An. Aula Dei (1988), 19 (1-2): 63-77.

Agrophysiological analysis of several near-isogenic lines of barley under Mediterranean conditions

by **J.L MOLINA-CANO[1]*; J.M. RAMOS[2]; L.F. GARCIA DEL MORAL[2]; F. ROCA DE TOGORES[1]**

[1] La Cruz del Campo, S.A. Fábricas de Cerveza y Malta. Depto. de Mejora de Cebadas. Av. Andalucía, 1. 41007 Sevilla
[2] Universidad de Granada. Facultad de Ciencias. Depto. de Biología Vegetal. 18001 Granada
* Present address: IRTA. Alcalde Rovira Roure, 177. 25006 Lérida

ABSTRACT

J.L. Molina-Cano, J.M. Ramos, L.F. García del Moral y F. Roca de Togores. 1988. Agrophysiological analysis of several near-isogenic lines of barley under Mediterranean conditions. *An. Aula Dei* 19 (1-2): 63-77.

After reviewing critically the main ideas stated by Donald (1968) as a basis to define an ideotype in plant breeding, an alternative approach based on genetical and physiological experiments is put forward.

To avoid the misleading effects of differences in genetic background we have used near isogenic lines obtained from the adapted variety Beka.

In this first report, whose aim is the characterisation of the genetic material, we have used growth, genotype x environment and cluster analyses to demonstrate that whereas the eight genotypes studied differed by very few genes, they are so strikingly different both from agronomical and physiological perspectives that they are most suitable for our aim of defining a barley ideotype for Mediterranean environments when the project is completed.

INTRODUCTION

Donald (1968) based his new theoretical approach to the breeding of new varieties through the use of ideotypes mainly on the criticism of the classical ways to improve crop yields, namely "defect elimination", e.g. the correction of imperfections of the variety to be replaced, such as disease susceptibility, physical disadvantages (for instance weak straw) low quality, and so forth, and "selection for yield", which is an intent to improve yield without consideration of the why or wherefore of that greater yield.

His proposal was for the development of an alternative and new philosophy, "the breeding of model plants or ideotypes", based on the long known use by man of models to solve a great range of problems. This new approach should lead to the design of a plant: (i) theoretically capable of greater production than the genotype it is to replace and (ii) of such a phenotype as to offer reasonable prospect that it can be bred from available material.

Whereas Donald (1968) lists several examples of characters known to influence yield positively, he also recommends that the ideotypic-variety must be subjected to "rigorous selection for yield". This last statement could mean: (i) that the new added characters might act in an unpredictable manner, (ii) that, in fact, the new approach is overall an empirical one such as the one criticized at first, "selection for yield itself", and (iii) that the genetic background of the variety could influence yield as much as the unknown combination of the model characters added to it *de novo*. It is surprising that Donald (1968) gives the last recommendation even if his wheat ideotype was conceived for "... well-fertilized, well-watered lands as of irrigation areas of northern Europe..." What could be the fate therefore of a cereal ideotype designed by following his theoretical scheme for a region with erratic rainfall, low fertility soils, unpredictably sharp-rising temperatures in the late season, and unpredictable frosts during both the vegetative and generative phase? It is likely therefore another approach has to be taken when trying to define a barley ideotype valid for the agroecological conditions prevailing through most of Spain and the Mediterranean countries.

We have tried here to lay the foundations for the definition of such a barley ideotype through an experimental approach based on the knowledge of the effect of various physiological parameters, derived from growth analysis techniques, on yield value and its stability.

However the originality of our approach lies not with the last statement, because cooperation between plant physiologists and breeders is not new, but on the use of *true near-isogenic lines* as experimental material to avoid the misleading results derived from the effect of the genetic background on plant adaptation and yield. This criticisms might be relevant, for example, to the work of Craufurd et al. 1987 who used an array of different genotypes of widespread geographic origin to study such a problem, without really knowing the effect of genotype x environment interactions arising from the different genetic backgrounds used.

To overcome the problem pointed out by Donald of the uncertainty of adaptation of the ideotype to the desired environment, we have used Beka a barley variety with a long known adaptation to the Spanish growing conditions, and near-isogenic lines which have been bred firstly, through inducing mutations on that variety, secondly, by selecting mutants with strikingly different plant architectures and phenological characters but good adaptation to our conditions, and thirdly by breeding recombinants from these primary mutants.

We have to point out at this moment that from now onwards we are going to use indistinctly the words near-isogenic line, mutant and recombinant. The reason is that although we have followed the conventional breeding procedure for obtaining the mutants, we do not have complete certainty of the lack of genetic differences other than the ones recorded, for instance in biochemical characters. These differences, if present, could have arisen either from existing differences within the mother variety or from genetic changes induced by the mutagenic treatment or from both at the same time. The first case is known in self-pollinated species, particulary in barley, and is caused by the current procedure of purifying the breeding lines (Molina-Cano, 1984). These problems are usually left aside in mutation breeding work, where all lines bred after the mutagenic treatment are called mutants (Gaul, 1964; Konzak and Mikaelsen, 1977; Sigurbjörnsson, 1983; Gottschalk and Wolff, 1983; Bosnes et al, 1987).

Most of the characters studied were included in the list by Rasmusson (1984) as traits with potential for increasing grain yield by ideotype breeding in small grains.

Classical Plant Growth Analysis (Kvet et al., 1971; Evans, 1972; Warren Wilson, 1981) envisages the growth of crop plants (biomass accumulation, CDW) as a consequence of both their capacity for light interception (leaf area index, LAI) and the activity of their photosynthetic organs (production of dry matter per unit of leaf area, 1/LAR). These factors depend directly upon the basic physiological processes of photosynthesis, respiration and photosynthate translocation and may be used to investigate the influence of genetical and environmental factors on crop growth and grain yield and its components.

The photosynthates needed for filling the barley kernels come from two different sources: a) the carbohydrates stored during the vegetative phase in shoots and leaves and b) the assimi-

lates synthesized after ear emergence (Watson et al., 1963; Evans and Wardlaw, 1976). The assimilation rate after ear emergence depends on the duration of photosynthesis itself (leaf area duration, LAD) and of its efficiency in producing materials for filling the kernels (G), (Thorne, 1974).

We are, on the other hand, going to use the classical approach of Finlay and Wilkinson (1963) for studying genotype x environment interaction for grain yield in the lines used, as a necessary step to characterise them from the agronomical point of view. The estimations given later on are only approximate ones, because of the small number of environments used (four). It is necessary to point out that this paper is only a preliminary report of a research project whose aim is to define a barley ideotype for arid Mediterranean environments.

MATERIAL AND METHODS

Plant material

Beka, the parental variety used, was chosen for its extremely good adaptation to the arid Mediterranean conditions prevailing across most of the barley area in Spain. It has been widely grown in our country since its release in 1965.

500 g. dry seeds of Beka were irradiated with Gamma rays (20 Krad) and the three mutants used in this study selected in M_2 as described by Molina-Cano (1982).

As was stated in the above paper, two of the mutants (gene 1 and gene 3) were recessive, and this was also the case for gene 2 (Molina-Cano, unpublished results). Gene 3 (the one carried by CC 003-75) was then identified as a mutation at locus ert-d, as described by Persson and Hagberg (1969), (Molina-Cano, 1982).

Three mutants, that were strikingly different from a morphophysiological point of view (see Table 5), CC 001-75 (gene 1), CC 002-75 (gene 2) and CC 003-75 (gene 3) were crossed in all three possible combinations excluding reciprocals, and the three binary recombinants were then selected in F_2 and purified in F_3 and F_4. They were named CC 064-83 (recombinant 12), CC 065-83 (recombinant 13) and CC 066-83 (recombinant 23). The triple recombinant was bred by crossing CC 064-83 x CC 065-83, selected in F_2 and purified in F_3 and F_4. All the four recombinant genotypes are described in Table 5.

Field methods

Four environments were tested, in order to get a good sample of Mediterranean environments adequate for barley cultivation during the years 1985, 1986 and 1987. The sites were: Alcalá del Río (Sevilla), 12 m. above sea level, characterised by good soil, appropiate rainfall (about 600 mm.) sharp rise of temperatures in May, and lack of rainfall usually from heading to ripening; Domingo Pérez (Granada), 900 m. above sea level, with good soils, lower rainfall (around 500 mm.) but very good maturing conditions (mild temperature during May and June), and Colomera (Granada), 600 m. above sea level, with about the same rainfall as Domingo Pérez, but poorer soils and, usually, hard conditions from heading onwards, i.e. sharp rise of temperatures and lack of rainfall.

A trial was laid out at every environment consisting of a randomised block design with four replications, the plot size was 12.6 m^2, and each plot consisted of 8 rows, 11 m. long and 15 cm. apart in Alcalá del Río 1985 and 1986, but of 6 rows, 11 m. long and 20 cm. apart in Domingo Pérez and Colomera 1987. The triple recombinant CC 607-86 was not included in the trials at Alcalá del Río 1985 and 1986 because it was selected in the spring 1986. The physiological analysis was only carried out at the following environments: Domingo Pérez 1987 and Colomera 1987.

The statistical methods used to analyse the results were analysis of variance, regression, correlation (Sokal and Rohlf, 1969) WPGMA cluster analysis (Sneath and Sokal 1973), and the Finlay and Wilkinson (1963) technique to assess genotype x environment interaction, through the regression of variety yields on environmental mean yields. WPGMA clustering strategy has been shown to be useful to classify both landraces and commercial cultivars of barley (Molina-Cano, 1976, 1977).

Physiological methods

For the growth analysis in this study, the plants growing in 0.5 m. of row per plot (selected completely at random) were collected at intervals of about 15 days during the principal development stages until ripening (Large, 1954). Later on, in the laboratory, 5 representative plants per plot were used to estimate the means of the following primary values: a) total above-ground dry matter (W) and separate dry weight values of leaves, tillers and ears (after drying at 70 °C-80 °C to constant weight); b) leaf lamina area (A) by using a photoelectronic planimeter LI-COR 3000; c) number of plants per unit area (N). From these data, the values of each growth index were calculated as follows:

CDW = LAI. 1/LAR; NW = NA. W/A (Warren Wilson, 1981)
LAD = (LAI anthesis + LAI Maturity)/2 x (time to anthesis-time to maturity) (Hunt, 1982)
G = Grain yield/LAD (Watson et al., 1963).

RESULTS AND DISCUSSION

Yield per plant variation and growth analysis

The environment was the principal factor determining yield per plant differences among genotypes (Table 1). In Colomera, with low rainfall and high temperatures from stem elongation onwards, line 3 yielded significantly more than the other ones (Table 1) probably because of a better equilibrium between the yield components. There was also a group of genotypes with intermediate level of yield, i.e. Beka, and lines 2 and 23, due to a misbalance of certain yield component in each case. The lower yielding lines were the earlier and shorter ones, all carrying gene 1, i.e. lines 1, 12, 13 and 123; all of them had very reduced tillering and thousand kernel weight.

At the other site, Domingo Pérez, with better soils, enough rainfall and mild temperatures during grain filling, we can classify the genotypes into two groups (Table 1) a high yielding group made up of Beka, and lines 2, 3, 23 and 123, characterised because of having high values of at least two yield components which varied among genotypes. The second group of low yielding varieties consisted of lines 1, 12 and 13, all again carrying gene 1, and having low number of grains per spike and thousand kernel weight.

The data obtained from growth analysis (Table 2) indicate a close dependence of yield variations on Crop Dry Weight at anthesis, CDW, (in turn depending on LAI, Leaf Area Index) on the one hand, and on Leaf Area Duration, LAD on the other.

Variation patterns of LAI and LAD among genotypes were similar to those of yield. Thus in both environments the very early, low yielding genotypes also had the lowest LAI and LAD (Table 3). The study of the components of those indexes shows that their variation depended more on changes in leaf size than on number of leaves per plant or of plants per square meter. This fact poses a great disadvantage for the early genotypes, which have a smaller "source" at anthesis, and thus their ability to accumulate carbohydrate reserves diminishes. The importance

Table 1.- Yield per plant and its components in two environments (Domingo Pérez and Colomera, 1987).

Environment	Line	Gene(s)	Grain Yield/ plant(g)	Spikes/plant	Kernels/spike	Thousand Kernel weight(g)	Spikes/m^2
Domingo Pérez 1987	Beka	Wild type	2.33 a	2.40 ab	22.68 b	42.95 a	615 abc
	Line 1	1	1.78 d	2.48 a	16.90 e	42.55 a	668 ab
	Line 2	2	2.22 ab	2.40 ab	22.85 b	40.48 b	652 ab
	Line 3	3	2.17 ab	2.18 bc	22.98 b	43.55 a	569 bc
	Line 12	1 & 2	1.80 cd	2.55 a	18.00 dc	39.15 bc	703 a
	Line 13	1 & 3	2.12 ab	2.55 a	19.30 d	42.85 a	590 bc
	Line 23	2 & 3	2.03 bc	2.15 c	24.90 a	37.88 c	529 c
	Line 123	1.2 & 3	2.34 a	2.60 a	20.98 c	43.10 a	712 a
Colomera 1987	Beka	Wild type	2.05 ab	2.15 ab	23.93 a	40.20 a	431 b
	Line 1	1	1.33 f	2.10 bc	17.08 c	37,08 bc	393 bc
	Line 2	2	1.87 bc	2.10 bc	24.25 a	36.73 bc	395 bc
	Line 3	3	2.20 a	2.35 a	24.03 a	38.88 ab	485 a
	Line 12	1 & 2	1.38 f	1.90 c	20.35 b	35.50 c	332 d
	Line 13	1 & 3	1.65 d	2.05 bc	20.45 b	39.35 a	381 bcd
	Line 23	2 & 3	1.83 cd	2.10 bc	24.78 a	34.98 c	375 cd
	Line 123	1.2 & 3	1.62 e	2.18 ab	19.20 bc	38.78 ab	418 bc

Note: Means followed by the same letter within each column at each environment do not differ significantly at $p < 0.05$ level in analysis of variance.

Table 2.- Growth indexes at anthesis and naturity in two environments (Domingo Pérez and Colomera, 1987).

Environment	Line	Gene(s)	Anthesis			Maturity	
			CDW	LAI	1/LAR	LAD	G
Domingo Pérez 1987	Beka	Wild type	446 a	2.52 a	177 c	6.55 a	81 c
	Line 1	1	258 c	0.97 c	277 a	2.33 c	183 a
	Line 2	2	405 ab	2.10 ab	195 c	5.68 a	89 c
	Line 3	3	420 ab	2.30 ab	182 c	5.99 a	84 c
	Line 12	1 & 2	333 bc	1.29 c	259 ab	3.83 b	107 bc
	Line 13	1 & 3	290 c	1.24 c	239 b	2.87 bc	145 ab
	Line 23	2 & 3	443 a	2.34 a	189 d	5.94 a	84 c
	Line 123	1.2 & 3	410 ab	1.81 b	233 bc	4.01 b	124 bc
Colomera 1987	Beka	Wild type	436 b	2.73 b	157 d	6.03 b	78 a
	Line 1	1	325 c	1.59 c	208 ab	3.25 c	65 a
	Line 2	2	434 b	2.65 b	165 cd	6.42 ab	79 a
	Line 3	3	656 a	3.68 a	179 bcd	7.58 a	78 a
	Line 12	1 & 2	308 c	1.58 c	195 ab	3.18 c	62 a
	Line 13	1 & 3	308 c	1.47 c	214 a	2.93 c	90 a
	Line 23	2 & 3	419 bc	2.50 b	167 cd	6.08 b	76 a
	Line 123	1.2 & 3	328 c	1.54 c	213 a	2.79 c	94 a

Note: Means followed by the same letter within each column at each environment do not differ significantly at $p < 0.05$ level in analysis of variance.

Table 3.- Components of the growth indexes LAI and LAD at anthesis and maturity in two environments (Domingo Pérez and Colomera, 1987)

			Anthesis				Maturity			
Environment	Line	Gene(s)	Leaves/ plant	Leaf area(cm^2)	Plant area(cm^2)	Plants/ m^2	Leaves plant	Leaf area(cm^2)	Plant area(cm^2)	Plants/m^2
Domingo Pérez 1987	Beka	Wild type	13.5 a	7.7 a	103 a	244 a	6.9 a	5.0 a	34 bc	218 a
	Line 1	1	11.8 a	3.2 c	39 b	240 a	6.1 a	1.4 c	9 e	235 a
	Line 2	2	10.8 a	7.8 a	83 a	255 a	6.9 a	6.5 a	45 a	223 a
	Line 3	3	11.2 a	9.1 a	97 a	237 a	7.6 a	6.5 a	47 ab	216 a
	Line 12	1 & 2	10.6 a	4.5 bc	47 b	253 a	9.0 a	3.1 b	27 cd	238 a
	Line 13	1 & 3	11.9 a	4.1 bc	49 b	253 a	5.6 a	3.4 b	18 de	231 a
	Line 23	2 & 3	9.3 a	9.2 a	94 a	251 a	7.8 a	5.7 a	42 ab	220 a
	Line 123	1.2 & 3	10.7 a	5.3 b	56 b	271 a	7.1 a	3.1 b	22 cd	226 a
Colomera 1987	Beka	Wild type	13.9 a	11.5 ab	159 ab	172 a	7.3 a	6.4 a	47 a	187 a
	Line 1	1	9.1 b	9.4 b	83 c	193 a	5.4 ab	4.8 c	25 b	203 a
	Line 2	2	12.8 a	10.0 b	129 c	204 a	7.3 a	6.6 a	47 a	204 a
	Line 3	3	14.8 a	12.4 a	184 a	200 a	6.9 a	6.6 a	46 a	205 a
	Line 12	1 & 2	9.1 b	9.7 b	89 c	177 a	4.8 b	5.7 b	27 b	186 a
	Line 13	1 & 3	9.6 b	9.4 b	90 c	167 a	4.5 b	5.4 b	25 b	199 a
	Line 23	2 & 3	13.6 a	10.7 ab	146 b	169 a	7.7 a	6.5 a	50 a	187 a
	Line 123	1.2 & 3	9.1 b	9.4 b	84 c	183 a	4.9 b	4.5 c	22 b	189 a

Note: Means followed by the same letter within each column at each environment do not differ significantly at $p < 0.05$ level in analysis of variance.

of the last factor in regions with water deficit during grain filling has been pointed out repeatedly (Austin et al., 1980; Lawlor et al., 1981; Ramos et al., 1985). Furthermore, the reduced LAD and earliness of those genotypes induce a lower photosynthetic capacity and opportunity for photosynthate translocation to the growing kernels, thus setting limits to crop yield.

Genotype x environment interaction for grain yield

The data used for the Finlay and Wilkinson (1963) analysis come from 3 locations and 3 years, making up a total of 4 environments (Table 4a). There are obviously too few locations to carry out a robust regression analysis but, as can be seen from Table 4b and Fig. 1 most of the straight lines of best fit obtained have good r^2 values (except genotype 3) and they give us a preliminary idea about the behaviour of the different groups of genotypes. It should be noted also that analysis of the triple recombinant has not been carried out because it has been tested in only two environments to date.

From Table 4b and the Figure 1 we can roughly divide the genotypes into three groups:

I) Those carrying gene 1, i.e. 1, 12 and 13, characterised by very steep slopes and negative intersections with the Y axis.

II) Parental variety Beka and genotypes 2 and 23 with a small slope and a positive intersection.

III) Genotype 3 with a negative slope but very poor line fitting (see Table 4b).

The data presented have supported the idea of an epistatic behaviour of gene 1 on genes 2 and 3, for when it is present in a line, its yield variation is similar, independent of whether anoth er gene is present. This is also reflected by the growth analysis and morphophysiological data presented elsewhere in this paper.

On the other hand, we can only conclude from these data that the genotypes used react to changes in the environment in a manner so different (taking into account the small genetic differences existing among them) that they constitute excellent plant material for proceeding with the studies to define the desired ideotype: we do not intend at this moment to discuss any of the suggested differences in yielding behaviour, but to point out that they exist.

Morphophysiological characterisation of the genotypes

Seven characters were used for this (Table 5) of which all except leaf angle were measured both at Domingo Pérez 1987 and Colomera 1987, and the results presented in the above Table are the averages.

The similarity among genotypes, studied by using the WPGMA clustering method (Sneath and Sokal, 1973) yielded the dendrogram depicted in Figure 2. From this dendrogram we can draw the following conclusions, assuming that the differences in genetic background referred to in the introduction are nonexistent:

I) There is a strong overall similarity among genotypes carrying gene 1, and all of them clustered together.

II) The second big cluster is made up of Beka, with a low overall similarity with its counterparts, and lines 2, 23 and 3, being very close.

III) There ir a clear general epistatic effect of gene 1 where it is present.

IV) Gene 2 is also epistatic over gene 3, because lines 2 and 23 clustered together at a high similarity level.

Although the overall gene effects are the ones shown in Fig. 2, that does not mean that every epistatic gene is acting in this manner over all the studied characters. In fact, as shown in Table 5, gene 1 is epistatic over genes 2 and 3 with regard to the following characters related to canopy structure and earliness:

Table 4a.- Grain yield (kg/ha adjusted to 15% moisture content).

Line	Gene(s)	Environments: Alcalá del Río 1985	Alcalá del Río 1986	Domingo Pérez 1987	Colomera 1987	Line mean
Beka	Wild type	5922	5430	5052	4798	5300
Line 1	1	5937	5836	3711	2175	4414
Line 2	2	6060	6824	4881	4910	5668
Line 3	3	5447	5249	4821	5951	5367
Line 12	1 & 2	5959	6733	3954	1684	4582
Line 13	1 & 3	6545	5989	3828	2648	4752
Line 23	2 & 3	5388	6241	4844	4692	5291
Line 123	1.2 & 3	–	–	4722	2683	–
Environment mean (1)	–	5894	6043	4560	3637	–
CV (%)	–	5.6	8.0	10.7	20.0	–
LSD ($p<0.05$)	–	494	723	710	1059	–

(1) Without considering the yield of Line 123.

Table 4b.- Genotype x environment interaction for grain yield: Line yield regressed on environment yield (site x year) calculated from data of Tabla 4a.

Line	Gene(s)	Regressión parameters (2): Intersection with the Y-axis (a)	Slope (b)	Goodness of fit (r^2)
Beka	Wild type	3400	0.37*	0.77
Line 1	1	-3526	1.57*	0.98
Line 2	2	1912	0.74	0.81
Line 3	3	6144	-0.16*	0.14
Line 12	1 & 2	-5271	1.95*	0.98
Line 13	1 & 3	-3139	1.56	0.96
Line 23	2 & 3	2616	0.53	0.74

(2) Regresión line $y = a + bx$. r^2 = coefficient of determination
* $b = 1$, $p < 0.05$

Table 5.- Morphophysiological description of the studied genotypes (Domingo Pérez and Colomera 1987).

Line	Gene(s)	Leaves/plant at anthesis	Leaf area (cm^2)	Leaf angle	Length of the main shoot (cm)	Days to anthesis	Days anthesis -maturity	Spike density (no. Kernels) /cm rachis)
Beka	Wild type	13.9a	9.6ab	70.9	75.6a	137b	26a	2.8c
Line 1	1	10.5bc	6.3c	71.5	55.6cd	130d	24a	2.9c
Line 2	2	11.8abc	8.9b	68.5	59.0c	138ab	25a	4.4a
Line 3	3	13.0ab	10.8a	69.3	65.8b	139a	25a	3.6b
Line 12	1 & 2	9.8c	7.1c	71.0	51.6d	129d	25a	4.4a
Line 13	1 & 3	10.8b	6.7c	72.8	57.9c	133c	22b	3.5b
Line 23	2 & 3	11.4abc	9.9ab	68.8	58.1c	139a	25a	4.2a
Line 123	1.2 & 3	9.8c	7.4c	73.6	61.3b	133c	22b	3.6b

Note: Means followed by the same letter within each column do not differ significantly at $p < 0.05$ level in analysis of variance.

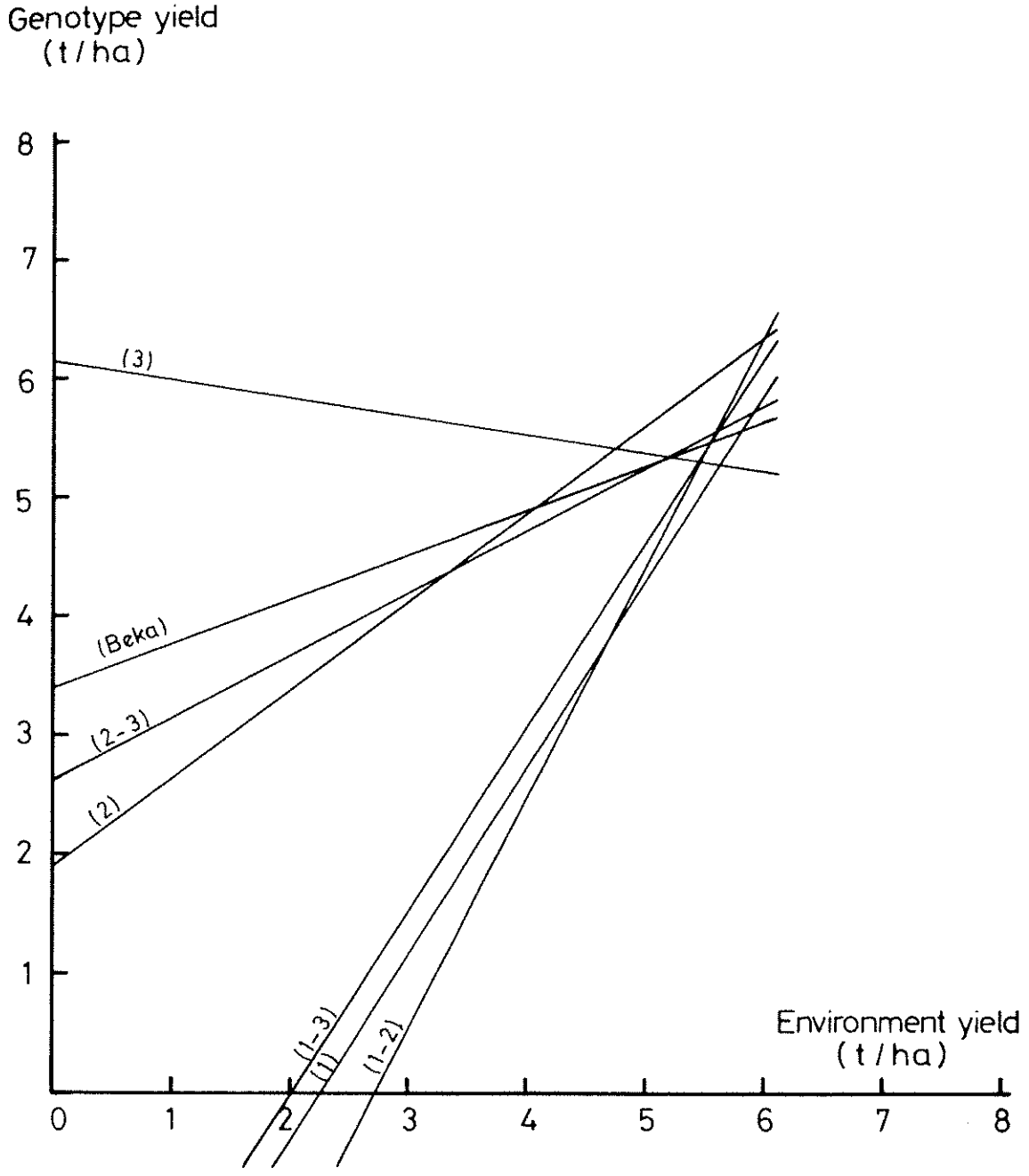

Figure 1.- Genotype x environment interaction for grain yield

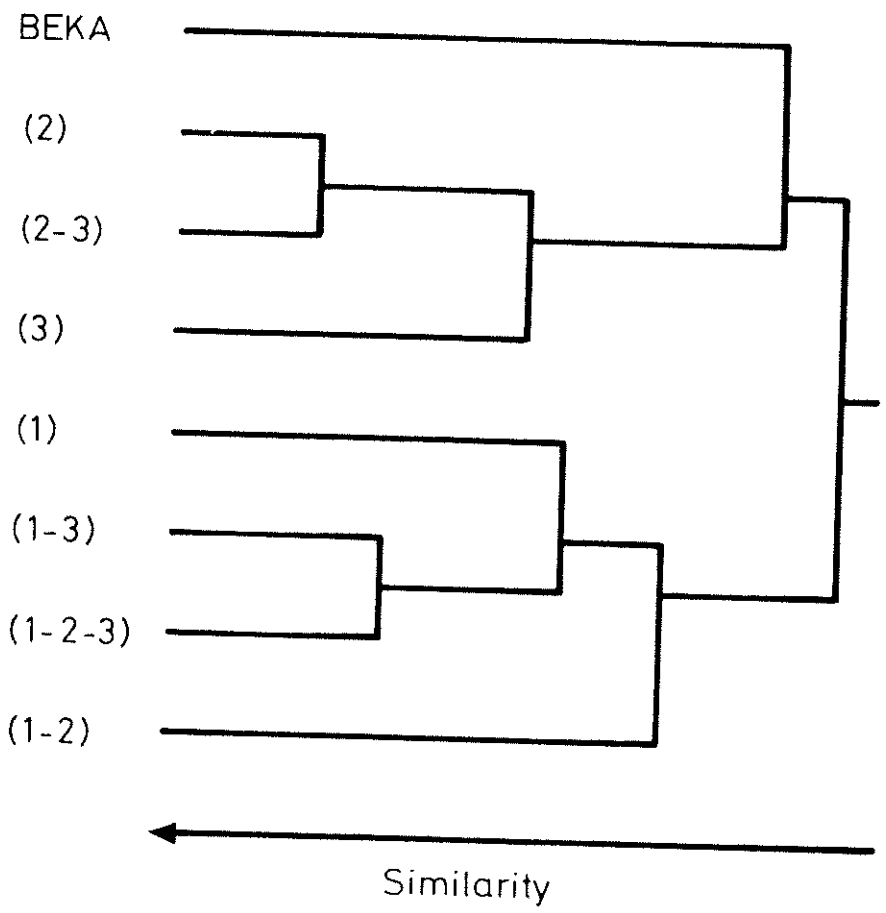

Figure 2.- Results of clustering by using WPGMA method the 8 genotypes based on 9 morpho physiological characters.

- Number of leaves/plant at anthesis
- Mean leaf area at anthesis
- Leaf angle
- Days to anthesis

Whereas gene 2 acts as epistatic on gene 3 on the characters:

- Number of leaves/plant at anthesis
- Lengh of the main shoot
- Spike density.

Generally speaking, when gene 1 is present the plant has fewer and smaller leaves with a more erect angle, and is much earlier than the wild type.

Gene 2 always induces a denser ear, even in the presence of gene 1. Moreover, the interaction bewtween genes 2 and 3 produces a plant with fewer leaves, shorter main shoot and denser spike than the wild type Beka.

CONCLUSIONS

From the preliminary data presented here we can conclude:

1) All genotypes are very different from both morphophysiological and agronomic points of view in spite of sharing the same genetic background.

2) The morphophysiological study correlates very well with the grain yield study in spite of the limited data used and the wide differences between the methods employed.

3) Stemming from the point of the good adaptation to Mediterranean environments of both parent and derived varieties and the big morphophysiological differences existing among all of them, we consider they constitute genetic material which is very suitable for defining an ideotype by following a non speculative approach.

ACKNOWLEDGEMENTS

We would like to thank Drs. F. García-Olmedo and G. Salcedo for their thorough review of the manuscript.

We also thank Mr. Simón Hassán for his excellent computing assistance and Miss Soledad del Valle for her very good technical work, and Dr. Owen T. Jones, Biological Control System Limited (Cardiff, UK), for reviewing the language.

RESUMEN

Se propone un método para definir un ideotipo de cebada, basado en experimentos genéticos y fisiológicos, partiendo de la crítica del enfoque usado por Donald (1968).

Se han usado líneas de cebada aproximadamente isogénicas procedentes de la variedad Beka –cuya adaptación a nuestros climas es notoria– para evitar los efectos indeseables que se derivan de trabajar con fondos genéticos diferentes.

En este primer artículo, cuyo objeto es, solamente, caracterizar el material, se han usado métodos tales como el análisis del crecimiento vegetal, el análisis de la interacción genotipo x ambiente y el análisis de enjambres, cuyos resultados han demostrado, que aunque los ocho genotipos estudiados difieren en muy pocos genes, son marcadamente distintos tanto desde el punto de vista fisiológico como el agronómico. Se concluye que el material es el adecuado para, mediante trabajos adicionales ya en marcha, definir un ideotipo de cabada para climas mediterráneos.

REFERENCES

Austin, R.B.; C.L. Morgan; M.A. Ford; R.D. Blackwell. (1980). Contributions to grain yield from pre-anthesis assimilation in tall and dwarf barley phenotypes in two contrasting seasons, **Annals of Botany** 45: 309-319.

Bosnes, M.; E. Harris; L. Aigeltinger; O.A. Olsen. (1987). Morphology and ultrastructure of 11 barley shrunken endosperm mutans, **Theor. Appl. Genet.** 74: 177-187.

Craufurd, P.Q.; N.J. Clipson; R.B. Austin. (1987). An approach to defining an ideotype for barley in low-rainfall Mediterraean environments, **Proceedings of an International Symposium on Improving Winter Cereals under Temperature and Soil Salinity Stresses**, Cordoba (Spain) October 1987 (in press).

Donald, C.M. (1968). The breeding of Crop Ideotypes, **Euphytica** 17: 385-403.

Evans, G.C. (1972). The quantitative analysis of plant growth. Blackwell, Oxford.

Evans, L.T.; I.F. Wardlaw. (1976). Aspects of the comparative physiology of grain yield in cereals, **Advances in Agronomy** 28: 301-359.

Finlay, K.W.; G.N. Wilkinson. (1963). The analysis of adaptation in a plant breeding programme, **Austral. J. Agric. Res.** 14: 742-754.

Gaul, H. (1964). Mutations in Plant Breeding, **Radiat. Bot.** 4: 155-232.

Gottschalk, W.; G. Wolff. (1983). Induced Mutations in Plant Breeding. Berlin, Heidelberg, New York, Tokyo, Springer Verlag, pp 14-17.

Hunt, R. (1982). Plant growth curves. The functional approach to plant growth analysis. London, E. Arnold, 248 pp.

Konzak, C.F.; F. Mikaelsen. (1977). Selecting parents and handling the M_1-M_3 generations for the selection of mutants. In: Manual on Mutation Breeding. International Atomic Energy Agency, Vienna, pp 125-138.

Kvet, J.; J.P. Ondok; J. Necas; P.G. Jarvis. (1971). Methods of growth analysis. In: Plant Photosynthetic Production. Manual of Methods. Sestäk, Z,; Catsky, J.; Jarvis, P.G. (Eds.), The Hague, Dr. W. Junk, pp 343-391.

Large, E.C. (1954). Growth stages in cereals. Illustration of the Feekes scale, **Plant Pathology** 3: 128-129.

Lawlor, D.W.; W. Day; A.E. Johnston; B.J. Legg; K.J. Parkinson. (1981). Growth of spring barley under drought: crop development, pothosynthesis, dry matter accumulation and nutrient content, **J. Agric. Sci.** Camb. 96: 167-186.

Molina-Cano, J.L. (1976). A numerical classification of some European barley cultivars, **Z. Pflanzenzüchtg** 76: 320-333.

Molina-Cano, J.L. (1977). Numerical taxonomy as an aid to barley germplasm collection, **Barley Genet. Newslett.** 7: 45-50.

Molina-Cano, J.L. (1982). Genetic, agronomic and malting characteristics of a new Erectoides mutant induced in barley, **Z. Pflanzenzüchtg.** 88: 34-42.

Molina-Cano, J.L. (1984). Bases biológicas para la producción de semillas de cereales y leguminosas autógamos, **Comunicaciones INIA**, Serie: Producción Vegetal, n.º 60, pp 13-17.

Persson, G.; A. Hagberg. (1969) Induced variation in a quantitative character in barley. Morphology and cytogenetics of erectoides mutants, **Hereditas** 61: 115-178.

Sneath, P.H.A.; R.R. Sokal. (1973). Numerical Taxonomy. Freeman, San Francisco and London, 571 pp.

Sokal, R.R.; F.J. Rohlf. (1969). Biometry. Freeman, San Francisco and London, 776 pp.

Ramos, J.M.; L.F. García del Moral; L. Recalde. (1985). Vegetative growth of winter barley in relation to environmental conditions and grain yield, **J. Agric. Sci. Camb.** 104: 413-419.

Rasmusson, D.C. (1984). Ideotype research and plant breeding. In: Gene manipulation in plant improvement. Gustafson, J.P. (Ed.). 16th Stadler Genetics Symposium, Plenum Press, N. York, pp 95-119.

Sigürbjörnsson, B. (1983). Induced Mutations. In: Crop Breeding. Wood, D.R. (Ed.), Madison, Wisconsin, American Society of Agronomy and Crop Science Society of America, pp 153-176.

Thorne, G.N. (1974) Physiology of grain yield of wheat and barley, **Rothamsted Experimental Station, Report for 1973,** part 2, pp 5-25.

Warren Wilson, J. (1981). Analysis of growth, photosynthesis and light interception for single plants and stands, **Annals of Botany** 48: 507-512.

Watson, D.J.; G.N. Thorne; S.A.W. French. (1963) Analysis of growth and yield of winter and spring wheats, **Annals of Botany** 10: 41-72.