EVALUATION OF CARBON ISOTOPE DISCRIMINATION AS SELECTION CRITERIA FOR YIELD AND WATER USE EFFICIENCY IN LENTIL.

A. MATUS*, C. VAN KESSEL and A. E. SLINKARD. University of Saskatchewan, Saskatoon, SK., Canada.

INTRODUCTION

During photosynthesis in C_3 plants the stable isotope ^{13}C is discriminated against, relative to ^{12}C. Thus, C_3 plants contain a smaller ratio of ^{13}C to ^{12}C than is found in the CO_2 of the air. Carbon isotope discrimination (CID) decreases as water use efficiency (WUE) increases, i.e., CID will be lowest in those plants that fix the most carbon per unit of water transpired (Farquhar and Richard 1984). They reported a negative correlation between CID and WUE for wheat grown in a greenhouse. If WUE improved under drought stress, then both DM and seed yield should increase unless harvest index is reduced. That is, CID should be negatively correlated with both DM and seed yield, suggesting that CID could be used to indirectly select for seed yield. However, first CID must be correlated with seed yield under stress, have higher heritability than seed yield and be easier and cheaper to measure than seed yield (Baker 1992). The objectives of this study were to: 1) screen lentil cultivars for genetic differences in CID, 2) determine the magnitude of the cultivar by soil moisture level interaction for CID and, 3) Determine the relationship between CID and both WUE and DM yield of lentil across soil moisture levels.

MATERIALS AND METHODS

Ten diverse lentil cultivars were grown in a greenhouse in soil-filled pots during the summers of 1991 and 1992 at three soil moisture levels. The three soil moisture levels were 100% field capacity (FC), 50% FC and 30% FC. Soil moisture levels were allowed to drop to 80% FC, 50% FC and 30% FC before they were brought back to 100% FC. The experimental design was a split-plot with four replications. Soil moisture levels were the main plots and cultivars were the subplots treatments. One blank pot for each replication monitored water loss to provide an estimate of evaporation from the soil surface. Water loss was determined gravimetrically. Above ground dry matter at 80% flowering (DMF) was harvested and dry weight determined. A composite sample of dry leaves was analyzed for CID. WUE was determined as above ground dry matter (DMF) production (g) divided by total water used (kg).

RESULTS

Significant differences among lentil cultivars were observed for DMF (Table 1). Soil moisture levels had a significant effect on average DMF and CID. Cultivar means for DMF increased as soil moisture levels increased from 30 to 50 to 80% FC. CID decreased significantly as soil moisture level decreased from 80 to 50 to 30% FC. Increasing drought stress increased WUE in one year and decreased it the other year. The cultivar by soil moisture level interaction was significant for DMF, but not for WUE or CID.

CID was not correlated with WUE or DMF at any of the soil moisture levels or when averaged over soil moisture levels or years (Table 2).

DISCUSSION

For a physiological trait to be useful in breeding for yield three conditions must apply: 1) genetic variability must be present for the trait, 2) the trait must be correlated with yield and 3) the trait must be easier and cheaper to measure than yield. Lentil cultivars did not differ in WUE or CID when averaged over soil moisture levels or years. The correlation between CID and WUE or DMF was not significant at any of the soil moisture levels or when averaged over soil moisture levels or years. Moreover, CID is time consuming and more expensive to measure than yield. These results indicate that CID does not meet the basic requirements for use in selecting for improved DM yield or WUE.

Table 1. Mean above ground dry matter per plant at flowering (DMF), water use efficiency (WUE), and carbon isotope discrimination (CID) of leaves at flowering for ten lentil cultivars grown under well-watered (Wet), medium-watered (Med) and drought-stressed (Dry) conditions in pots in the greenhouse (summers, 1991 and 1992).

	DMF (g)				WUE (g kg^{-1})				CID x 0.001			
Cult.	Wet	Med	Dry	Mean@	Wet	Med	Dry	Mean@	Wet	Med	Dry	Mean@
1	3.17	1.75	0.77	1.90	3.25	3.96	4.33	3.85	22.05	20.75	17.15	19.98
2	3.40	1.93	0.76	2.03	3.43	4.60	4.32	4.11	21.65	20.47	17.07	19.73
3	3.44	2.19	0.76	2.13	3.24	4.51	4.40	4.05	21.76	20.04	17.10	19.64
4	2.27	1.32	0.64	1.41	3.74	4.69	4.38	4.27	22.16	20.78	17.04	20.00
5	3.23	1.84	0.56	1.86	3.17	3.40	3.92	3.70	21.82	20.43	17.03	19.76
6	3.42	1.95	0.66	2.01	3.11	4.03	5.09	4.08	21.87	20.53	16.98	19.79
7	2.90	1.87	0.64	1.80	2.72	3.77	3.61	3.37	22.14	20.24	17.46	19.95
8	3.37	1.97	0.62	1.99	2.92	4.45	4.41	3.93	22.27	20.53	17.25	20.02
9	2.56	1.78	0.70	1.68	3.20	4.58	4.03	3.94	22.19	20.56	17.00	19.86
10	2.55	1.98	0.60	1.71	2.87	4.70	4.13	3.90	22.57	20.84	17.09	20.17
Mean	3.03	1.86	0.67	1.85	3.16	4.33	4.26	3.92	22.03	20.52	17.12	19.89

Source of variation	DF	MS	MS	MS
Water level	2	111*	34.0	507.0**
Years*water levels	2	25**	122.0**	1.0
Cultivars	9	1*	1.5	0.6
Year*cultivar	9	0.3	0.8	0.3
Water level*cult.	18	0.4*	0.7	0.3
Year*water level*cult.	18	0.2	1.4**	0.3
Error	162	0.2	0.6	0.2
C.V. (%)		20.0	20.0	2.3
St. error (cultivar)		0.1	1.2	0.1

@ Mean over the three water levels.
*, ** Significant at the 0.05 and 0.01 level, respectively.

Table 2. Correlations+ between carbon isotope discrimination (CID) of above ground dry matter at flowering and dry matter yield at flowering (DMF) and water use efficiency (WUE) in well-watered (Wet), medium-watered (Med) and drought-stressed (Dry) plants of ten lentil cultivars grown in pots in the greenhouse (summers, 1991 and 1992).

	Water levels			
Trait	Wet	Med	Dry	Mean@
DMA	-0.604	-0.579	-0.117	-0.588
WUE	-0.427	0.290	-0.535	-0.166

\+ Calculated over 10 cultivars (df=8).
@ Mean over the three water levels.

CONCLUSIONS

1. Lentil cultivars did not differ in WUE or CID when averaged over soil moisture levels or years.
2. The cultivar by soil moisture level interaction for CID was not significant.
3. No relationship was observed between CID and DMF or WUE in lentil when averaged over soil moisture levels or years.
4. These results indicate that CID cannot be used under greenhouse conditions to indirectly select for WUE or DMF in lentil.

LITERATURE CITED

Baker, R. J. 1992. Selection indices for stress tolerance. Second International Food Legume Research Conference, Cairo, Egypt. 11-16 April, 1992.

Farquhar, G. D. and R. A. Richard. 1984. Isotopic composition of plant carbon correlates with water-use efficiency of wheat genotypes. Aust. J. Plant Physiol. 11:539-552.