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# Genetic differences in digestibility of forage maize hybrids*

B. Deinum[1] and J. J. Bakker[2]

[1] Agricultural University, Department of Field Crops and Grassland Science, Wageningen, Netherlands
[2] Goverment Institute of Research on Varieties of Cultivated Plants (RIVRO), Wageningen, Netherlands

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**Summary**

The collection of hybrids submitted for agronomic testing under Dutch conditions was also tested for whole crop digestibility. In both years, 1976 (warm) and 1978 (cool), highly significant genetic differences were found in digestibility. This digestibility was only partly correlated with ear percentage (r = 0.48 and 0.46), possibly because the hybrids had already been screened for this character. However, digestibility was highly correlated with digestibility of cell-wall constituents of the stover (r = 0.85 and 0.80 respectively). So, apart from breeding for yield and dry-matter content, breeding for stover quality appears to be very promising. However, this breeding will not be simple as a good correlation between stover quality and stover morphology has not yet been found.

## Introduction

It is generally accepted in warmer climates that the nutritive value of forage maize is positively correlated with grain content. However, in the cool and cloudy autumn of Western Europe only poor correlations between digestibility of the whole crop and ear content are found (Bunting, 1975; Gallais et al., 1976). Moreover, research in USA and Europe has shown that 'brown midrib' mutants are more nutritious than normal analogues because of reduced lignification and better digestibility of the cell-wall constituents of the stover (Muller et al., 1972).

To test the relevance of this information we investigated whether there are genetic differences in digestibility of forage maize in Holland and to what extent these differences are related to ear content or to cell-wall digestibility of the stover. This was tested on the hybrids submitted to RIVRO over two years, and the results are summarized in this paper.

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## Material and methods

The test was performed on 27 hybrids in 1976 and 29 hybrids in 1978 (FAO 200-270). Only those hybrids with a promising yield and dry-matter content were tested. The season of 1976 was extremely hot and dry, whereas the summer of 1978 was very cool.

In each year three locations were used for this trial: Heesch (sand) Zelhem (sand) and Bruchem (clay).

At harvesting, the hybrids were tested for yield of fresh and dry matter, ear content, dry-matter content of ear and stover and susceptibility to disease. For each hybrid at each location the samples of the 4 replicate plots of ear and stover were bulked prior to analysis. The stover samples of both years were analysed for organic matter, cell-wall constituents (cwc) and in vitro digestibility of organic matter according to the methods of Goering & van Soest (1970). In 1978 the ears were also analysed for in vitro digestibility.

Standard maize samples of known in vivo digestibility of organic matter ($D_{om}$) were included in the in vitro analyses to correct for possible differences in activity of rumen microflora etc. In 1976 the ears were assumed to have a $D_{om}$ of 83.0 %.

These data enable us to calculate the apparent digestibility of organic matter for the whole crop (% $D_{crop}$) and of the cell-wall constituents of the stover (% $D_{cwc}$). Percentage $D_{crop}$ can be used to calculate D value and net energy for lactation and fattening.

## Results and discussion

### *General data of the sites*

Table 1 presents the data on average yield, dry-matter content, ear contribution and % $D_{crop}$ for each location together with the coefficients of variation caused by the hybrids. It shows that there were considerable differences in yield and ear content

Table 1. Average yield and composition of maize at the 3 locations and overall mean in 1976 and 1978. The coefficients of variation, caused by the hybrids, are given in parenthesis.

| | Heesch | Zelhem | Bruchem | Mean |
|---|---|---|---|---|
| *1976* | | | | |
| DM yield (t/ha) | 7.1 ( 4.3) | 10.3 (5.0) | 13.4 (8.4) | 10.2 (6.9) |
| % DM | 30.3 ( 7.1) | 36.9 (5.5) | 37.5 (5.1) | 34.9 (5.8) |
| % ear | 45.6 ( 9.6) | 49.2 (8.2) | 62.7 (3.7) | 52.5 (5.9) |
| % $D_{crop}$[1] | 75.7 ( 1.0) | 74.7 (1.6) | 74.4 (1.1) | 75.0 (1.1) |
| *1978* | | | | |
| DM yield (t/ha) | 14.0 ( 4.7) | 17.2 (4.7) | 17.2 (4.3) | 16.1 (3.7) |
| % DM | 28.1 ( 4.8) | 31.7 (6.4) | 30.8 (6.2) | 30.1 (5.4) |
| % ear | 44.8 (12.5) | 48.6 (5.8) | 51.7 (5.2) | 48.4 (5.8) |
| % $D_{crop}$ | 74.4 ( 1.6) | 75.6 (1.5) | 74.5 (1.6) | 74.8 (1.4) |

[1] % $D_{crop}$ = apparent digestibility of organic matter of the whole maize crop.

Table 2. Statistical analysis on % $D_{crop}$ and % $D_{cwc}$.

| | % $D_{crop}$[1] | % $D_{cwc}$[1] |
|---|---|---|
| *1976* | | |
| Mean of all varieties | 75.0 | 67.8 |
| Means of two extreme varieties | 73.6-76.0 | 64.2-71.8 |
| LSD ($P < 0.01$) | 1.19 | 3.01 |
| *1978* | | |
| Mean of all varieties | 74.8 | 65.6 |
| Means of two extreme varieties[2] | 72.4-76.6 | 62.4-67.8 |
| LSD ($P < 0.01$) | 1.59 | 2.26 |
| P variety × year | 0.16 | 0.58 |
| F interaction | 1.49 | 0.85 |

[1] $D_{crop}$ = apparent digestibility of organic matter of the whole maize crop; % $D_{cwc}$ = digestibility of cell-wall constituents of the stover.
[2] The extreme varieties of 1978 were the same as those in 1976.

between the sites in 1976 because of drought, but there was hardly any difference in % $D_{crop}$.

*Digestibility of the hybrids*

Table 2 presents % $D_{crop}$ and % $D_{cwc}$ in 1976 and 1978 (average of the three sites) together with the range of digestibility among hybrids for each of these quality attributes, and the result of the statistical analysis. Both characters showed a rather small variety × year interaction. However this interaction was greater for % $D_{crop}$ than for % $D_{cwc}$. The high significance of the cultivar effect indicates great genetic differences with regard to digestibility. This was also evidenced from the reasonable

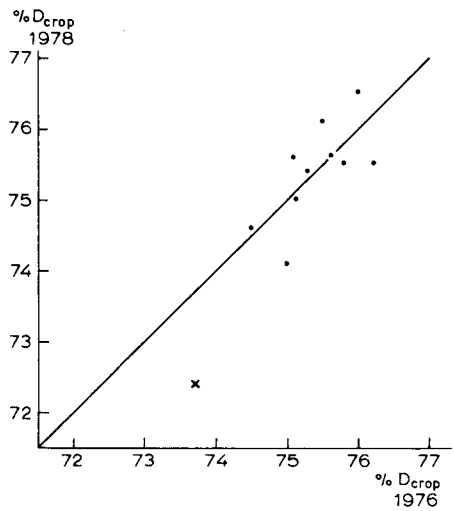


Fig. 1. The correlation between hybrid digestibility in the two years (X = hybrid with about 10 % inbred plants in 1978).

correlation of hybrids between sites (r = 0.7 to 0.8) to show that highly digestible hybrids on one field would probably be highly digestible when grown on another field. These correlations were found both in the warm year of 1976 and in the cool one of 1978. The correlation of those hybrids tested in both years was also rather high (Fig. 1); the deviations along the 1:1 line in this figure are partly due to random errors and also possibly due to hybrid × year (or temperature + drought) interactions.

*The origin of genetic differences in digestibility*

It is often suggested in the literature (Schmid et al., 1976) that a high ear content is desirable for silage quality and for digestibility. In these experiments almost all the factors that are responsible for % $D_{crop}$ showed genetic variation. Even % $D_{ear}$ varied as shown by two hybrids with a consistently lower digestibility by 2 % on all three fields in 1978. Variations in the other factors were greater.

Fig. 2 shows all relevant correlations, and reveals that they were almost identical in both years, despite the different weather conditions. The correlation between % $D_{crop}$ and % ear was about 0.5. This is low compared to the 0.67 of Schmid et al. (1976). However, ear content as a percentage of total shoot dry matter ranged from 11 to 67 in their trials whereas it ranged from 41 to 61 in our trials (Fig. 3a). It is not yet clear whether this low correlation is caused by the screening policy of plant breeders and RIVRO.

The other relevant correlation is that between % $D_{crop}$ and % $D_{cwc}$. This appears to be very high (r = 0.80 in 1978 and r = 0.85 in 1976; Fig. 3b). The correlation of 1976 would have been somewhat lower if the genetic differences in ear digestibility could have been incorporated. These correlations suggest that % $D_{cwc}$ explains about three times as much of % $D_{crop}$ as % ear so breeding for high % $D_{cwc}$ seems very ap-

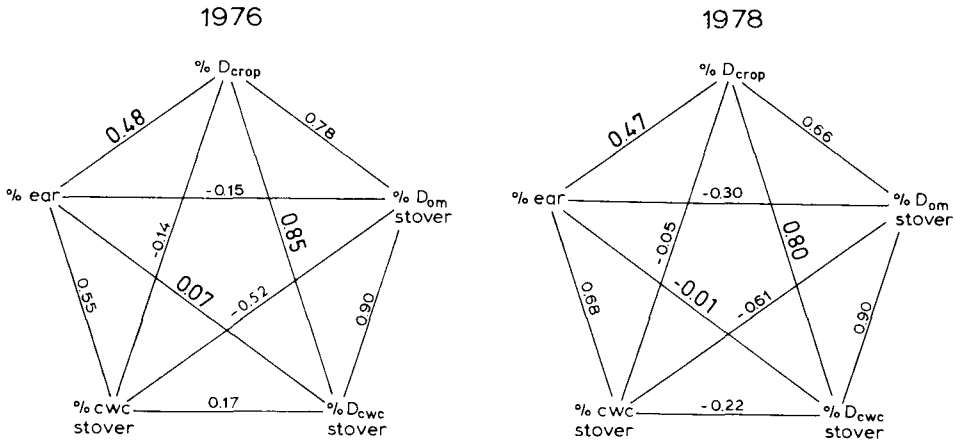


Fig. 2. Correlation coefficients between the different relevant constituents of maize in 1976 and 1978 (all constituents expressed in % of organic matter).

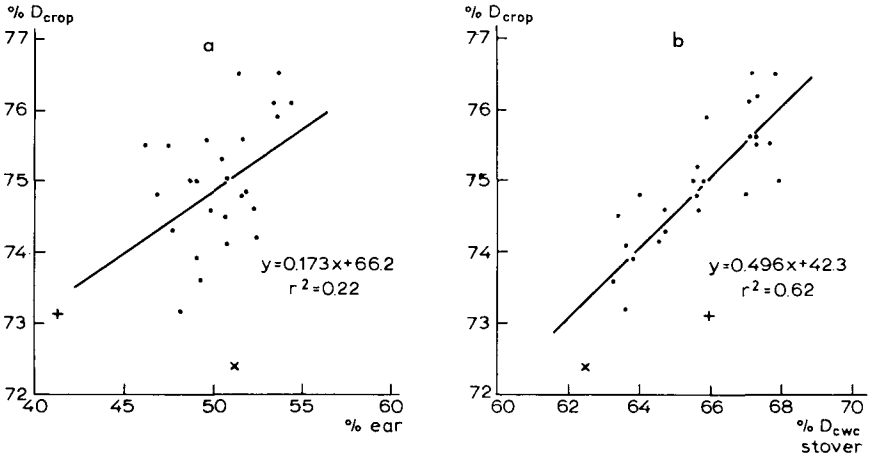


Fig. 3. Relation between % $D_{crop}$ with % ear and % $D_{cwc}$ in 1978 (all expressed in % of organic matter).

propriate in this group of hybrids. The combined effect of % $D_{cwc}$ and ear is shown in Table 3. These equations indicate that 1 % increase in % $D_{crop}$ would be achieved by an increase of 6 to 8 % in ear or by an increase of 2 to 3 % in % $D_{cwc}$.

Grain filling partly occurred from translocation of solubles from the stover as shown from the fair positive correlation between % ear and % cwc stover (Fig. 2).

The lack of correlation between % ear and % $D_{cwc}$ is very important. It indicates, at least in the Dutch climate, that early maturing hybrids with a faster grain filling do not necessarily show a greater lignification of the cell walls of the stover or a greater decrease in cell-wall digestibility. This lack of correlation also suggests complete independence of grain filling and % $D_{cwc}$.

Table 3. Regression of % $D_{crop}$ with some constituents.

| | $r^2$ | RSD |
|---|---|---|
| *1976* | | |
| % $D_{crop}$ = 0.134 (% ear) + 67.8 | 0.23 | 0.76 |
| % $D_{crop}$ = 0.354 (% $D_{cwc}$) + 51.0 | 0.72 | 0.46 |
| % $D_{crop}$ = 0.117 (% ear) + 0.341 (% $D_{cwc}$) + 45.5 | 0.90 | 0.28 |
| *1978* | | |
| % $D_{crop}$ = 0.173 (% ear) + 66.2 | 0.22 | 0.93 |
| % $D_{crop}$ = 0.496 (% $D_{cwc}$) + 42.3 | 0.62 | 0.64 |
| % $D_{crop}$ = 0.176 (% ear) + 0.500 (% $D_{cwc}$) + 33.2 | 0.85 | 0.41 |

% $D_{crop}$ = apparent digestibility of organic matter of the whole maize crop
% $D_{cwc}$ = digestibility of the cell-wall constituents of the stover

*Prospects for the plant breeder*

It has become evident that % $D_{cwc}$ is of major importance for the digestibility of forage maize. It is also possible that animal intake may be better with a higher % $D_{cwc}$ (Gallais et al., 1976). It would be very worthwhile, therefore, for the plant breeder to identify inbreds and hybrids in a visual way as is done for 'brown midrib' material. However, so far no visual aid or simple laboratory technique has been found in this material. We tested various correlations, but found no effect of plant height, dry-matter content of the stover, leafiness, resistance to stalk rot or to lodging.

There is, however, considerable heritability, not only because genetic differences in digestibility were consistent over the sites and the years, but also because the less digestible hybrids had some inbreds in common, and the more digestible hybrids had other inbreds in common. This heritability and its possible correlations with stem morphology will be tested further in a cooperative research project of the Agricultural University and two domestic plant breeders with two diallel crosses.

Whatever the outcome of this future research, it can be stated that apart from breeding for yield and dry-matter content (correlated with ear %) there is good prospect for success in breeding for better stover quality.

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