The Role of $\Delta^{13}C$ as a Means of Screening for Phenotypic Traits and Water Use Efficiency in Summer Wheat (*Triticum aestivum* L.)

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Introduction

At the conference in Rio de Janeiro in 1992 'sustainable agriculture' was postulated as the means to meet the need for food of approximately 9.7 billion people by 2030 (World Bank, 1992). Breeding of low-input varieties is considered of great promise if associated with improvements in management techniques.

At present, prospects of higher productivity through increasing use of fertilizers and pesticides, new varieties and modern agricultural management techniques are not exhausted (Evans, 1987). In the Northern Indian states Madhya Pradesh, Punjab and Haryana nearly by 50% 56 Mio. t (FAO 1993) of the total wheat production in India is produced with high input levels. However, problems due to decreasing soil fertility, loss of soil structure, leaching of fertilizer and increasing resistance to pesticides is becoming more evident. The adaptability of a plant to future reductions in inputs is therefore gaining in importance.

A collaboration between the Department of Plant Breeding, Haryana Agricultural University at Hisar/India and the Institute of Agronomy in the Tropics (IAT)/Germany was initiated in 1991. The aim was to evaluate the adaptation of summer wheat genotypes (*Triticum aestivum* L.) to drought conditions. The role of the root system and the infection of the roots by the indigenous arbuscular mycorrhizal fungi (AMF) population in efficient nutrient and water uptake was investigated by undertaking several field experiments.

Fig. 1: Map of India

Material and Methods

At the experimental farm of the Haryana Agricultural University in Hisar/North India (Fig. 1), field trials were conducted from 1991-93 under restricted water and fertilizer supply. The irrigation was reduced to two-fold irrigation (crown-root-stage, boot-leaf-stage). A full (120 kg N, 60 kg P, 25 kg Zn) or half dose of fertilizer was applied at seeding (P, Zn) or split evenly between seeding and heading (N).

Twenty summer wheat genotypes were evaluated in 1991/92: two older Indian varieties, two of the first High Yielding Varieties (HYV's) released in India, thirteen improved HYV's, two lines from CIMMYT and the Japanese variety 'Norin 10'. In 1992/93 the number of varieties was reduced to nine genotypes.

The soil at the experimental farm is an Aridisol. The sandy-loamy soil had a high pH (7.8) and a high amount of total P (540 - 640 mg kg-1) in contrast to a low plant available P (3.5 - 5.1 mg kg-1 Olsen-P).

During the time of wheat growth from December to April three sprout and root samples were taken (tillering, boot-leaf-stage, flowering). The root length was calculated by using the line intersect method (Tennant, 1975). Afterwards the root samples of one plot (10 plants) were pooled and the infection with the indigenous AMF was estimated after the roots were stained with trypan blue (Phillips and Haymann, 1970) and expressed as percentage of root infection (Giovanetti and Mosse, 1980).

The water-use efficiency (WUE) was measured by ^{13}C discrimination and denoted as Δ.

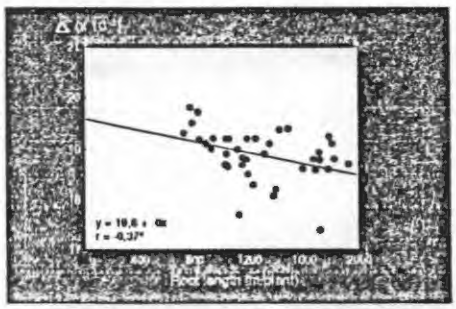

Fig. 2: Correlation between root length and carbon isotope discrimination of 20 wheat varieties at high and reduced fertilizer input (* sign. for P<0.05, n=40)

Results

The carbon isotope discrimination (Δ) was negatively correlated (r=-0.37*) with root length (Fig. 2) and positively correlated with aboveground biomass (0.42**) and grain yield (0.43**) at high and reduced fertilizer input under restricted irrigation (Fig. 3). Since Δ is known to be strongly negatively correlated with WUE, it appears that Δ may be used as an effective selection criteria for adaptive phenotypic traits.

The Δ-value of a genotype with an intensive root system but with a low grain yield was often found to be the same as a genotype having a small root system but high aboveground biomass. In that case Δ seems to be a useful selection criteria for higher total biomass. Hence, Δ as selection standard for high WUE in wheat breeding programs where root studies are not practical, the selection should be undertaken in an almost homogenous population where large variation in rooting pattern is not to be expected.

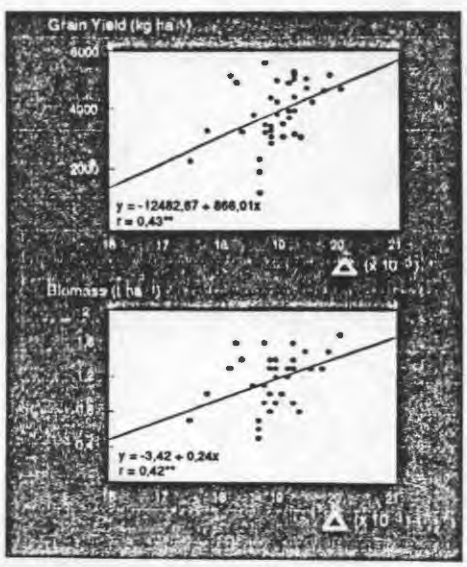

Fig. 3: Correlation between grain yield, biomass and carbon isotope discrimination of 20 wheat genotypes at high and reduced fertilizer input (** sign. for P<0.01, n=40)

In the field trial with nine cultivars in 1992/93 under restricted irrigation there was a significant difference in rooting patterns and % infection rate with AMF between the genotypes (Tab. 1). The total root lengths (m plant^{-1}) at Anthesis of the highest yielding genotypes ('R 3077', 'IWP 72' and 'WH 157') were not significantly different (Tab. 1). However the % infection of the wheat roots at Anthesis between the above mentioned cultivars differed significantly. 'IWP 72' reached a Δ-value of 18.824 with low % infection rate and the same root length as 'WH 157' whereas the cultivar 'WH 157' had a significantly higher % infection with AMF and a significantly lower Δ (18.402). It appeared that different Δ-values are related to contrasting infection rates with the indigenous AMF.

'IWP 72' and 'R 3077', two cultivars with different rooting patterns, showed similar WUE. The higher infection with AMF of 'R 3077' in comparison to 'IWP 72' seemed to be compensation for the lower root length. Thus, variation in mycorrhizal dependence between wheat cultivars may need to be considered in breeding programs when using Δ as a selection criteria for better WUE.

Tab. 1: Grain yield (kg ha^{-1}), infection with AMF (%) at Anthesis, root length (m plant^{-1}) at Anthesis and carbon isotope discrimination of 9 wheat genotypes at high and reduced fertilizer input under restricted irrigation (LSD 0.05)

Variety	Grain yield	% AMF infection	Root length	Δ x 10^{-3}
IWP 72	6720	17	1319	18.824
PUW 226	4990	26	1155	18.370
S 848 A1	4370	34	1148	18.580
WL 711	5820	22	1405	18.756
Hartac	5320	28	1424	18.611
HD 2285	4750	33	947	18.255
C 306	5160	29	1432	18.698
WH 157	6070	33	1258	18.402
R 3077	6900	38	1013	18.800
LSD (0.05)	1251	[illegible]	312	[illegible]

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