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in

Molina-Cano J.L. (ed.), Brufau J. (ed.).
New trends in barley quality for malting and feeding

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 20

1991
pages 35-44

Breeding barley for malting and feeding quality

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SUMMARY - In an attempt to illustrate the present day situation of barley breeding for grain quality following the classical procedures, a critical review is made of the methods used nowadays both of breeding and analytical evaluation of the quality. As an example of the results obtained most recently, a description is made of the high lysine varieties, free from proanthocyanidins, rapid germination mutants and finally, an analysis is made of the production of quality barley in the EEC. It is concluded that, to a great extent, the quality barleys have a high percentage of common characteristics, especially those of a structural nature, whether their final destination be feeding or malting.

RESUME - "Amélioration génétique de l'orge pour la qualité du malt et des concentrés pour bétail". Afin d'illustrer la situation actuelle de la sélection de l'orge pour la qualité du grain selon les méthodes classiques, une étude critique est présentée concernant les procédures utilisées aussi bien pour la sélection que pour l'évalutaion analytique de la qualité. Comme exemple des résultats les plus récents, les variétès à haute teneur en lysine, celles ne contenant pas de proanthocyanidines, et des mutants à germination rapide sont décrits. Finalement la production d'orge de qualité au sein de la CEE est analysée. La conclusion est que, dans une grande mesure, les orges de qualité ont un grand nombre de caractéristiques communes, particulièrement celles qui concernet leur structure, que leur destination finale soit l'alimentation du bétail ou la brasserie.

Introduction

A global vision is offered to state the present situation of the breeding methods for barley quality, including both selection procedures and, in greater detail, micromalting and analysis methods which can be used to aid breeding programmes.

As a sample of the results obtained recently using some of these methods, the selection of genotypes with a high lysine content (thus increasing the quality of barley for animal feeding), lacking in proanthocyanidins and with a faster germination rate (increasing in both cases the malt quality) will be presented so as to concentrate finally on the study of the evolution of quality barley in the EEC in general and particularly in Spain, in both cases as a consequence of the introduction of the improved varieties of higher quality.

Breeding methods

For a better understanding of the results to be presented subsequently, a brief description will be made of three of the methods used, that can now be considered classical in barley breeding for the increase in seed quality.

For a more complete revision, consult Molina-Cano (1990).

Crossing followed by genealogical selection

This is probably the method most frequently used for quality improvement and amongst the countless variants included under the names "genealogical" or "pedigree", that used by Molina-Cano (1990) will be described.

Crossings in the field can be carried out in our Mediterranean climates during the spring, with very good results in the percentage of seeds obtained, although if this is carried out during the winter in the greenhouse, the programme can be brought forward by one year in spite of the lower percentage of success in the hybridizations.

The handling of the segregating generations can be performed as follows:

The F_1 is cultivated in bulk and purified against possible self fertilization. The F_2 is sown by pneumatic drilling or by row seeding with a low dosage of seed.

In F_2, plants or ears are selected bearing in mind, principally, earliness, height and disease resistance as well as the type of plant and ear. The hierarchization of the crossings according to their apparent value, to later take at random a number of plants or ears from each in accordance with this classification, also gives very good results especially when many different combinations are handled, as ought to be the case. A first test of malting quality can be carried out using seed from the F_2 generation, taking a bulk sample from each population, in order to acquire an idea of the relative value of each combination.

From F_3 to F_5 ears or plants to row selections are still being carried out, giving increasing importance to, however, the apparent production ability of the rows and their phenotypical uniformity still insisting on the disease resistance and length of the vegetative cycle.

The purification of the material starts at F_5 at the same time as the evaluation of the production ability and ecological adaptation, which begins at a single site in F_6 and is carried out with the aid of multisite experiments in F_9. Furthermore, the systematic evaluation of the global malting quality is intensified in F_5 although if some of the characters that we are going to select are of simple inheritance such as content of beta-glucans, proanthocyanidins or presence of the *lys 3a* gene for a high lysine content, then screening can begin in F_3.

Finally, in F_{10} the new varieties can be sent to the official trials that legally precede their possible commercialization.

Induced mutagenesis

Just as the genealogical method is one of general use for the improvement of barley, the use of mutagenesis can only be recommended in concrete cases, such as, for example, when one wishes to correct a defect of a variety which is otherwise acceptable and well adapted.

The most frequently used mutagen is the Sodium Azide (N_3 Na) which, being of simple use, has a very high effectivity.

In Fig. 1 one can observe, as an example, the programme the author followed at La Cruz del Campo in order to correct particular defects in an adapted variety, and whose results will be commented on at a later stage.

Mutagenesis is quicker than crossing followed by genealogical selection, as shown in the example of the previously mentioned programme that began in December 1983 and where mutants were presented at official trials in July 1989, six years later.

YEAR	GENERATION	BREEDING OPERATIONS
1983-84	M_1	M_1 growing and mutants selection
1985	M_2	Agronomic selection
1986	M_3	Agronomic selection and germination test
1987	M_4	Yield trial. Germination test.
1988	M_5	Multisite yield testing. Micromalting
1989	M_6	Submission of 3 mutants to Official Trials

Fig. 1. Mutation breeding programme with 'Troubadour' barley.

Diploidization of haploids through crossing with *Hordeum bulbosum*

This is a method developed since the finding of Kasha and Kao (1970) in which, on pollinating flowers of cultivated barley with pollen of the wild diploid species *Hordeum bulbosum* L., generally the elimination of the 7 chromosomes coming from the latter is produced in the zygotes, not forming endosperm, but embryo (Fig. 2).

If these embryos are cultivated in a sterile nutritive medium and if the haploid seedlings (n = 7 chromosomes) are treated with colchicine, totally homocygotic diploids (2n = 14) will be obtained.

In its application to barley breeding, flowers from the F_1, F_2, or F_3 plants of the selected crosses are fertilized with pollen from *H. bulbosum* and in this way the diploids obtained finally will be different inbred lines that will make up a random sample of those which probably will be obtained in such crosses and that will directly enter the field evaluation stage.

In 1988, IRTA began a breeding programme of malting barley such as that described (Fig. 3) in collaboration with Svalöf AB of Sweden.

This autumn 216 varieties of the first cycle, coming from a year of selection in the field, will be sown in order to carry out the first evaluation of grain yield and malting fitness.

Quality evaluation methods

As a general introduction to this section, it is necessary to point out that the quality evaluation methods which are fit to apply in barley breeding, must be, in general, specially developed for this purpose since the great number of samples to be analysed, their small size

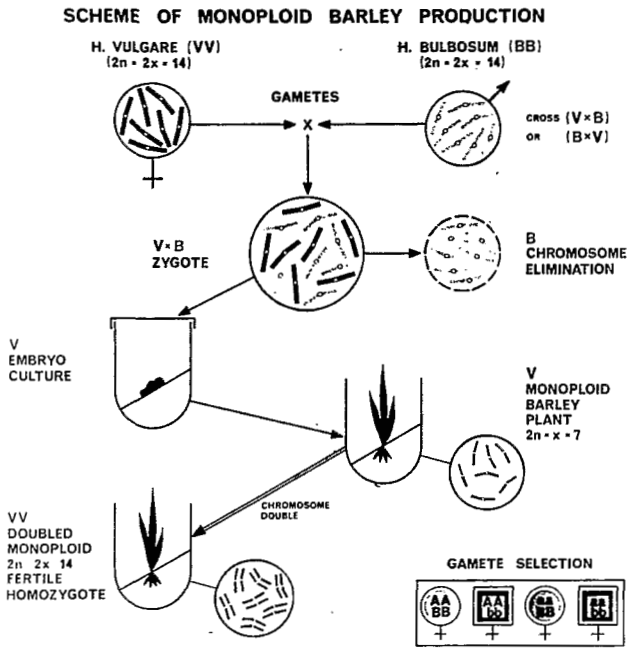


Fig. 2. Haploidization with *Hordeum bulbosum* (from Jensen, 1976).

YEAR	GENERATION	
1988	F_1	Crossing with *H. bulbosum* and chromosomic duplication.
1989	Inbred lines	Obtention of seed of inbred lines
1990	Inbred lines	Selection of lines in the field. Micromalting.
1991	Inbred lines	First year trials (1 site). Micromalting.
1992	Inbred lines	Second year trials (4 sites). Micromalting.
1993	Inbred lines	Third year trials (12 sites). Micromalting. Decision on varieties to present to Official Trials.
1994	Inbred lines	Official Trials.

Fig. 3. Haploidization with *Hordeum bulbosum* (IRTA programme).

and the short time available in which to obtain results (Ellis, 1986; Molina-Cano, 1986) greatly condition its design which must provide the lowest possible functioning costs.

It can be affirmed (Ellis, 1989) that as yet neither sufficiently rapid methods have been achieved, since malting is essential, nor methods which are sufficiently economical, since producing and analysing a sample of malt for this purpose could cost an average of 150 US dollars.

Likewise, the greater variability of nitrogen content of the grain derived from ear progenies than that of the grain derived from plot progenies makes the qualitative determinations during the visual selection stage rather unreliable.

Finally, the disturbing effects of the genotype x environment interaction and the high level of heterozygosis in the first generations complicate the situation still further.

Bearing in mind the aforementioned, the next step is to analyse the evolution of the qualitative evaluation methods in barley, emphasizing, fundamentally, in the malting quality, since Anna Pérez-Vendrell will discuss the evaluation methods of feeding quality in a later chapter.

Despite saying that malting is indispensable for a reliable evaluation of the malting quality, one must first discuss the predictive methods without malting the grain.

These methods began to be developed in the Grain Research Laboratory of Canada during the 30's and 40's by the Meredith and Bendelow team and consisted of the determination of the potential extract and the amilolytic activity in previously digested barley flour, in the first case with a solution of malt enzymes and in the second with papain. They were not very successful and Dr. Bendelow confirmed (1980, pers. comm.) that there was no reliable method that did not include a previous malting.

Amongst the most fashionable evaluation methods is that of the determination of the milling energy, developed by Allison *et al.* (1979) in what was then the Scottish Plant Breeding Station. It is based on the principle that barley of a high malting quality, and also those which hold a high nutritive value, have a more floury endosperm, as Dr. Palmer has also stated in a previous chapter, making, therefore, the energy consumed in milling them inferior. Likewise, those of poor quality give very high milling energy values. However, this method is less discriminatory for barleys of intermediate quality (Taylor and Swanston, 1987). A good correlation does not exist, therefore, between milling energy in barley and malt extract. It is, nevertheless, important to point out that the milling energy of malt and the extract are narrowly correlated (Swanston and Taylor, 1988). Its use has been proposed as an even more preliminary tool, in order to evaluate the hardness of developing and previously dried grain even six weeks before harvesting under Scottish conditions (Swanston and Cowe, 1989).

Although the viscosity of an acid extract of barley flour is quite closely correlated to the beta-glucan content (Aastrup, 1979), nowadays the breakthrough achieved in

the determination methods of total beta-glucans (Pérez-Vendrell and Francesch, 1991) outdates this procedure.

When in a crossing between two genotypes with high and low diastatic power, these also differ in the zymotype of beta- amylase, the subsequent selection by the isoenzymatic type of the parent with a high diastatic power serves, in turn, to identify segregating lines which are carriers of this favourable character (Swanston, 1980).

The sedimentation test of Zeleny (Reeves *et al.*, 1979) when applied to barley in its initial form is imprecise due to the influence of the grain moisture content (Glennie-Holmes, 1990). It does not seem therefore recommendable even for a preliminary screening.

The resistance to pearling (Glennie-Holmes, 1990) would be another measure of the hardness of the barley grain, which is not applicable in breeding programmes but is applicable in commercial malthouses in order to select the best samples of varieties of recognized quality.

The first micromalting devices to be developed, for example that of Whitmore and Sparrow (1957) in the Plant Breeding Institute of Cambridge, had capacity for an acceptable number of very small samples, although the problems were due to their being of manual handling, making their function expensive and cumbersome besides having a limited level of precision.

Later prototypes of completely automatized and even computer controlled micromalters have been developed with capacity for a number of samples greater than 100 and even up to 300 according to the size of the individual sample, that in some types can be modified at will (Atkinson and Bendelow, 1976; Gothard *et al.*, 1980; Takeda *et al.*, 1981; Glennie-Holmes *et al.*, 1990; and some others such as those of Carlsberg and Abed of Denmark and the Joe White and Phoenix of Australia). The latest models developed obtain high levels of efficacy thus improving precision and profitability.

One must remember, however, that the most expensive and cumbersome aspect of the evaluation of quality in the breeding lines, is encountered not in the production of micromalts, but in the subsequent analysis of these. As small sized samples are analysed (up to 20 or 30 g), the official analytic methods of the EBC are not, in general, applicable in their original form, but must be adapted to such small quantities of samples, diminishing both the precision and accuracy, the former being more worrying since the validity of the results is relative and never absolute.

Consequently, it is very important to know the margin of error of a particular micromalting apparatus, in function of the analysis to be carried out subsequently.

Even though the evaluation of a commercial malt according to the EBC procedures can be based on a very high number of parameters, that of a breeding programme sample is based on a much lesser number, such as the five characters included in the Q quality index of the EBC (Molina-Cano, 1986) and in an even lesser number as in the Carlsberg method (Ingversen *et al.*, 1989) which uses only the alfa-amylase activity and beta-glucan content of the malt with very good results to classify samples of a breeding programme.

Within the predictive methods for previous screening in malt, the use of the previously mentioned milling energy must be considered.

Results

Varieties with a high lysine content

The protein balance of barley is so unbalanced that when it is used as an exclusive component of the diets of monogastric animals the low lysine content becomes apparent, acting as a limiting nutritive factor. Research to improve this situation was first successful in Svalöf (Sweden) in 1967, with the discovery of 'Hiproly', the first variety with a high lysine content (Munck *et al.*, 1970).

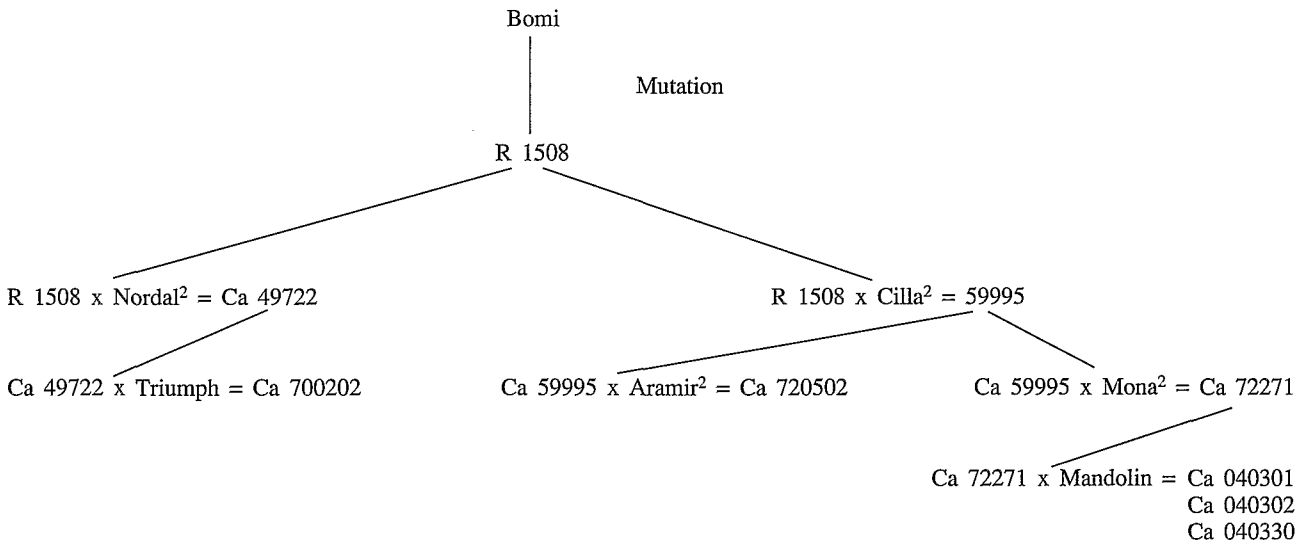
The subsequent isolation of the 'Riso 1508' mutant in 1971 (Doll et al,. 1974), performed in Denmark, brought about the evidence of its superiority as a parent in breeding programmes for a high lysine content, due to the fact that the efficient expression of the 'Hiproly' gene (*lys 1*, located at chromosome 7) needs a high content of the total grain protein (Bang-Olsen *et al.*, 1987).

However, the *lys 3a* gene carried by 'Riso 1508', and also located at chromosome 7, produced unfavourable pleiotropic effects, such as wrinkled grain with a low starch content and consequently a low production per hectare.

Munck and his team, began an ambitious breeding programme in Carlsberg (Denmark) at the beginning of the 70's in order to incorporate the *lys 3a* gene to high yielding genotypes (Fig. 4).

The fact that the *lys 3a* gene produces in the carrier grains much larger embryos than the normal ones, appreciated without having to remove them from the paleae has been of great help in the breeding programmes. In fact, the massive screenings of material that could be out after verifying this fact, abandoning the expensive, slow and tedious chemical methods, brought about the improvement of grain architecture and yield (Fig. 5).

Nevertheless, the grain production of these genotypes is found to be even lower than that of the advanced quality cultivars such as 'Triumph' (Fig. 6). This occurs



Zita = 203/7748 x Vada
Mandolin = Lola x 65144
Triumph = Diamant x 1402964/6

Fig. 4. Pedigree of the lines with a high lysine content from Carlsberg (Bang-Olsen *et al.*, 1987).

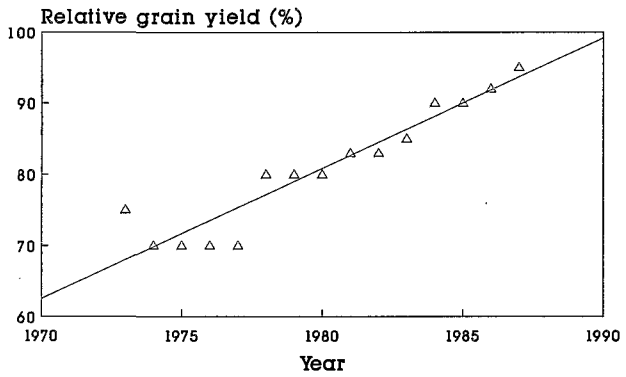


Fig. 5. Yield of barley genotypes with high lysine content (Munck and Bang-Olsen, 1990, pers. comm.).

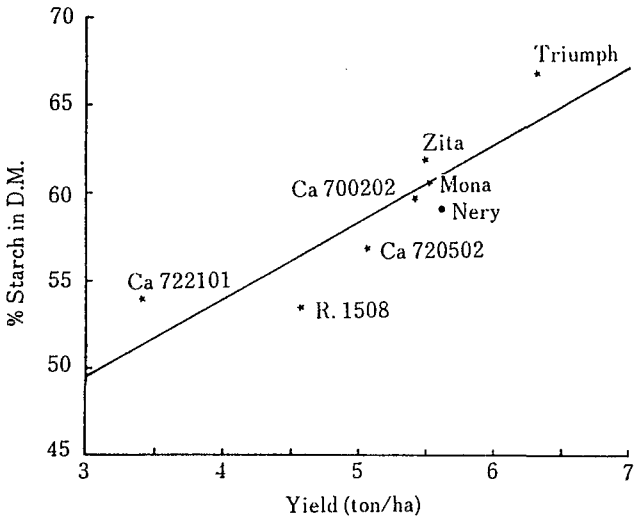


Fig. 6. Correlation between grain yield and starch content in standard and high lysine genotypes (Bang-Olsen *et al.*, 1987).

since the grains of high lysine genotypes have a lesser starch content than the normal cultivars and this factor is strongly correlated to the yield per hectare.

Another problem as yet unresolved is the scarce stability of the yields over sites and years, that are unfortunately already found to be 10% below the most productive non malting cultivars. The perspectives for the future are optimistic if a great cooperative breeding programme can be launched between several European countries, in which a reasonable probability of success could be achieved counting on the increase in size of the global programme and the effect of the different environments which is mostly unknown. The efforts in this sense have been, until now, fruitless.

Cultivars free from proanthocyanidins

Chill haze formation in beer during storage, is due to the precipitation of the soluble protein on reacting with the polyphenols, of which proanthocyanidins are the main group. 70- 80% of the proanthocyanidins of beer come from barley and the remainder from hops (Andersen, 1989).

Nowadays, the breweries manage to increase the coloidal stability using certain additives. An elegant, economical way to solve this problem, besides being more acceptable to the consumer, would be to use varieties of barley free of proanthocyanidins, which has been made possible since Von Wettstein *et al.* (1977) discovered the first mutant of this type.

Since then, Jorgen Larsen and his team in Carlsberg (Denmark) have induced thousands of mutations in interesting varieties. Afterwards seven different monofactorial recessive loci were identified, e.g. *ant* 13, 17, 18, 19, 21, 22 and 25 (Andersen, 1989).

The transference of these genes by backcrossing to many different genetic backgrounds during these years has shown hopeful although not definitive results (Larsen *et al.*, 1987).

It has been proved that the mutants in the *ant* 18 and 19 loci have shown a deficient grain development and as we have no conclusive evidence on the *ant* 21, 22 and 25 genes all the work has, therefore, been based on transference of *ant* 13 and *ant* 17 to other genetic backgrounds.

Unfortunately, the *ant* 17 gene hinders enzymatic development during malting in the aleurone layers of the carrier lines, diminishing its interest in spite of the fact that the first variety free of proanthocyanidins registered in a commercial list ('Galant') is a mutant for this locus obtained from the variety 'Triumph'.

Therefore *ant* 13 is the source of the majority of the lines studied up to the present date. As can be observed in Tables 1 and 2, these genotypes combine an acceptable yield with quite a good malting quality, although perhaps the Kolbach indexes are too high. This can be explained because in the standard lines some of the malt proteins are precipitated by the existing proanthocyanidins and thus eliminated during the filtration of the wort; this, naturally, does not occur in the lines without proanthocynadins, therefore the fraction of protein which remains soluble is greater.

Table 1. Yield and grain features in proanthocyanidin-free lines in fungicide treated trial (Andersen, 1989).

Genotype	Relative grain yield (%)	Thousand kernel weight (g)	Grading (%>2.5 mm)
Grit	100	48	96
ant 13-350 x Grit	104	56	97
ant 13-350 x Grit	100	56	95
ant 13-350 x Apex	87	56	97
ant 13-278 x ant 13-152	99	55	98
ant 13-278 x ant 13-152	92	54	97
ant 13-264 x (Evasum x Aramir)	96	56	96

The present situation (Larsen, 1990 pers. comm.) is such that the spring genotypes free from proanthocyanidins have quite a good quality although their yield still cannot compete with that of the standard varieties, whereas the opposite occurs with the winter genotypes (Table 3). The perspectives for the future are hopeful whilst the relative grain yield can continue to increase and some of the problems of quality of the *ant* 13 gene can be resolved. Other mutants would have to be induced and studied.

Finally, it must be said that a spring variety with good yield and quality, will be submitted to official trials in the United Kingdom in 1991 (Larsen, 1990, pers. comm.)

Table 2. Yield, grain features and malting quality of proanthocyanidin-free lines carrying the ant-13 gene in fungicide treated trial (Andersen, 1989).

Line	Relative grain yield[1] (%)	Thousand kernel weight (g)	Grading (%>2.5 mm)	Malt extract yield (%)	Viscosity (cp)	Kolbach (%)
Ca 100809	85	56	98	78	1.71	50
Ca 123604	92	54	97	83	1.68	53
Ca 123609	95	52	96	80	1.80	39
Ca 307704	86	55	97	82	1.61	51
Ca 310504	83	53	97	81	1.60	54
Ca 310706	84	58	97	80	1.64	51

[1] 'Grit' = 100

Mutants of rapid germination

The mutants bred by the author at La Cruz del Campo (Molina- Cano *et al.*, 1989) are a good example of the use of mutagenesis in resolving problems of global quality in barley. The main problem of using 'Troubadour', a two-rowed spring cultivar with a very high grain yield over a large part of Spain, in malthouses is its low level of endosperm modification when malted under normal conditions. Thus, the objective was to obtain rapid germination mutants.

From seeds treated with N_3Na in 1983, more than 800 mutants were obtained, three of which have shown to be the most interesting, since they combine a higher speed of germination than that of 'Troubadour', with a lower content of beta-glucans and a greater capacity of endosperm breakdown during malting that, in turn, produces a greater extract yield and greater activities of α-amylase and ß-glucanase (Table 4). The three mutants TR-9, TR-43 and TR-49, produce more grain than the original cultivar through the numerous trials performed in various sites in Spain for several years (Table 5) which led La Cruz del Campo to submit them to official trials as new cultivars in 1989 with excellent results (Table 6).

The analysis of the aforementioned and other data not presented here, leads one to think that the mutations affected the genes that govern the hormonal balance of ABA and GA during germination.

Table 3. Yield, grain features and malting quality of proanthocynidin-free spring and winter lines (Larsen, 1990, pers. comm.).

Line (gene)	Relative grain yield (%)	Grading (%>2.5 mm)	Malt extract yield (%)	Kolbach (%)	Wort colour
SPRING					
Ca 104506 (17)	104	92	80.3	40	2.5
Ca 126320 (17)	104	91	79.4	37	2.2
Ca 405204 (13)	99	83	79.5	43	2.8
Ca 509403 (13)	98	83	80.3	45	2.5
WINTER					
Ca 350102 (13)	108	94	78.8	27	2.8
Ca 350107 (13)	108	97	77.9	31	1.9
Ca 350117 (13)	109	95	77.2	27	1.9
Ca 554605 (13)	108	91	77.4	32	2.8
Plaisant	100	67	77.4	26	1.6

Table 4. Malting quality of 'Troubadour' barley mutants[1].

Genotype	Total ß-glucan content of barley[2] (%)	Malt			
		Extract yield[3] (%)	Kolbach[3] (%)	ß-glucanase[4] (units/kg)	α-amylase[5] (Phadebas units)
Troubadour	3.72c	78.97b	35.00b	414.6b	288.7b
TR-9	2.70b	80.23a	34.75b	415.5ab	306.6ab
TR-43	2.43b	80.52a	38.75a	451.6ab	318.8a
TR-49	2.27a	80.23a	37.00b	477.4a	324.5a

[1] Means followed by the same letter do not differ significantly at p<0.05 level
[2] 2 sites in 1988
[3] 1 site in 1987 and 3 in 1988
[4] 10 sites in 1989
[5] 2 sites in 1990

Table 5. Agronomic behaviour of 'Troubadour' barley mutants (data based from 8 environments).

Genotype	Days sowing-anthesis	Grain yield adjusted to 15% moisture	
		kg/ha	%
Troubadour	119.3	5.279	100
TR-9	116.7**	5.697**	108
TR-43	116.3**	5.628*	107
TR-49	116.0**	5.504	104

* Significantly different at p<0.05
** Significantly different at p<0.01

Table 6. Yield performance of 'Troubadour' barley mutants in Official Trials, 1991 (over 17 trials across Spain).

Genotype	% Official controls
TR-9	107*
TR-43	106*
TR-49	105*

* Significant at p<0.05

It is important to point out that the wide phenotypic spectrum produced, probably by exclusive modification of major Mendelian genes, creates hopes for its use in a not too distant future in experiments of genetic transformation, supposing that adequate markers are identified.

Evolution of quality barley production in the EEC, as a consequence of plant breeding activities

The production of spring barley in the EEC (excluding Spain) is concentrated in France, West Germany, Great Britain and Denmark, who jointly produced in the 1980's on average more than 85% of the total in the Community.

The production of quality malting barley in these four countries has decreased gradually from 1981 to 1990, with an average of approximately two million hectares with a production of about eight million tonnes annually (Fig. 7).

The reason for this decrease is the competition with winter barley and other more productive crops. One must point out, however, the important role the 'Triumph' cultivar and its progeny have played in the maintenance of this crop in Europe. This cultivar, bred in the Democratic Republic of Germany at the beginning of the 70's, has been widely grown in Great Britain, France and also in Denmark. Its excellent quality, high grain yield and great resistance to lodging and powdery mildew has made this possible. Nowadays, 'Alexis', a daughter of 'Triumph', occupies more than 28% of the cultivated area of spring barley in the Federal Republic of Germany and likewise other varieties derived from this one: 'Natasha', 15% in France and 'Triumph' 18%, and in Great Britain 'Blenheim' 28% and 'Triumph' 18%. As an exception, in Denmark, 19% of the cultivated area is occupied by 'Grit', a variety of excellent quality, also bred in the Democratic Republic of Germany, but not derived from 'Triumph' (EBC, 1990).

The situation in Spain is completely different, since this crop has occupied more and more cultivated area throughout the last decade (Fig. 8), exceeding a million

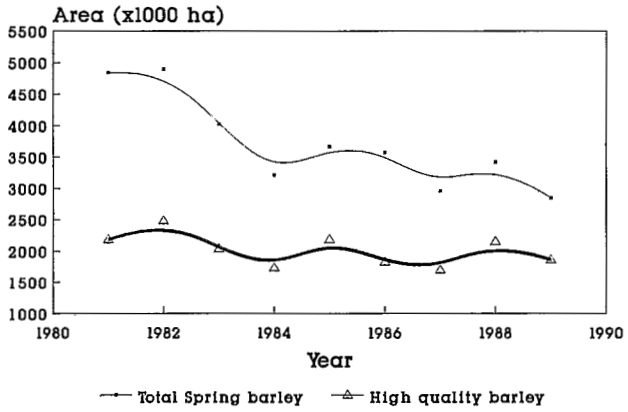


Fig. 7. Evolution of the cultivated area of spring barley in France, Germany, Denmark and Great Britain (1981-1989).

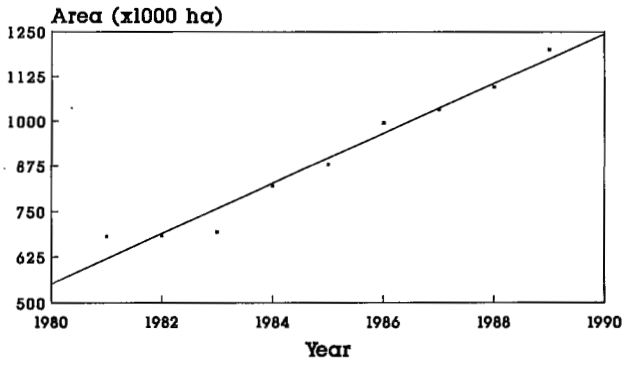


Fig. 8. Evolution of the cultivated area of quality barley in Spain (1981-1989).

hectares in 1987 which supposes a mean annual production of more than two million tonnes of quality malting barley. It is probable that this production could increase with the substitution of obsolete varieties of nil quality with high quality varieties adapted to the difficult conditions of the Spanish drylands. The national activities of malting barley breeding are on the increase, some 10 good quality Spanish varieties having been registered during the last 10 years.

Should this occur, we could manage to produce between 5 and 6 million tonnes of quality malting barley annually, which would place Spain at the head of the world production of this type of grain.

The greatest part of the Spanish cultivated area devoted to quality malting barley is occupied by the 'Beka' cultivar although 'Kym', 'Trait d'Union', 'Dobla', 'Hassan' and 'Zaida' also play an important and in some cases increasing role.

Conclusions

During the last ten or fifteen years, the global improvement of barley quality by genetic improvement has been made possible with considerable success, following programmes exclusively designed to improve both the nutritive (Bang-Olsen *et al.*, 1987) and malting values (Andersen, 1989; Molina-Cano *et al.*, 1989).

At this point it is worth considering that the improvement of the global malting/feeding quality is possible and even desirable. Bearing in mind that the ultrastructure of the barley grain of good malting quality is identical to that of a good nutritional value (Palmer, 1991, this publication) it would only be necessary to establish the difference between both types of barley in the fact that the type destined to malting has to germinate efficiently, or rather, its enzymatic balance must be adequate. In this sense it is convenient to point out that the proteins with a high biological value (nutritive) belong to the group of the enzymatic proteins (albumins and globulins) whereas the unfavourable proteins for malting (hordeins) are also unfavourable for feeding since they are indeed deficient in lysine and produce a high degree of packaging of the starch granules, making them much less digestible.

This is the moment, therefore, to consider that "feeding barley" is not a residual concept defined as: "that which is not of good malting quality" not even "that with a high content of total protein", but that with a high quantity of enzymatic proteins and starch with a low level of packaging (low in hordein) and a low content of husk and beta-glucans. If, furthermore, it germinates adequately, how is it different from a good malting barley?.

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