibre (%)	0.950	0.839	0.862	0.985	0.950	0.896	0.946	0.548	0.950	0.950	0.548	0.932	0.670	0.887	0.985	0.976	0.337	0.862	0.946	0.862	0.841
Fat (%)	0.896	0.862	0.887	0.422	0.932	0.932	0.887	0.976	0.997	0.985	0.932	0.819	0.896	0.976	0.896	0.756	0.802	0.976	0.896	0.946	0.883
Ash (%)	0.896	0.862	0.887	0.422	0.932	0.932	0.887	0.976	0.997	0.985	0.932	0.819	0.896	0.976	0.896	0.756	0.802	0.976	0.896	0.946	0.883
Carbohydrates (%)	0.887	0.640	0.950	0.422	0.932	0.862	0.997	0.337	0.997	0.839	0.787	0.932	0.946	0.997	0.708	0.950	0.337	0.787	0.985	0.896	0.809
Mean	0.827	0.849	0.819	0.807	0.854	0.847	0.846	0.796	0.824	0.816	0.825	0.833	0.801	0.833	0.834	0.831	0.836	0.825	0.842	0.817	0.828

Table 3. Euclidean genetic distance (EGD) matrix of landrace populations based on 34 morpho-agronomic traits.

	NSt1	NSt2	NSt3	NSt4	NSt5	NSt6	NSt7	NSt8	NSt9	NSt10	NSt11	NSt12	NSt13	NSt14	NSt15	NSt17	NSt18	NSt19	NSt20	NSt21
Mean EGD	8.099	9.266	7.527	7.328	9.015	7.952	7.083	7.834	9.910	7.362	9.069	8.137	8.593	8.584	8.758	8.101	7.603	7.273	7.110	7.846
minimum	5.518	7.705	5.557	5.609	7.013	5.877	5.514	5.877	7.229	5.186	7.088	6.319	6.718	6.111	5.841	5.840	5.518	4.889	4.889	5.840
maximum	11.524	10.714	10.255	8.934	12.363	11.587	9.010	9.910	12.363	9.413	11.755	10.165	10.714	11.529	10.635	10.124	10.301	9.782	9.172	9.188

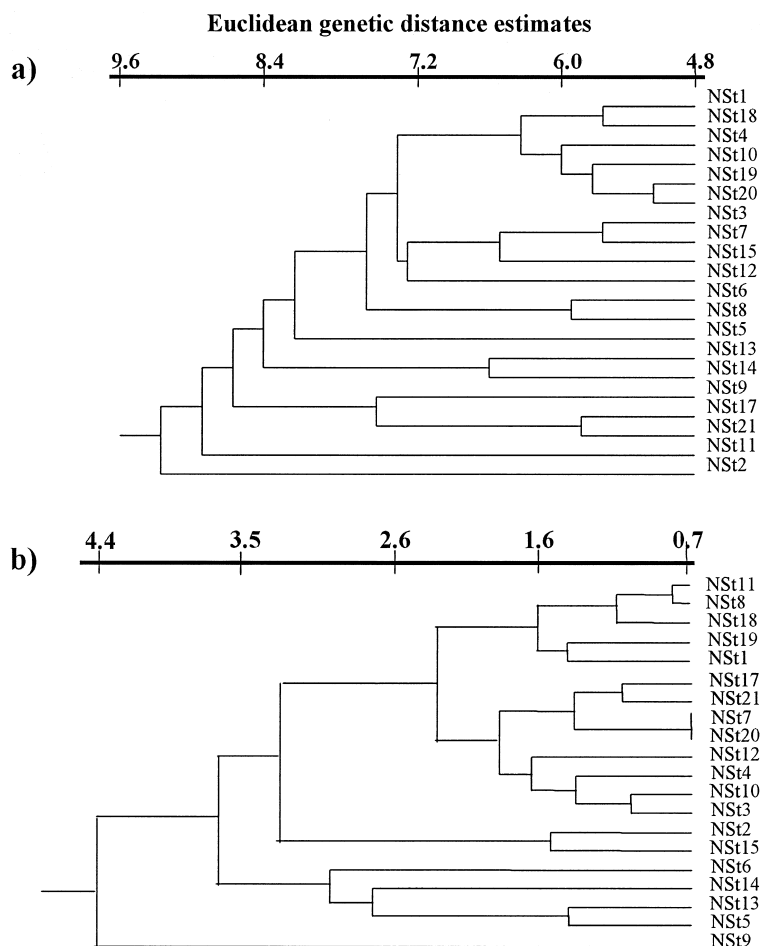


Figure 2. Dendrogram of the 'Nostrano di Storo' farmer populations constructed according to the UPGMA method and based on the Euclidean genetic distance estimates. a) dendrogram based on the 34 observed traits; b) dendrogram based on the 5 ear traits on which the selection by farmers is made.

and NSt15 (1.81%). Carbohydrates ranged from 79.91% of NSt15 to 82.41% of NSt2 (80.9% on average). No significant differences between populations were observed for each of the five qualitative traits.

#### *Within vs. between population differences*

All morpho-phenological and agronomic traits but two (plants with no ear and susceptibility to corn

borer) showed highly significant differences within populations.

It is interesting to note that differences for important agronomic and morphologically distinctive traits like plant height, stalk diameter, plant growth habit, apical sterility, kernel yield, and protein content were highly significant within populations only. On the whole, between population differences were significant for 14 out of 34 traits. As far as qualitative traits are concerned, differences in protein, fat, and



Table 4. Correlation matrix of seven principal components and quantitative traits of landrace populations with Eigen values, relative and cumulative proportion of total variance.

Traits	Common principal component coefficients						
	1st	2nd	3rd	4th	5th	6th	7th
Tassel emission	0.884	0.323	0.013	0.208	0.189	0.122	0.835
Silk emission	0.083	0.049	0.067	0.062	0.036	0.035	-0.267
Pollen dispersion	0.872	0.351	-0.061	0.201	0.167	0.118	0.527
Ear length	0.101	0.095	-0.018	0.085	0.052	-0.032	0.219
Red silk	0.815	0.470	0.115	0.112	0.132	0.151	0.546
Plant height	0.042	-0.101	-0.025	-0.185	-0.045	-0.003	0.067
Ear insertion height	0.859	-0.004	-0.005	0.080	-0.271	-0.106	0.424
Kernel yield	-0.327	0.235	-0.090	-0.031	-0.018	0.004	0.261
Cob weighth	0.542	0.532	0.246	-0.351	-0.439	-0.121	0.333
Smut infection	0.106	-0.075	0.040	0.079	-0.089	-0.002	0.131
Apex length	0.726	-0.476	0.161	0.120	0.240	-0.332	0.448
Crude fibre	-0.008	0.034	0.183	-0.022	-0.048	-0.007	-0.112
Eigen values observed	5.528	1.790	1.445	1.270	0.746	0.491	0.358
Relative proportion of total variance	46.07	14.91	12.04	10.58	6.22	4.09	2.99
Proportions of variance expected	25.86	17.53	13.36	10.58	8.49	6.83	5.44
Cumulative proportion of total variance	46.07	60.98	73.02	83.61	89.82	93.91	96.90

carbohydrates content were significant at within populations only, while crude fibre and ash content did not show significant differences either within nor between populations.

Altogether, the SDI values (Table 2) averaged over all descriptive traits are similar for all populations, ranging from 0.796 (NSt8) to 0.849 (NSt2). Nevertheless single values show that phenotypic variability

is not equally present in all populations for the same trait or for all traits in the same population. For instance, NSt9 shows particularly low values for both male (0.657) and female (0.657) flowering date, apical sterility (0.154), ear length (0.679), and number of rows per ear (0.582). Among the ear traits, the number of rows per ear varies from 0.531 (NSt10) to 0.976 (NSt19).

#### Cluster analysis and genetic distances

Quantitative trait data were used for defining a matrix of the genetic distances between landrace populations. The average genetic distance over all landrace populations was  $8.122 \pm 0.103$  (Table 3). Based on pairwise comparisons the most similar populations were NSt19 and NSt20 (4.889), NSt10 and NSt20 (5.186) while the most dissimilar populations were NSt5 and NSt9 (12.363).

The dendrogram (Figure 2a) evidence that 6 populations are tightly grouped and clearly separated from all the others. It is interesting to note that NSt9, NSt11, and NSt2 are the most distant ones from the core of the landrace. Their mean genetic distances were 9.910, 9.069, and 9.266 respectively (Table 3).

Dendrogram in Figure 2b, based on the 5 ear traits and on lower euclidean genetic distance estimates, shows a quite different clustering thus modifying the composition of the group of populations identifiable as the most similar ones.

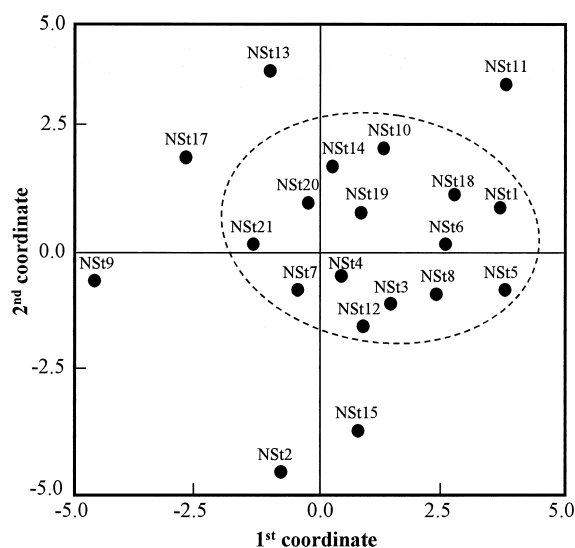


Figure 3. Genetic distances among 'Nostrano di Storo' farmer populations. The centroids were plotted according to the first two coordinates with the UPGMA method.

### *Principal component analysis and most discriminant traits*

The correlation matrix of the seven principal components is reported in Table 4.

The characters that displayed the best discriminatory ability and utility for a morpho-agronomic characterization were: tassel and silk emission, pollen dispersion, ear length, silk colour, plant height, ear insertion height, cob weight, tassel apex length, corn smut susceptibility and crude fibre content of meal.

The first four components with eigenvalues greater than 1 were able to explain 83.61% of the total variation. In particular, the first component, which explains 46.07% of the total variation, was positively and strongly associated with tassel emission, pollen dispersion, and ear insertion height, and in decreasing importance, with red silk colour, apex length and cob weight, while was negatively associated with kernel yield (Table 4). This means that populations with high values of component 1 have a longer growing cycle, highly inserted ears, and lower kernel yields. The second component, which explains 14.91% of the total variation, was positively, but moderately associated with cob weight and red silk, and negatively associated with tassel apex length. Populations with high component 2 are therefore characterized by high cob weight and short tassel apex.

The scatter diagram showing the separation of landrace populations according to the first two coordinates is reported in Figure 3.

### **Discussion**

The Italian landrace 'Nostrano di Storo' is a type of flint maize with very brilliant orange kernels and flint texture, whose production is entirely utilized, as flour, for human consumption. It represents a niche crop with important social and economic significance for local people. This landrace is actually grown on about 200–250 ha within an alluvial plain of about 1,000 ha as a whole, situated in the low Chiese Valley, Province of Trento, North-Eastern Italy, and enclosed within mountain chains. Most farmers (66%) sows maize in fields smaller than 1 ha while the rest of fields have an area ranging from 1 to 5 ha. The total production of maize meal has passed from 30 t of 1991 to the current 300 t and its total market value from about €15,000 to more than €500,000. As a matter of fact, although still locally known and fully appreciated as maize 'polenta', its demand shows a steady increase

due to the deeper attention that consumers pay to the autochthonous, locally cultivated crops, usually grown according to low-input agronomic practices, and to their consciousness towards the current dualism existing between conventional and novel foods.

The regional valorization of the landrace has greatly contributed to its on-farm conservation through the continued cultivation and management by farmers in the agroecosystem where it has evolved.

The flint maize germplasm cultivated at Storo has originated from an ancient introduction grown in the area since mid 18th century and belongs, with few exceptions, to a single population.

The seed lot to be used for the next cropping season is selected by each farmer from ears singled out from his own harvest according to his own criteria of correspondence to the 'Nostrano di Storo' standard phenotype. This procedure is possible since harvesting is still mostly made by hand and each farmer carries out wind ear drying and stores his own seed stock. Selection is made without control of the pollen source or of the plant phenotype. According to farmers, the ears selected correspond to the ear ideotype in terms of length, thickness, kernel size and colour and so are the best well-developed ears and well-filled kernels (without fungi or insect damage). Each farmer usually applies a selection coefficient of  $2.5 \times 10^{-3}$ . That means a strong selective pressure which enabled to maintain the population identity although sources of contamination might have been present.

Although since the 1970s hybrids for silage have been grown, the hand harvesting of the ears and the criteria of ear selection have acted to limit the genetic contamination and to preserve the phenotypic identity of this landrace whose standard phenotype can be described on the basis of distinctive and landrace-specific traits.

Most populations required less than three months from sowing to male and female flowering, even though a proterandry of 4 days is present. The average plant height for the landrace is 2.4 m, but plants up to 3 m can be frequently found. Despite the remarkable plant height, the stalk diameter has a small size (17.4 mm) and this, with the high ear insertion, is one of the factors responsible for the high incidence of broken ( $1.66 \text{ m}^{-2}$ ) and lodged ( $0.41 \text{ m}^{-2}$ ) plants. A distinctive trait is the ear insertion height which on average is equal to 151 cm. The tassel primary branch habit is moderately crooked and the leaf insertion shows quite narrow angles. Across all populations a proportion of plants varying between 5 and 20% shows red silks. An ear length of about 17 cm, a thickness of 3.4 cm

and a number of 13.8 rows are the average distinctive traits of ears as well as a length of apical sterility of 7.9 mm. Despite an average of 4.7% of barren plants, the mean number of ears per plant is higher than 1 due to some plants producing two or three ears. The yield of landrace populations is on average of 4 t/ha. An additional distinctive trait is that the 100 kernel weight, although highly variable both within and among populations, is as low as 16 g and thus much lower than that of commercial hybrids (more than 27 g).

The incidence of the European corn borer attack in the landrace population is less than 4%, but a high susceptibility to corn smut seems to be one of the main failures of the landrace, varying between 25 and 92% the proportion of infected plants.

Meal composition analysis revealed 10.4% of protein, 80.9% of carbohydrates, 5% of fat, 2.1% of crude fibre and 1.6% of ashes.

Selection carried out over the years produced little genetic differentiation within the original population. In fact, the genetic variation was much higher within than between populations: half of the quantitative traits investigated did not show any significant difference among populations whereas all traits but two showed highly significant differences within single populations. This result agrees with theoretical expectations because on the basis of the breeding system of maize, the genetic variability of the whole landrace should be ample, distributed among individuals and as large among as within populations. The low genetic diversification among populations can be explained by taking into account the gene flow among the farmer's fields which can likely have occurred through both pollen dispersion and seed exchange among farmers. This hypothesis is further supported by the absence of correlation between genetic and geographic distances ( $r = 0.095$ ).

The high variability that can be found within each population strengthen anyway the hypothesis that all populations belong to the same landrace. These results would explain why local farmers do not discriminate among their own populations.

The traditionally adopted management procedure does not aim to prevent the sowing of hybrids in contiguous areas to landrace populations. The land owned and cultivated by each farmer is scattered all over the whole area and is sown at each cropping season without any physical isolation between local populations and introduced varieties. Moreover, the adoption of hybrids of different class and the uniform planting date of landrace materials do not lead to a

sufficient difference in flowering time to permit reproductive isolation.

Gene contamination caused by pollen dispersal from commercial hybrids may have occurred and may still occur, but it seems it has been adequately controlled through the selection made by farmers. Nevertheless, a certain level of genetic erosion of the landrace may have occurred as the detectable genetic differentiation of some of the farmer populations from the landrace core seems to indicate. Populations that were clustered separately from the core scored the highest values of kernel yield (on average 4.21 t/ha vs. 3.86 of the remaining populations). Moreover, NSt11, clustered apart because of its highest mean genetic distance, showed a kernel yield as high as 4.37 t/ha. The absolute value of kernel yield along with evidences on the mealy rather than glassy fracture of kernels suggest genetic introgression from commercial varieties with important effects over the genetic structure of the landrace.

Conservation of the genetic resources in the agroecosystem in which they have evolved (*in situ* conservation) is now being more widely considered, as complementary to strategies based on gene banks (*ex situ* conservation), for limiting genetic erosion and so preserving genetic diversity (Altieri and Merrik 1986; Cohen et al. 1991). If it is true that *in situ*, on-farm, conservation has been proposed essentially for wild relatives of cultivated plants, it is also true that when considered for major crops this alternative continues to be highly polemic, unfeasible from a socio-economic perspective (Louette 1999). This does not seem the case of the flint maize landrace 'Nostrano di Storo' because of its economic importance as a market niche which is the base of farmers' interest. As well this is true for some other landraces of different crops in Italy, as suggested by Hammer and Perrino (1995), Hammer et al. (1997).

Moreover, on-farm conservation of landraces is seen as a dynamic system that could help maintaining intact the technical, social, cultural and environmental context in which they have occurred and evolved. In view of this, the whole of morpho-phenological and agronomic traits together with molecular markers could be the basis for the recognition of a protected geographic indication (IGP) mark of the landrace which would further enhance not only its on-farm conservation, but also its market value (Negri et al. 2000).

This is at present the case of the landrace 'Nostrano di Storo'. Would it become difficult to pursue this strategy and would it be advisable to integrate it with

*ex situ* conservation, populations NSt1, NSt3, NSt4, NSt7, NSt10, NSt18, NSt19, NSt20, could be taken as the core of the landrace. The 'Nostrano di Storo' core has been identified on the basis of all statistical analyses performed on ear and morpho-phenological plant traits.

Replanting each variety from small samples of seed, as in the case of 'Nostrano di Storo', theoretically leads to a loss of alleles (Maruyana and Fuerst 1985). For an open pollinated plant as maize, the theoretical work of Crossa (1989) has shown that a seed lot formed from less than 40 ears i) does not permit the conservation of alleles whose frequency in the population is less than 3% (rare alleles), and ii) is conducive to the loss of heterozygosity superior to 1% when there are less than three different alleles per locus. Thus, the use of reduced and variable quantity of seeds could lead to the fluctuation of genetic diversity and of its partition.

As a consequence, if farmers would manage the reproduction of seed lots in isolation from each other, the diversity of some seed lots could probably decrease due to an increase of inbreeding effect, leading to a loss of production potential. So, gene flow is both responsible for the creation, and necessary for the restoration, of the genetic diversity of seed lots taken from populations submitted to genetic drift associated to their reduced size.

The traditional selection carried out annually by farmers and the use of their own seed or of seed acquired by other farmers has several practical implications in order to maintain: i) the distinctive morphological traits of the landrace by singling out the best ideotype-like ears; ii) the peculiar qualitative characteristics of kernels to be used for making maize 'polenta'; and iii) the level of distinctiveness even when the pollen source is not controlled. Traditional seed selection seems, therefore, to be an efficient means of conserving the integrity of the ear characteristics even though gene flow between local and introduced materials can likely occur and lead to fluctuation of genetic diversity that may be detectable as additional variability of the landrace plant traits.

Although data reveal a large amount of diversity with respect to several characters, the overall results support the hypothesis that the selection operated by farmers is effective for maintaining plant phenotype identity of the landrace. As a matter of fact, the 'Nostrano di Storo' distinctive ear characteristics such as number of rows per ear, length, thickness, weight and colour can be maintained over the time owing to

their relatively high heritability. Knowledge of heritability of morphological traits is fundamental for planning conservation programs aimed at preserving the distinctiveness of the landrace, as it influences the effectiveness of selection and preservation of specific traits.

At the plant level, it seems that modern varieties are more a source of phenotypic diversity than a factor inducing genetic erosion. In our case study, introductions had not resulted in a large shift effect on the landrace. As indicated by Brush (1992), genetic erosion may be a phenomenon that is too complex to be captured in the equality 'introduction of varieties = loss of genetic diversity'. The magnitude of seed exchange among farmers and pollen dispersal among plantations makes possible the preservation of diversity of the landrace as a whole and explains the absence of differentiation between landrace populations.

Maize landraces in general, and the landrace 'Nostrano di Storo' in particular, represent not only valuable autochthonous sources of potentially useful traits, but also irreplaceable banks of highly co-adapted genotypes. Information on its distinctive and characteristic traits could be used to identify the core farmer populations suitable to become the basic nucleus for the maintenance of the 'Nostrano di Storo', to plan on-farm conservation programs of this valuable Italian flint maize landrace and to recognize the landrace as a unique germplasm source with specific geographic origin.

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