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Optimization of the digestible dry matter yield from semi-exotic populations of maize

Por **F. CASAÑAS*, L. BOSCH*, A. FERRET**, A.M.C. VERDU*, J. PLAIXATS**, E. ALBANELL** and F. NUEZ*****

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ABSTRACT

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Semi-exotic populations of maize with late maturity can be obtained by crossing exotic germplasm with adapted inbred lines. Being very productive, these populations give an appropriate starting point for the development of long season forage maize suitable for mild weather zones.

Criteria to be considered for the discrimination between semi-exotic populations regarding their production of digestible dry matter are discussed in base to preliminary results.

Although the materials are intended for use as forage, maximization of ear yields still appears as a basic factor. Selection for stover digestibility and/or cell wall and/or against NDF would be complementary aspects to be considered as a strategy for improving the nutritive quality of the plant. Although further research is needed, none of the criteria seem incompatible with increased production and the choice of a trait depends strongly on the ease of recording it.

INTRODUCTION

A forage maize breeding programme is being developed in our laboratory to obtain maize suitable for mild Mediterranean-type conditions, whith very long growing seasons (Casañas et al., 1989). The strategy followed takes advantage of the amplitude of the growing period in order to increase stover and grain production by

* Escola Superior d'Agricultura, Urgell 187, 08036 Barcelona, Spain.
** Facultad de Veterinaria, UAB, 08193 Bellaterra, Spain.
*** E.S. Ingenieros Agronómos, Camino de Vera, 46022 Valencia, Spain.

increasing the maturity rating. South and Central American populations are used as very long season germplasm; these are crossed with high yielding inbreds, elite for the production of grain, to generate semi-exotic base populations from which to start the selection.

Information available regarding the digestibility of maize and the implications thereof in forage breeding programmes refer mostly to early materials. However, even within the limited amount of materials studied, optimal traits for selection have not been clearly established. This is true for both the ease of measurement and genetic characteristics of the trait. Opinions regarding the most effective way to improve nutritive quality range from selection in favor of the digestibility of the cell wall content of the stover (Deinum & Struik, 1986; Dolstra et al., 1987) to selection for the digestibility of the whole plant (Gallais et al., 1983).

The objetive of this study is to generate preliminary data concerning the relationship between the traits involved in the yield and nutritive quality of the maize plant in very long season semi-exotic material. The parameters considered are discussed with regard to their suitability for use in forage maize breeding programmes using semi-exotic populations.

MATERIAL AND METHODS

The exotic populations (Table 1) were chosen from a previous study of a larger group in which the maturity rating of the material and its vegetative development were recorded. The earliest populations were disregarded. All the populations, except V-464 of unknown origin, were supplied by CIMMYT.

Table 1. Exotic populations studied.

1. ETO Amarillo
2. ETO Blanco
3. Composite Pira Naranja
4. Composite Piracar
5. Composite Centroamericano A
6. Composite Caribeño M.C.2
7. Composite Centroamericano 1
8. Composite Centroamericano 5
9. Cuba 24
10. Chiapas 26
11. GUAT-GPO-12-5-A
12. GUAT-GPO-17-3-A
13. GUAT-GPO-18-2-A
14. GUAT-GPO-18-3-A
15. Pepitilla
16. USACA-MEX-1
17. Chiapas-13
18. V-464

The semiexotic populations were formed by crossing the exotic material with inbreds Mo17 and B73 which are considered good representatives of adapted late pure lines.

The thirty-six offspring (18 from Mo17 and 18 from B73) were studied under irrigation using a randomized complete block design with three replications and a density of 65,000 pl/ha. Each plot consisted of a single row with 36 competitive plants. The commercial hybrids P3183 (Pioneer, FAO 800) and Mo17 x B73, widely employed within its maturity rating (FAO 700), were used as checks. The experiment was hand planted and carried out in Terrassa (Barcelona, NE Spain).

The following traits were recorded in each plot:

- days to pollen shedding (df)
- ear height (eh)
- total height (th)
- days from planting to harvest (har). Plants were harvested (separating the stover from the ear) when the mean grain moisture in the three replications was approximately 40% (considered the optimum moment for whole plant silage).
- index of plants affected by smut on a scale from 0 to 2 (is). To improve statistical analysis original data were transformed according to the expression is'= is+1/2.
- dry matter yield of the ear (ey)
- dry matter yield of the stover (sy)
- total dry matter yield (ty)

A single representative sample of stover from the three replications of each population (previously chopped as if for silage) was dried at 60°C in a forced air oven, and was ground to pass a 1 mm screen of a mill. With this material duplicated determinations were performed on:

- digestibility of the dry matter of the stover (Ddm), using the enzymatic method proposed by Aufrère (1982)
- content of neutral detergent fiber of the stover (NDF), using Van Soest & Wine's method (1967)
- crude fiber content of the stover (CF)
- crude protein of the stover (CP), using Kjeldhal method (Nx6.25)
- ash (A)
- digestibility of the cell wall content (Dcwc), by means of the equation used by Struik (1983): Dcwc = 100-(100-(Dom+9)) (100-A)/NDF; Dom was obtained from Ddm through the expression Dom = 0.875 Ddm + 9.19 proposed by Aufrère and Demarquilly (1989).

The yield of digestible dry matter of the stover (PDdm) was estimated from the digestibility of the dry matter of the stover and the dry matter yield of the stover. In the estimation of the total yield of digestible dry matter (tPDdm), it was assumed that the ear presented a constant value of digestibility (Deinum & Bakker, 1981).

The correlations among the different traits were calculated from the mean phenotypic values of all populations, excluding the check hybrids.

RESULTS AND DISCUSSION

In several semi-exotic populations the total dry matter yield (ey + sy) was superior to that of the check hybrids (Table 2), although the total yield of digestible dry matter was similar, due to a higher proportion of ears in the hybrids. However, the fact that some unimproved semi-exotic populations produced as much or more than the commercial hybrids offers good prospects for breeding programs. In fact, the proportion of ear in the best semi-exotic materials is mostly above 40%, and exceds the 30% proportion of grain proposed as a lower limit by Pinter (1986).

On the average, crosses with the inbred tester B73 yielded more grain than those with Mo17 (Table 2). This is reflected by the total yield of digestible dry matter, the grain being the most digestible part of the plant. No differences were presented between the two semi-exotic families for the rest of the traits (Table 2).

Traits related with yield showed the highest coefficients of variation (Table 2) probably due to their complex nature. Their variability would be the final expression of variabilities in all the traits influencing production. Furthermore, yield can be strongly influenced by the environment.

The variability within the traits for digestibility of the dry matter of the stover (Ddm) and its cell wall content (Dcwc) was very low. The low variability of the cell wall content had been previously cited by Zimmer and Wermke (1986), whereas Deinum (1987) indicated that this trait showed considerable variation (both estimates correspond mainly to groups of early hybrids). In general, all the coefficients of variation corresponding to traits related to nutritive quality were extremely low.

The correlation between the characters studied (Table 3, and Figures 1 and 2) suggest that the trait to be optimized (tPDdm) depends primarily on the production of ear. No correlations, however, were found between this trait and either the digestibility of the stover or the digestibility of the cell wall content. It is thus clear that, in the framework of these materials which show increased stover yield due to the introduction of exotic germplasm (Casañas et al., 1990), the first stage of selection should maximize the amount of grain produced within populations with a great vegetative development.

The digestibility of the cell wall seems to have a greater influence on the digestibility of the vegetative part ($r= 0.84 \pm 0.05$) than does the proportion of cell wall (estimated from the NDF, $r= 0.62 \pm 0.10$). Furthermore, in our material, Dcwc is not correlated to the proportion of the cell wall (NDF). This is contrary to the systematically negative correlations reported by Deinum (1987) in early hybrids. In any case, selection for the digestibility of the cell wall would be a good way to improve quality. The main drawback lies in that its estimation is more complex than for either NDF or stover digestibility, both candidates for selection (selection against NDF or in favour of stover digestibility). However, the estimation of these parameters could be simplified enormously by the use of the NIR method, modifying above considerations.

The broad-sense heritability of these traits estimated in hybrids show similar values: Dolstra and Medema (1990) obtained a value of 0.77 for the Dcwc, and Zimmer and Wermke (1986) obtained a value of 0.81 for NDF, whereas the

Table 2. Mean values of the traits studied in the 15 semiexotic populations which were found to be the best producers of digestible dry matter. Average of all the offspring with lines Mo17 (Mo17x) and B73 (B73x).

Population	tPDdm kg/ha	ey kg/ha	ey/ty	sy kg/ha	Ddm	PDdm kg/ha	har	Dcwc	df	eh cm	th cm	is'	CP %	CF %	NDF %
B73x18	15390	10799	.41	15198	.43	6535	142	.44	84.7	228	342	.87	7.36	34.06	70.47
Mo17x5	15354	8347	.34	16055	.53	8509	137	.55	82.7	193	297	.76	7.09	34.58	70.19
P-3183	15041	12550	.58	9135	.52	4750	130	.56	76	127	234	.74	6.1	35.85	73.96
B73x2	14969	9063	.39	13703	.55	7537	133	.55	80.7	197	302	.79	8.39	32.48	65.63
B73x5	14044	11101	.51	10294	.48	4941	137	.51	82.7	216	316	.90	8.3	36.1	70.15
Mo17x9	13726	8806	.40	13276	.49	6505	134	.49	81.3	194	300	.86	7.47	34.41	67.8
B73x12	13035	8901	.44	11247	.51	5736	137	.53	86	223	325	.84	7.29	35.38	69.82
Mo17x18	12977	5731	.27	15330	.54	8278	142	.52	86.3	207	316	.79	7.58	33.3	64.75
B73x16	12850	9218	.47	10374	.51	5291	133	.54	80.7	181	286	.76	7.48	35.37	70.78
B73x6	12814	8849	.42	11825	.47	5558	133	.50	81	201	308	.76	7.8	35.57	71.98
B73x4	12480	8951	.47	10280	.50	5140	133	.53	80.3	202	300	.91	7.1	37.04	71.55
Mo17x17	12423	5203	.45	13588	.60	8153	137	.57	81.3	190	292	.92	8.10	31.06	61.45
Mo17xB73	12406	10697	.59	7126	.51	3634	130	.55	76.7	133	240	.71	7.39	36.07	72.18
B73x1	12391	7886	.40	11615	.51	5924	130	.54	80.7	191	285	.79	8.35	35.39	69.54
Mo17x4	12236	8524	.43	10929	.48	5246	133	.52	77.3	191	291	.74	6.31	37.39	73.55
B73x	12302	8096	.41	11394	.50	5663	136	.51	82.5	208	311	.89	7.76	34.86	69.32
Mo17x	10758	5613	.31	12113	.51	6155	138	.51	82.6	193	300	.90	7.74	35.24	68.30
CV	.169	.314	.03	.152	.07	.188	.03	.07	.030	.07	.05	.32	.072	.047	.039
lsd ($p \leq 0.05$)	2566	2402	.28	2303		1161			2.6	29	33	.03			

Table 3. Correlations among mean phenotypical values of the traits studied (* p≤0.05).

	tPDdm	ey	sy	ey/ty	Ddm	PDdm	har	df	eh	th	is'	CP	CF	NDF	Dcwc
tPDdm															
ey	.83*														
sy	50*	-.03													
ey/ty	.58*	.93*	-.54*												
Ddm	.13	-.27	.29	-.23											
PDdm	.45*	-.14	.92*	-.55*	.64*										
har	-.30	-.38*	.27	-.56*	-.33*	.09									
df	-.12	-.09	.08	-.34*	-.37*	-.07	.62*								
eh	.25	.40*	-.01	-.18	-.44*	-.19	.44*	.65							
th	.21	.29	.11	-.24	-.42*	-.08	.55*	.72*	.94*						
is'	-.54*	-.50*	-.15	-.13	-.09	-.15	.43*	.35*	.16	.20					
CP	-.34*	-.41*	-.05	-.51*	.25	.07	.10	.06	-.09	-.03	.48*				
CF	-.24	.12	-.44*	-.49*	-.63*	-.61*	-.05	-.01	-.04	-.11	.05	-.27			
NDF	.10	.45*	-.35*	.30	-.62*	-.53*	-.21	-.14	.04	-.06	-.26	-.50*	.79*		
Dcwc	.32	.15	-.01	.14	.84*	.30	-.65*	-.61*	-.54*	-.60*	-.35*	-.08	-.22	-.02	

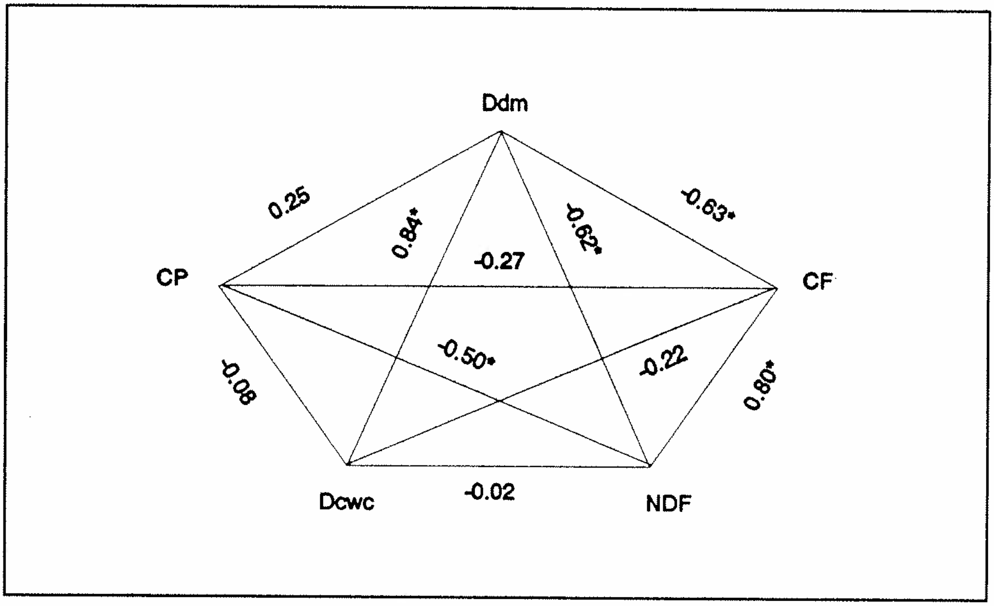

Figura 1. Correlations among estimators of stover nutritive quality.

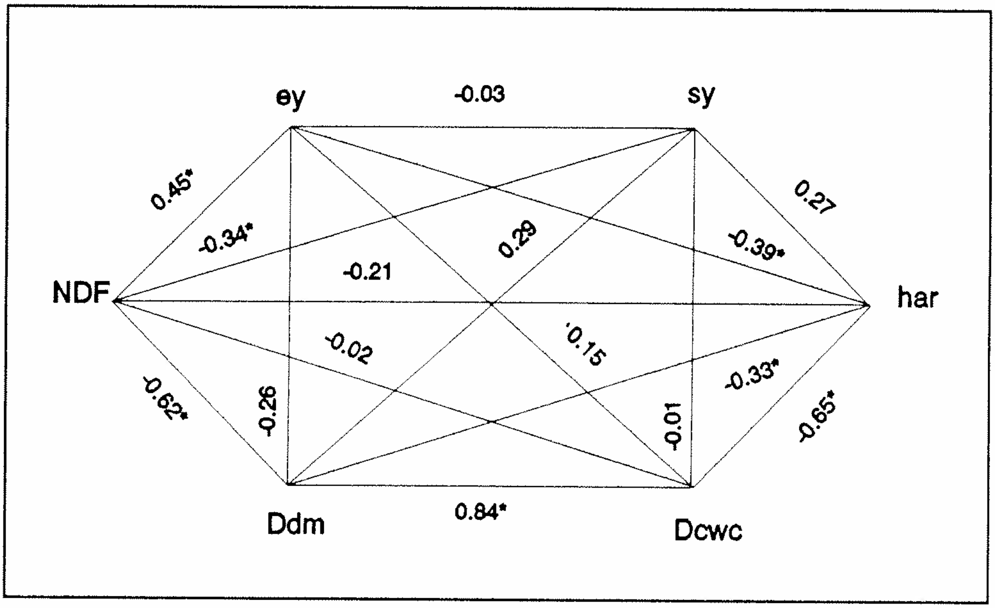

Figura 2. Correlations between nutritive quality and yield.

heritability of the digestibility of the stover was estimated at 0.79 by Zimmer and Wermke (1986).

Considering the correlations between the estimators of the nutritive quality of the stover and the vegetative and production parameters (Table 3 and Figure 2), we point out that both the digestibility of the cell wall and stover are negatively related to what could be called "exotic traits". In effect, both are negatively correlated to days to pollen shedding, days to harvest, smut index (only with Dcwc), height of the ear, and total height. As significant correlations were not found between these traits and NDF, it must be supposed that exotic materials are associated with low Dcwc, and this is responsible for the decrease in Ddm.

As a conclusion from these preliminary results, selection for greater ear yield in high stover-producing materials should be combined with a selection against NDF and/or in favour of Dcwc. Both factors, influencing the digestibility of the stover (Figure 2), have advantages and disadvantages. NDF is negatively correlated to stover yield and positively to ear production (Figure 2). Therefore, attempts at decreasing the proportion of cell wall content would probably also lower the yield of grain. On the other hand, performing a selection in favor of high stover yield might induce a reduction in the proportion of the cell wall content with a consequent increase in digestibility.

Selection in favor of increased Dcwc does not appear to affect important production traits (Figure 2) making it an optimum parameter. However, the use of this trait is restricted by its difficult estimation, much more complex than the simple determination of NDF. Ease of determination becomes especially important when a great quantity of samples must be handled.

Selection for stover digestibility, determinated for example by the cellulase method, is another option. Estimation of this parameter is somewhat more problematic than for NDF yet easier than for Dcwc. According to the correlations presented (Figure 2), such a selection should not influence the yield of either grain or stover.

RESUMEN

La introducción de material exótico de maiz cruzándolo con líneas puras adaptadas, permite la obtención de poblaciones semiexóticas de ciclo muy largo. Estas poblaciones resultan un punto de partida adecuado para la obtención de maices forrajeros de ciclo largo aptas para zonas de climatología benigna, ya que son muy productivas.

Se discuten, en base a resultados preliminares, los criterios a considerar para discriminar entre poblaciones semiexóticas teniendo en cuenta que debe optimizarse la producción de materia seca digestible.

La maximización de la producción de mazorca, a tenor de los resultados, aparece como un aspecto fundamental a pesar de tratarse de materiales con destino forrajero. La selección a favor de la digestibilidad de la parte vegetativa de la planta y/o de la pared celular, y/o contra el contenido en pared celular (FND), serían aspectos

complementarios a tener en cuenta como estrategia para mejorar la calidad nutritiva de la planta. Aunque se precisan ensayos adicionales, ninguno de estos criterios parece incompatible con incrementos de producción y la elección de uno u otro parámetro se ve fuertemente influenciada por el distinto grado de dificultad que presenta la estimación de cada uno de ellos.

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