MORPHO-PHYSIOLOGICAL TRAITS OF THE ROOT RELATED TO PRODUCTIVITY IN SUGAR BEET

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ABSTRACT

The identification of adaptive traits involved in the response to water-nutritional stress is necessary for maintaining crop productivity at sustainable levels. The objective of this work was to determine: (1) the morpho-physiological traits - "root elongation rate" and "nitrate uptake rate" - involved in nutrient acquisition; (2) their relationship to seed quality and productivity. These traits were measured in three sugar beet varieties characterized by different sugar production ability. A significant correlation between root elongation rate and nitrate uptake rate was evidenced. The varieties characterized by higher root elongation rate and nitrate influx to the root after nutritional stress were those that showed the highest sugar yield. These traits are to be considered morpho-physiological markers of productivity.

ABRÉGÉ - CARACTÈRES MORPHO-PHYSIOLOGIQUES DE LA RACINE LIÉE A LA PRODUCTIVITÉ EN BETTERAVE A SUCRE

L'identification de caractères adaptatifs impliqués dans la réponse au stress nutritionel est nécessaire pour maintenir la productivité des plantes à des niveaux acceptables. L'objectif du présent travail était de déterminer: (1) les caractères morpho-physiologiques « d'allongement de la racine » et « taux d'assimilation du nitrate » impliqués dans l'absorption des nutriments; (2) leurs liens avec la qualité de la semence et avec la productivité. Ces caractères furent mesurés après un stress hydrique sur troi variétés de betteraves sucrières différentes par leur aptitude à produire du sucre. Une corrélation significative entre l'allongement de la racine et l'absorption des nitrates a été démontrée. Les variétés caractérisées par un grand taux d'allongement de racine et un afflux de nitrat élevé dans la racine après le stress nutritionel étaient celles qui ont donné le meilleur rendement en sucre. Ces caractères sont à considérer comme des marqueurs de la productivité.

KURFASSUNG - MORPHO-PHYSIOLOGISCHE MERKMALE DER WURZEL BEZOGEN AUF PRODUKTIVITÄT IN DER ZUCKERRÜBE

Für die Erhaltung eines guten Ertragsniveaus ist es notwendig, die Eigenschaften zu identifizieren, die an der Reaktion auf Wasser- und Nährstoffstress beteiligt sind. Das Ziel dieser Arbeit war:

(1) die Bestimmung der morpho-physiologischen Eigenschaften „ Wurzelverlängerungrate" und „Nitrataufnahmerate" (2) die Feststellung ihres Einflusses auf die Samenqualität und Produktivität. Beide Eigenschaften wurden gemessen nach Wasser- und Nährstoffstress bei 3 Zuckerrübensorten, die sich durch unterschiedliche Produktivität auszeichneten. Dabei könnten eine signifikante Korrelation zwischen Wurzelverlängerungrate und Nitrataufnahmerate nachgewiesen werden. Die Sorten mit der höchsten Wurzelverlängerungrate und Nitrataufnahmerate zeigten auch den höchste Zuckerertrag. Daher sind diese Eigenschaften als morpho-physiologische Marker für die Produktivität zu betrachten.

INTRODUCTION

The potential yield of the cultivated plants is higher than the realized yield due to water-nutritional stress (Blum, 1988; Wallace, 1989; Evans & Fischer, 1999). In order to reduce such difference it is necessary to study the traits that better allow adaptation to the variations of environmental conditions.

Research carried out by the *Dipartimento di Biotecnologie Agrarie* has allowed the identification, in maize and wheat, of some morpho-physiological traits of the nutrient acquisition related to productivity and involved in the mechanisms of adaptation to water-nutritional stress (Saccomani *et al.*, 1981; Saccomani & Ferrari, 1989; Cagnin *et al.*, 2001).

The objective of this study was to examine in three genotypes of sugar beet (*Beta vulgaris* subsp. *vulgaris* L. Sugar Beet Group) characterized by different root and sugar yield, the relationships among the "root elongation rate", "root/ shoot ratio", "nitrate uptake rate" traits, and the influence of qualitative characteristics of the seed on the above traits.

The study of the response of the above-mentioned parameters to nutritional stress could allow the identification of traits useful for the selection of genotypes that are better adapted to the fluctuations of nutrients concentration in the soil.

MATERIALS AND METHODS

The sugar beet cultivars Aaron, L002 and Rodolfo of Lion Seeds (Maldon, UK), which are characterized by different productivity and high (Good) and low (Poor) seed quality, have been used (Tab. 1).

One hundred seeds from each cultivar were germinated on blotter paper in the dark at 20°C. Three-day-old seedlings with primary roots of 10 to 20 mm were

transferred, inside pleated paper, to hermetic boxes for the measurement of the root elongation rate, which was carried out after three days, and positioned on plastic tanks over an aerated solution containing 400 µM $Ca(Cl)_2$, 200 µM KCl, 200 µM $MgSO_4$, 40 µM KH_2PO_4 and microelements, such as those described by Arnon & Hoagland (1940) for the measurement of the nitrate uptake rate. The boxes and the tanks were placed in a growth chamber at 25/18 °C, and 70/90% relative humidity within a 14 h light (60 W m^{-2}) and 10 h dark cycle. Sixteen-day-old nitrate depleted seedlings were transferred to a complete nutrient solution where chloride was replaced by nitrate (600 µM) in order to evaluate the nitrate uptake rate through nitrate disappearance from the uptake solution at 12 min over a 60 min period. Its concentration was determined using an Uvikon 922 spectrophotometer (Kontron, France) at 210 nm. The experiments were replicated 5 times. Each experiment was run in duplicate. The data was subjected to ANOVA using PLABSTAT software (Utz, 1991).

RESULTS AND DISCUSSION

Significant differences ($P < 0.05$) exist for the "root elongation rate" and "nitrate uptake rate" traits among the three sugar beet genotypes examined (Tab. 2).

The different characteristics of the seed do not influence the productivity of the three genotypes and the morpho-physiological traits examined. This could depend on the reduced qualitative differences of the seed between the Poor and Good fractions.

The nitrate uptake rate is correlated ($P < 0.01$) with productivity as observed in maize from Malagoli *et al.* (1993) (Fig. 1A and 1B). A significant relationship ($P < 0.05$) between this parameter and the root elongation rate was observed (Fig. 2).

The association of these two traits can also be defined, as "plastic response to stress". This is because it allows the plants to overcome the conditions of nutritional stress, increasing the volume of soil explored by the roots, as well as increasing the recovery rate of the internal concentration of the nutrients back to the normal conditions of fertility, as observed by Zhang & Forde (2000).

Therefore, the root elongation rate and the nitrate uptake rate, measured after deprivation, are morpho-physiological traits highly involved in the mechanisms of adapting to nutritional stress.

Such traits can assume the role of useful indexes for the selection of genotypes adapted to conditions of reduced water-nutritional availability.

Table 1. Characteristics of the seed and productivity parameters of the three genotypes examined. Yield data were obtained by Lions Seeds from field experiments conducted at three locations from 2000 to 2002.

	Seed size (mm)	1000 seed weight (g)	Root yield (t/ha)	Sugar content (%)	Sugar yield (t/ha)
Aaron Poor	2.75 - 3.25	11.0	77.7	15.4	12.0
Aaron Good	3.5 - 4.0	14.2	80.1	15.5	12.4
L002 Poor	< 2.0	10.4	69.2	15.8	10.9
L002 Good	> 2.5	14.4	69.9	15.7	11.0
Rodolfo Poor	< 3.0	10.0	63.7	15.2	9.7
Rodolfo Good	> 2.5 - 2.75	14.2	65.0	15.2	9.9
[1]L.S.D.		3.1	5.4	0.4	0.9

[1]*Least significant difference (P= 0.05)*

Table 2. Morpho-physiological traits determined in the three genotypes examined. Standard errors of mean ranged from 3 to 10 percent of the data reported.

	Root elongation rate (mm/d)	Root (g)	Shoot (g)	Root/Shoot	Nitrate uptake rate (nmoles/min/plant)
Aaron Poor	7.3	28.1	52.3	0.538	0.399
Aaron Good	7.4	27.3	53.2	0.509	0.397
L002 Poor	5.8	21.9	40.5	0.550	0.371
L002 Good	5.5	21.0	42.5	0.500	0.384
Rodolfo Poor	5.1	19.9	41.3	0.488	0.356
Rodolfo Good	5.0	24.2	48.1	0.500	0.363
[1]L.S.D.	0.4	5.3	9.8	0.038	0.012

[1]*Least significant difference (P= 0.05)*

Figure 1. Correlation between productivity parameters and nitrate uptake rate.

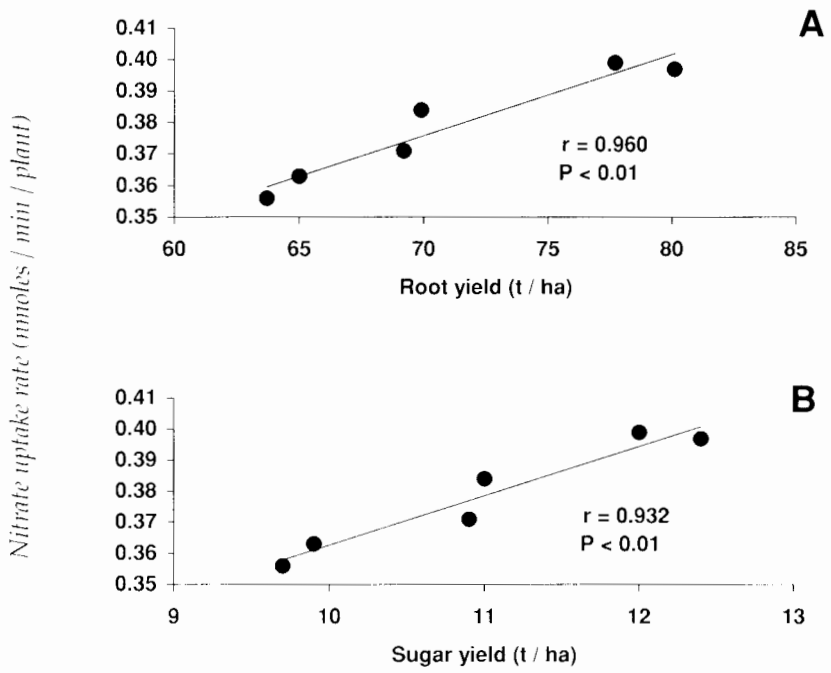
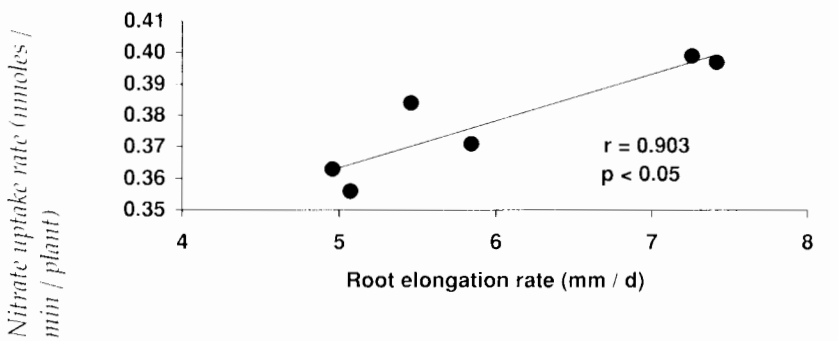


Figure 2. Correlation between root elongation and nitrate uptake rate.



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