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Barley germoplasm characterization using agronomic and quality traits

Caracterización del germoplasma de cebada en Uruguay, de acuerdo a variables agronómicas y de calidad de grano

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Abstract

Forty-six malting barley genotypes, including five commercial varieties, were evaluated in two years in order to characterize the genetic variability in breeding use in Uruguay, and its potential to over yield the varieties currently in use. The two analyzed years presented highly contrasting climatic characteristics.

The genotypes were grouped according to their relative performance in the two years for a group of fourteen agronomic and grain quality traits. A cluster analysis was carried out, and the traits responsible for each cluster separation, were studied.

The checks showed the ability to maintain a good grain yield and quality level in stressing climatic conditions. In the high yield year, several introduced genotypes exceeded the best checks, but they failed to maintain that superior performance in stressing climatic conditions. This performance was associated to longer cycles to anthesis and shorter grain-filling periods, which hinder the adaptation to national conditions. The use of introduced germplasm resulted in an inefficient way of reaching high yield potentials with high and stable grain quality.

Keywords: barley, germplasm, cluster analysis

Resumen

Se evaluaron 46 genotipos de cebada maltera de diversos orígenes, incluyendo 5 testigos comerciales de amplia utilización en el país, en dos años para caracterizar la variabilidad genética en uso en mejoramiento en el Uruguay y su potencial para superar los rendimientos actuales. Los dos años analizados fueron altamente contrastantes en términos climáticos.

Los genotipos fueron agrupados de acuerdo a su comportamiento relativo en los dos años para un conjunto de 14 variables agronómicas y de calidad física de grano, y analizados por análisis de grupos. Se estudiaron las variables que explicaron en cada caso la separación de grupos.

Los testigos mostraron la capacidad de mantener un buen rendimiento y calidad de grano en condiciones climáticas limitantes. En el año de alta producción varios genotipos introducidos superaron a los mejores testigos, pero ninguno mantuvo ese comportamiento superior en condiciones ambientales limitantes. Este comportamiento se asoció a ciclos a

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espigazón más largos y períodos de llenado de grano más cortos, que dificultan la adaptación a las condiciones nacionales. El uso de germoplasma introducido resultó un camino ineficiente para el logro de altos potenciales de rendimiento que se asocien a niveles altos y estables en calidad de grano.

Palabras clave: cebada, germoplasma, análisis de grupos

Introduction

The result of genetic improvement in any crop depends on the genetic variability available. In brewing barley, this is particularly important as it is a crop with relatively less genetic variability worldwide and with strong demands from the malting industry. Wych and Rasmusson (1983) referring to the latter factor, point out that it has acted as a severe limitation in terms of new germplasm use.

In Uruguay, Luizzi and Castro (1992) analyzed the genealogies of the authorized cultivars to market in the 1990-91 harvest, concluding that the genetic base used in national production was particularly narrow. This situation was similar to other production regions worldwide (Peeters, 1988).

Based on the above, the proper characterization of the available genetic base is a priority task for genetic improvement. For this, it is important to estimate the variability available in characteristics of agronomic or industrial interest, simultaneously contributing to the definition of new objective characteristics. Both tasks are a fundamental objective of the brewing barley research program of the Agronomy College since 1991.

Hoffman, *et al.* (1995) grouped the varieties sown in Uruguay into four groups according to their initial growth. The most recently released varieties showed lower initial growth rates with a very marked post-tillering increase. Castro *et al.* (1995) grouped those same materials according to grain yield, yield components, and cycle. They found that the group with the greatest yield potential (which includes the most recently released varieties) was characterized by achieving the best yields based on spike number, high grain weights and intermediate spike size, although higher than the previous materials. This yield was associated with a longer grain-filling period, with a reduction of the cycles to anthesis. Authors define this materials group as the main objective for national genetic improvement. Its main characteristics, in particular its slow initial growth and rapid pre-anthesis growth, and its long grain filling associated with shorter booting cycles, emerge as criteria of interest for genetic material selection.

Another objective of the brewing barley research program of the Agronomy College is to overcome limitations that affect the yield potential through genetic improvement (Castro *et al.,* 1994). Identifying groups of materials that increase potential yield under various conditions is a highly desirable outcome.

This study aimed to characterize the performance of the genetic base available in years, with contrasting yield expression conditions. The material introduced by the Agronomy College's improvement program and included in advanced stages of internal evaluation was used. Although this program is only one of the five existing at a national level[3], it represents in acceptable form the average availability of germplasm in the remaining ones.

MATERIAL AND METHODS

The job consisted of the data analysis from evaluation trials of the Experimental Station "Dr. Mario A. Cassinoni" (EE-MAC) improvement program, of the Agronomy College, for two years: 1992 and 1993. Average values per material were used and in those included in more than one trial, they were averaged. There were 46 genotypes analyzed in total, of various origins (See Table 1).

Table 1. Origin of materials included in the analysis.

Origin	Number
Commercial	**Clipper, MN 599, Bowman Stirling, Est. Quebracho**
Brazil	16
Argentina	1
USA	6
Canada	1
South Africa	5
Europe	10
Unknown	2

[3] The remaining programs belong to INIA La Estanzuela, Maltería Oriental, CYMPAY S.A. and Maltería Uruguay.

The trials were seeded in the EEMAC experimental field, on San Manuel formation soils (eutric brunosols).'The planting dates were 9-10 July 1993 and 15 July 1994. The plots were of 4.5 m^2 with three repetitions.

The variables analyzed were:

-Yield in grain (YIELD)(Kg/ha)

-Total dry matter (TDM) (Kg/ha)

-Harvest index (HI)

-Thousand Grain Weight (TGW) (grams)

-Grains per m2 (GRM2)

-Spikes per m2 (SP)

-% of grains with diameter > 2.8mm (% from 1_a) (P1)

-% of grains of diameter > 2.5mm (% from 1_a+2_a) (P12)

-Tillers per m2 45 days post-emergence (TIL)

-Percentage of plants with T0 (PTO)

-Tillering rate (TRAT)

-Booting cycle (in post-emergence days) (CYC)

-Tillers fertility (FERT)

-Grains per spike (GRSP)

In 1993, a cycle to physiological maturity and duration of grain filling were also measured (both in days).

Comparisons of genotype pairs were made to generate a similarity matrix based on the Average Taxonomic Distance similarity coefficient, which made it possible to build groups using the agglomerative UPGMA method of the NTSYS program.

The selection of the variables to be included in the analysis was first carried out by studying the correlation matrix and the main components, using the PRINCOMP procedure of the SAS program. Those variables highly correlated and with minor vectors were eliminated, until reaching an explanation of 85% of the total variation with the first four components. The finally included variables were: YIELD, TDM, HI, TGW, P1, TIL, FERT and SP.

For these analyses, each observation for each variety was considered as an annual average percentage for that variable, and the difference between the 1993 and 1992 values was calculated. The calculation was carried out as follows:

genotype x

variable y

ACxy: joint data of genotype x for variable y

92xy: 1992 data of genotype x for variable y

93xy: 1993 data of genotype x for variable y

92Y: 1992 mean of variable y

93Y: 1993 mean of variable y

ACxy= 93xy*100/93Y - 92xy*100/92Y

RESULTS AND DISCUSSION

Both years considered in the analysis presented contrasting characteristics in productive terms. Table 2 summarizes some climatic variables for both years during the crop cycle, while Table 3 presents the average values of the variables studied for both years. Performance in 1993 was lower than in 1992, which is probably explained by a warmer and wetter year, particularly during the grain-filling stages (table 2). Therefore, the performance analysis of the materials in both years determined differences between genotypes in terms of expression conditions of high potentials in one year and deficits in another.

Table 2. Summary of climatic characteristics for both years, during the crop cycle.

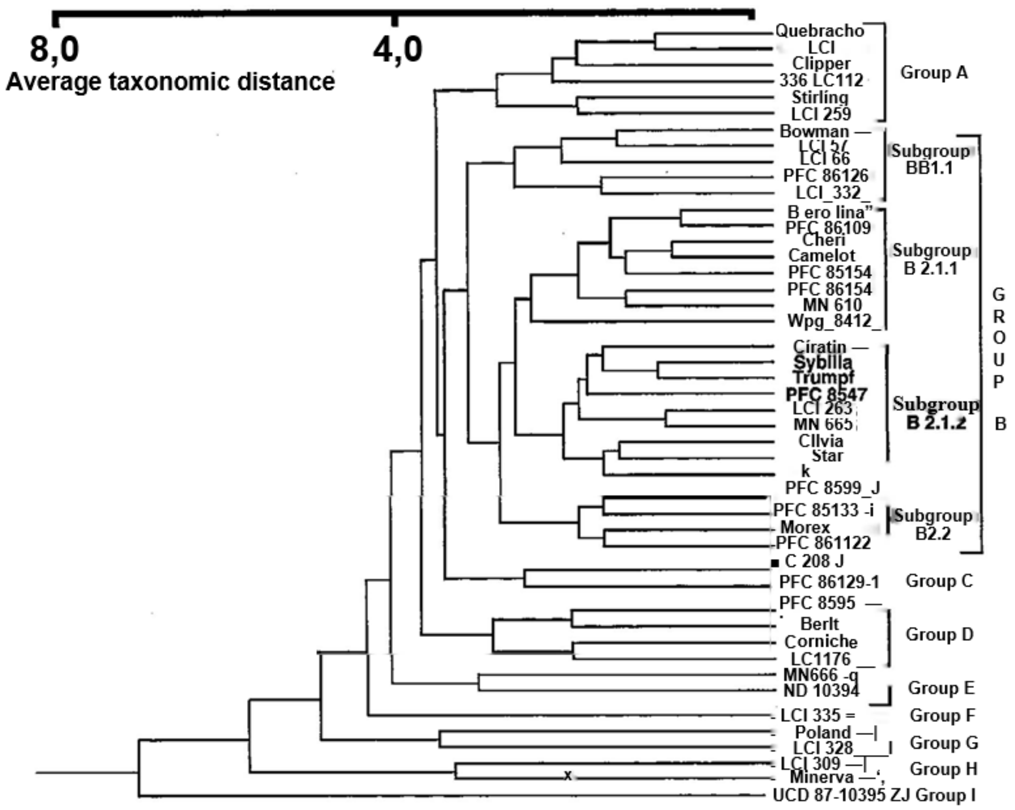
	Mean temperature (°C)	Cumulative precipitation (mm.)	Number of frosts	Duration (Days)
	Year 1992			
Booting emergence	13.52	176.5	21	80
Booting maturity	18.10	95.6	1	34
	Year 1993			
Booting emergence	13.49	63.1	19	78
Booting maturity	19.69	267.5	0	34

Table 3. Annual means for the different variables studied.

Year	YIELD	TDM	HI	PMG	GRM2	GRSP	SP	CYC
1992	5287	11809	0.399	47.5	11198	18.2	630	76.8
1993	3628	8714	0.366	41.5	8831	17.4	511	81.2

Year	P1	P12	TIL	T0	TRAT	FERT
1992	62.6	91.3	973	11.3	6.02	0.657
1993	48.1	87.0	941	24.2	5.61	0.556

Figure 1. Grouping dendrogram of the 46 materials



Those material groups that kept a prominent performance in both conditions are those of greatest interest for genetic improvement.

Figure 1 shows the grouping dendrogram of the genotypes analyzed. Group separation was done considering approximately 50% of the maximum distance between genotypes, which allowed a total of 9 groups to be visualized. Figure 2 shows a simplified diagram of this dendrogram, indicating in each group separation, the responsible variable, according to the SAS stepwise analysis. In group B case, considering that it represents 57% of the analyzed materials, it was subdivided until reaching a higher level of homogeneity within groups.

Table 4 presents the average values by groups and subgroups for all measured variables, whether or not included in the group analysis. A value of 0 implies that for that variable the group followed the general evolution from one year to the next.

A negative value indicates a fall above the average and a positive value indicates a fall below or even the maintenance of absolute values.

A series of small groups of materials (composed of one or two genotypes) are identified that underwent significant variations in their performance from year to year, generally negative. Groups E to I (8 genotypes in 46) represent 46% of the total variation analyzed, which highlights their little similarity with the rest of the genotypes. In general, variations in their performance in problematic years make it difficult to use them directly in production. The contribution of these materials is associated with their use in crossings, given that they have some interesting characteristics.

The rest of the groups concentrate most of the genotypes studied, and all of the commercial checks included in the trial. Within these genotypes, group D is separated from the set by its YIELD decrease and its TIL increase. In group D case, although it is not responsible for the separation, there is also a significant drop in HF.

Figure 2. Simplified dendrogram of the 46 materials grouping, indicating the variables responsible for the separation between groups.

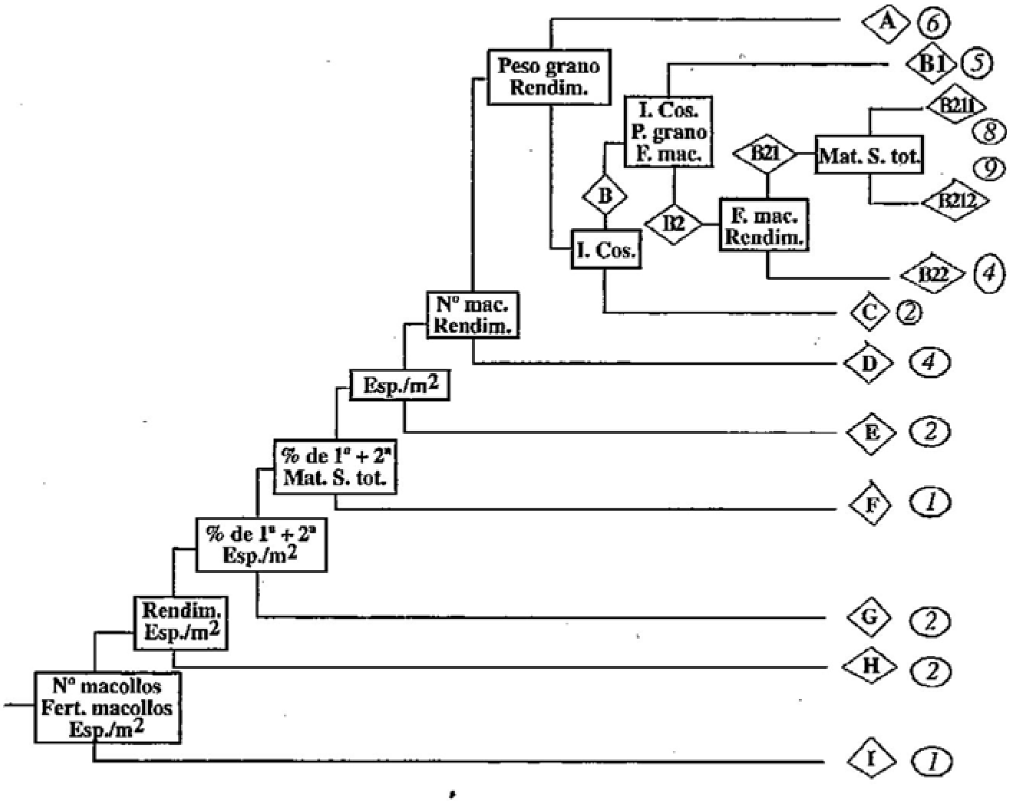


Table 4. Summary of the group means of the analysis set

Group	YIELD	TDM	CI	TGW	SP	GRSP	P1	P12	FERT	TIL
A	-4.0	-11.9	4.5	11.3	3.2	-10.7	23.5	5.9	15.5	-9.9
B	5.5	‘ 3.4	2.4	-1.4	-2.1	2.6	-0.8	0.1	-1.5	-2.5
C	-4.9	10.5	-14.1	-7.0	4.2	12.8	-12.8	-4.8	22.1	-18.2
D	-12.3	-5.0	-8.3	-1.0	23.9	10.5	-5.1	0.3	-10.5	33.8
E	2.7	-2.2	6.6	8.8	66.2	3.5	-4.6	-2.4	20.1	47.9
F	18.7	21.0	1.1	13.1	0.5	9.1	30.1	15.0	8.3	-7.7
G	-15.3'	-13.5	-2.0	-19.6	37.6	-56.1	-35.9	-13.0	9.8	30.5
H	-20.2	-6.3	-12.5	14.7	-76.0	-15.2	-2.8	1.8	-13.9	-63.0
I	-21.8	-10.5	-11.8	-20.3	-99.0	43.1	5.6	-11.5	-79.6	-4.2

Group	YIELD	TDM	CI	TGW	SP	GRSP	P1	P12	FERT	TIL
B1	10.8	2.1	8.4	6.2	2.3	-3.3	21.6	4.4	13.3	-12.8
B2	3.9	3.8	0.7	-3.6	-3.3	4.2	-7.1	-1.2	-5.7	0.4
B2	14.6	5.5	-0.6	-3.4	-0.5	1.2	-8.3	-1.7	0.8	-2.8
B2	21.2	-3.5	6.2	-4.6	-15.1	17.1	-2.2	0.9	-33.2	14.0
B211	-2.4	-1.7	-0.6	-5.0	-2.6	6.5	-13.2	-3.1	7.1	-12.5
B212	10.8	11.8	-0.6	-1.9	1.3	-3.5	-3.9	0.3	-4.9	5.8

This group is made up of a check cultivar (MN 599), which lowered its relative performance the most, in both years.

The following division differentiated group A, separated by grain weight (which increases in relative terms) and yield (which decreases). P1, P12 and HI also increase (although without separation responsibility). This group is composed of 3 of the 5 commercial cultivars included in the analysis, all three of the same origin (Australia). This group can represent the current production situation. It shows a drop in yields but maintains a large proportion of the weight and grain classification.

Groups B and C are separated by the evolution of the CI. Within group B there are some subdivisions by HI, TGW and FERT (subgroups B1 and B2), YIELD (subgroups B21 and B22) and TDM(subgroups B211 and B212). Among the groups formed, B1 stands out for improving the relative performance in yield, harvest index, weight and grain classification.

Group F stands out for its relative performance, however, the fact that it is a single genotype diminishes its importance. In addition, it was favored by a deficit performance in 1992 which attenuated the differences with 1993. As for the origin, it is a South African material related to several genotypes of group A.

The objective of an improvement program is to obtain genotypes that exceed the productive potential of the best cultivars in use at the production level, keeping the grain quality within the marketing standards. In years with severe limitations, these genotypes should maintain at least equivalent performance to the best checks. These checks and similar genotypes are represented by groups A and B1.

Their main characteristic is to present superior relative performance in bad years, which means that they maintain their average absolute values compared to the rest of the genotypes that present significant falls. Particularly in variables sensitive to environmental conditions and of great importance in terms of marketing such as weight and grain classification.

If that is how best commercial checks behave, and it is a desirable performance for new varieties, the materials that are grouped with them could meet the requirements mentioned for new cultivars. However, very few outperform (with similar performance) the average of the best checks. Table 5 shows the performance of the best check of each year and the evaluated materials that exceed them. In a year that allowed the expression of potentials (1992), there is a significant number of cultivars that surpass the best check both in yield and in grain classification. Under limiting conditions (1993), however, no material surpasses the best checks. On the other hand, genotypes that had shown an equivalent performance between years to that of the best commercial cultivars, still do not exceed them in the best condition year. This implies that it is a set of genotypes that present a trend between years similar to the best checks (which is a desirable objective) but with absolute values never higher and generally below these. This implies that they do not constitute a way to exceed the current potential. It is likely that within this set, progress can be achieved in specific aspects or in terms of malting quality (Castro and Emst, 1995), but a clear improvement in terms of yield potential is not expected.

Table 5. Best checks performance and number of materials that exceed them each year.

Year	Best check	YIELD	HI	P12
1992	Quebracho (Group A)	5625	0.433	95.3
	No. of superior genotypes Total	10	5	7
	Groups Ay B1	0	0	2
1993	Bowman (Group B1)	4149	0.381	95.0
	No. of superior genotypes Total	0	11	1*
	Groups Ay B1	0	5	1*

* Estanzuela Quebracho

Table 6. Performance in both years of the materials that surpassed the best check in 1992.

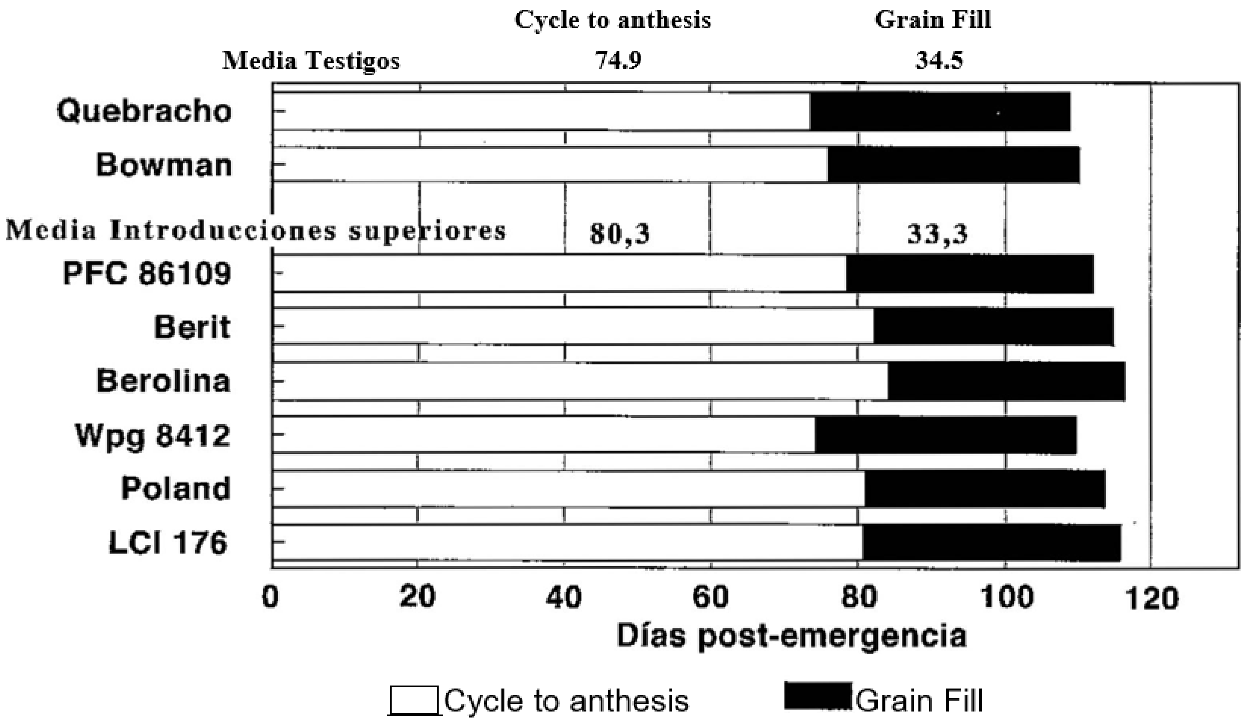
Genotype	Yield (kg/ha)		I, Harvest		Percentage of la+2a	
	1992	1993	1992	1993	1992	1993
PFC 86109	5791	3829	0.401	0.349	95.3	87.7
MN 610	5700	3823	0.424	0.380	91.1	88.8
Berit	5959	3229	0.442	0.377	88.9	86.8
Sybilla	5650	4076	0.436	0.392	92.0	84.3
Corniche	5638	3723	0.443	0.362	93.0	88.7
Berolina	5979	3957	0.422	0.375	89.3	82.9
Wpg 8412	5766	3861	0.377	0.350	94.5	83.8
Poland	6197	3279	0.412	0.348	89.3	72.3
LCI176	5848	3528	0.367	0.292	89.0	84.6
UCD 8710399	5831	3189	0.449	0.371	58.1	45.4
Quebracho	5625	3887	0.433	0.426	95.3	95.0
Bowman	5388	4149	0.407	0.381	95.5	97.1

As for the materials that surpassed the best check in 1992, Table 6 summarizes their performance, in both years, and what has already been observed in terms of trends between years, can be confirmed. Particularly noteworthy is the decrease in its grain classification performance, where none exceeded the P12 which constitutes the minimum commercial level (90%). Checks practically do not vary their classification from year to year, which ensures that beyond the limit of environmental conditions, the harvest will always be within the marketing margins.

The other materials, on the other hand, present an important risk factor in their grain classification, in case of being released for production. In years with optimal conditions, they are at the marketing limit, while in unfavorable conditions they may fall out of range.

Some of these risks are likely associated with relatively longer cycles to anthesis that delay the grain-filling time to warmer and, therefore, unfavorable conditions. Figure 3 shows the highest yielding genotypes cycles in 1993 (the only year where grain-filling duration was measured).

Figure 3. Cycle composition in 1993 of the materials with the best yield in 1992.



FINAL CONSIDERATIONS

The real chances of exceeding barley yield potential through the use of introduced germplasm are, depending on the information presented, scarce. Particularly with regard to obtaining high yields in grains of good physical quality (grain classification) on a sustained basis. This does not imply that it is impossible for the appearance of introduced materials that stand out from the rest and allow their use at the productive level, but there are low probabilities of this occurring. In general, high potential material introduced has long cycles that make it difficult to use in normal seeding times for our country. Advancing the seeding of these genotypes can be a solution, although the information obtained so far in early seeding does not indicate a clear superiority over commercial checks (Castro M., 1995).

The introduced material's contribution is clearer in aspects related to the malting quality. The years of genetic improvement with this objective in the world's main producing areas (USA, Central Europe, Australia) are reflected in genotypes with very good industrial quality. Castro and Ernst (1995) determined an averagely high maltability of the material introduced from these regions in use in the EEMAC program compared to commercial checks. It is, therefore, possible to achieve, with relative ease, materials with acceptable malt quality from introductions. That further explains the industry's strong interest in the use of these genotypes, which have the additional advantage of being, in many cases, known internationally as malt quality materials. The exporting advantages of these genotypes are obvious. However, such good malting performance does not mean good agronomic adaptation.

The possibilities of exceeding the yield potential and the achievement of stable and outstanding performances in terms of physical and chemical quality, therefore seem associated with national genetic improvement. The combination of the introduced material's contributions through crossings is the most probable way to obtain these results. That surely means working with longer cycles versus the direct use of introductions, but with better chances of success.

The agreement of the National Board of Barley Entities to allocate a significant percentage of resources to the genetic improvement is a reflection that the national industry agrees with this analysis.

Acknowledgements

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