Carbon isotope discrimination in diverse canola germplasm

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ABSTRACT

A range of canola genotypes were grown in two field trials and in an irrigated rain-out shelter in 2008. Leaf samples at early- to mid-flowering were analysed for carbon isotope discrimination (CID) as a potential trait linked to water-use efficiency and hence drought tolerance. Significant genotypic differences for CID were observed in all environments. Further research is required to determine whether CID will be useful for breeding improved canola cultivars and how this character is genetically controlled.

INTRODUCTION

The search for plant traits that may have a positive influence on crop productivity in dry environments has become increasingly important for Australian plant breeders, plant physiologists, and geneticists. One such trait that has shown promise, particularly in cereal crops, is carbon isotope discrimination (CID). CID is related to water-use efficiency (WUE) via the basic process of photosynthesis and transpiration (Farquhar et al 1982; Farquhar and Richards 1984; Condon et al 1993). High WUE would be an advantage to crops under all regimes of water availability, from unlimited soil moisture (e.g. full irrigation) to severe drought.

In canola (*Brassica napus*) there are only few reports on CID and, with the exception of Condon (1993), all cast doubt as to it's usefulness in canola (e.g. Matus 1995). The aim of this current work was to see whether useful genotypic differences were present which might be exploited in Australian canola breeding programs.

MATERIALS AND METHODS

Dryland

The first source of material for CID analysis was a dryland (rain-fed) field trial at Wagga Wagga in 2008 (drought block). The details of this experiment and the genotypes included are described by Moroni et al. (2009, elsewhere in this volume). Leaf samples for CID were collected at early- to mid-flowering (between 60 and 65 on the BBDH development scale) by cutting 15-20 random fully-expanded young leaves from below the main raceme. One sample was taken per each plot. These leaves were dried at 70°C for over 48 hrs in a forced-air dehydrator. The samples were then ground to a fine powder (< 20 μm; Cyclotec Model 1093) and sent for isotope-ratio mass spectrometry. The samples were analysed in the laboratory over three days.

The second source of material was an 'historic trial' of 30 canola cultivars from Australia and Canada sown as three replicates in a 6 x 15 plot grid, with 1.5 x 9 m plots of 4 machine-sown rows. This experiment was grown in the same paddock at Wagga Wagga as the drought block described above. It was managed as above, and leaf samples for CID were taken when plots were at the early- to mid-flowering stage (between 60 and 65 on the BBDH scale). The genotype names are listed on the x-axis as part of Fig. 2.

Irrigated

Thirty-one genotypes were grown in a rain-out shelter (ROS) at Wagga Wagga in 2008. Genotypes were replicated twice, except TARCOOLA which had 3 replicates. The layout was a blocked 7 x 9 plot grid where each plot consisted of four single rows of plants spaced evenly –

10 cm apart within a row, and 20 cm between rows. The plants were drip irrigated so that soil water was not limiting during the vegetative phase of growth. Leaf samples for CID were taken and analysed as described above. The genotype names are shown on the x-axis of Fig. 3.

Data was returned as carbon isotope composition values ($\delta^{13}C$) which were converted to $\Delta^{13}C$ assuming an isotopic composition of the air of -8 mille. Analysis of $\Delta^{13}C \times 10^3$ was carried out in Genstat v11 software using REML to estimate spatial, laboratory and genotype effects.

RESULTS and DISCUSSION

Some genotypes were common to each of the three experiments. Genotype effects for $\Delta^{13}C \times 10^3$ were significant in all three cases (drought block, P<0.001; ROS, P=0.002; historic trial, P<0.001). For C3 plants typical values for $\Delta^{13}C \times 10^3$ are in the range 15 to 24. In the drought block experiment the mean genotype values ranged from 19.96 for CB-TELFER to 17.64 for OASIS-CL (the only *B. juncea* genotype in the experiment). The LSD (5%) = 0.40.

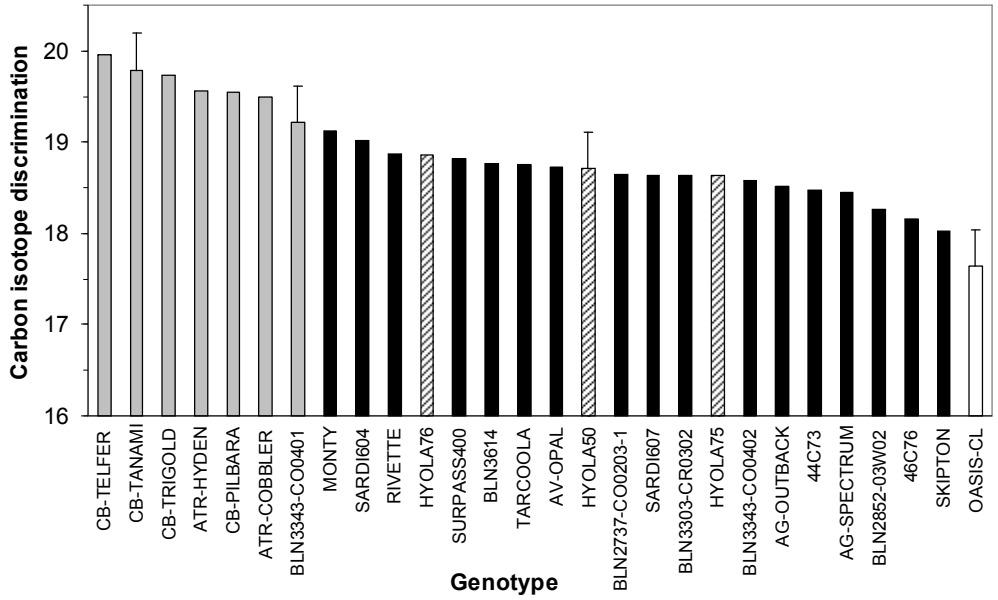

Fig. 1. Carbon isotope discrimination ($\Delta^{13}C \times 10^3$) predicted genotype means of 30 Brassica genotypes (all *B. napus* except OASIS-CL = *B. juncea*) grown in a field plot trial at Wagga Wagga, NSW in 2008. CID was measured on leaf samples taken at early- to mid-flowering. The LSD (5%) is given on selected genotypes to aid comparison. Shaded bars are seven triazine-tolerant (herbicide resistant) genotypes; hollow bar is OASIS-CL (*B. juncea*); and cross-hatched bars are F_1 hybrid cultivars.

In the historic trial the values for $\Delta^{13}C \times 10^3$ were generally higher, with less separation between genotypes (LSD[5%] = 0.64). AV-OPAL mean was = 20.92 and WESBELL = 19.27. In the ROS, the values were generally higher again with the mean for CB-TRIGOLD = 23.54, for SURPASS400 = 21.41, with LSD(5%) = 0.45. The ROS values were right at the top of the expected range.

The values for CID that we obtained in these trials are in the range similar to those reported by Condon (1993). Some genotypes had very low Δ values indicating that some current genotypes already have high transpiration efficiency. Condon (1993) calculated that if Δ were to be lowered by breeding from 20.5 $\times 10^3$ to 19 $\times 10^3$, then the relative gain in transpiration efficiency of leaf gas exchange would be about 25%. Such an increase would be expected to significantly improve yield. A low Δ value should mean that water-use efficiency in that genotype is higher than a genotype with high Δ, and the hope is that this is translated into improved grain

production. The CID dataset reported here is for only one season and further testing is being undertaken in 2009.

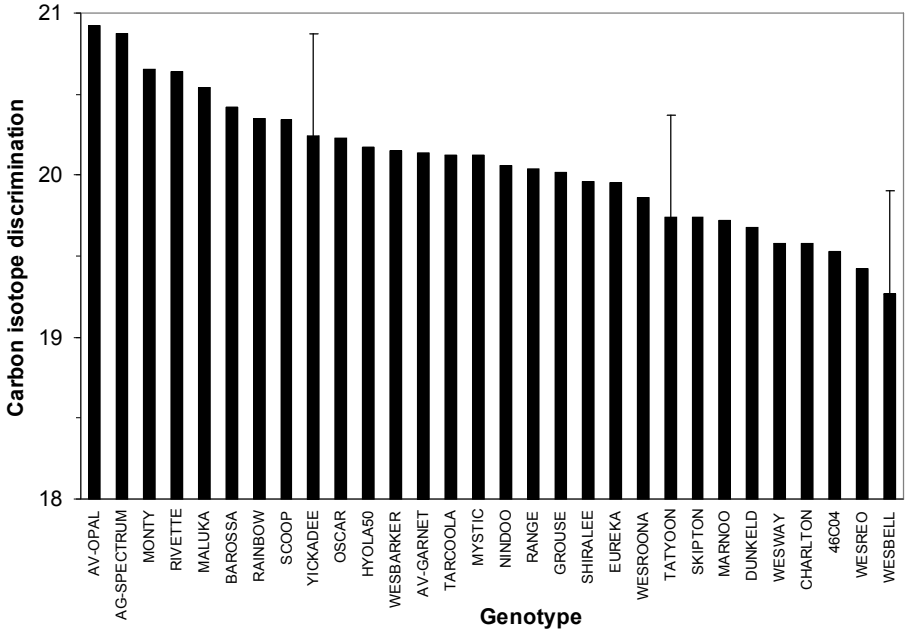

Fig. 2. Carbon isotope discrimination ($\Delta^{13}C \times 10^3$) predicted genotype means of 30 historic *Brassica napus* genotypes from Australia and Canada grown in a field plot trial at Wagga Wagga, NSW in 2008. CID was measured on leaf samples taken at early- to mid-flowering. The LSD (5%) is given on selected genotypes to aid comparison.

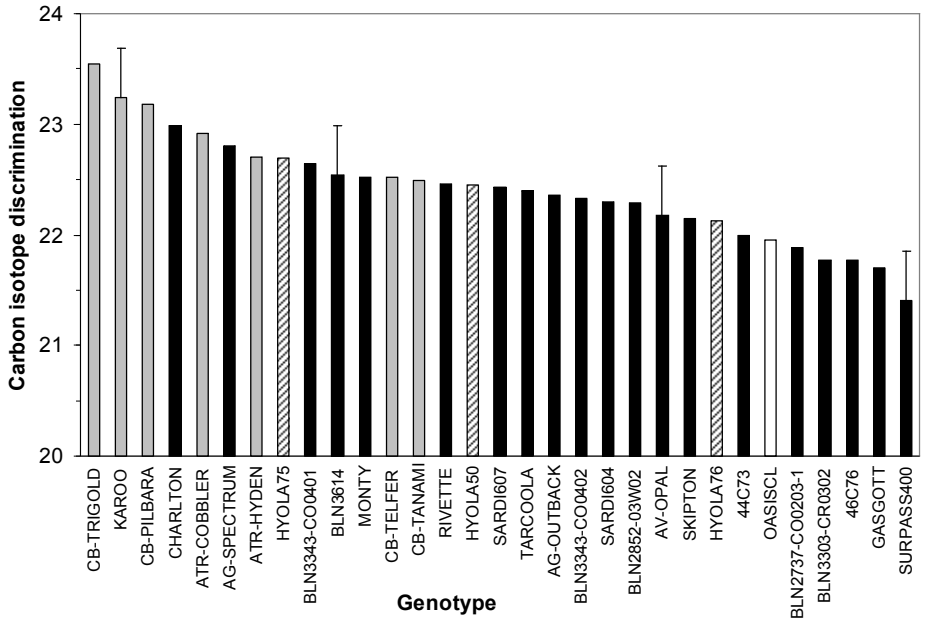

Fig. 3. Carbon isotope discrimination ($\Delta^{13}C \times 10^3$) predicted genotype means of 31 Brassica genotypes (all *B. napus* except OASIS-CL = *B. juncea*) grown in an irrigated rain-out shelter trial at Wagga Wagga, NSW in 2008. CID was measured on leaf samples taken at early- to mid-flowering. The LSD (5%) is given on selected genotypes to aid comparison. Shaded bars are seven triazine-tolerant (herbicide resistant) genotypes; hollow bar is OASIS-CL (*B. juncea*); and cross-hatched bars are F_1 hybrid cultivars.

The triazine-tolerant genotypes are known to have an impaired (low) photosynthetic capacity as a result of the reduced efficiency of photosynthesis II system. It is clear from this study that this low photosynthetic capacity also affects CID and may be the mechanism responsible for TT canola having reduced yield when compared to conventional types, at least in the absence of weeds.

These data have demonstrated that genotypic differences are present between canola genotypes and this has prompted further work to understand this character and its relationship with yield and other plant attributes.

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