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Durum wheat growth analysis in a semi-arid environment in relation to crop rotation and nitrogen rate

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SUMMARY – A research on durum wheat growth analysis was carried out at Sparacia farm (37°37'N, 13°42'E) during the 2000-01 and 2001-02 seasons in a typical semi-arid environment. The objective of this research was to determine the effects of crop rotation (continuous wheat and wheat-pea rotation) and N fertilizer rates (0, 60 and 120 kg/ha) on growth of four durum wheat varieties, characterized by different productive ability and adaptation. A split-split-plot design with three replications was used. The study highlighted the role of the crop growth rate (CGR) index in order to enable a better knowledge of the relationship among crop techniques and wheat yield response.

Key words: Growth analysis, crop rotation, nitrogen fertilization, durum wheat.

RÉSUMÉ – *"Analyse de la croissance du blé dur dans un environnement semi-aride par rapport à la rotation des cultures et au taux d'engrais azoté". La recherche sur l'analyse de croissance du blé dur a été effectuée à la ferme Sparacia (37°37'N, 13°42'E) pendant les campagnes 2000-02 dans un environnement semi-aride typique. L'objectif de cette recherche était de déterminer les effets de la rotation des cultures (rotation continue de blé et de blé-pois) et des taux d'engrais azoté (0, 60 et 120 kg/ha) sur la croissance de quatre variétés de blé dur, caractérisées par des capacités de production et d'adaptation différentes. Le plan expérimental employé a été le split-split-plot avec trois répétitions. Les résultats de cette étude ont accentué le rôle de l'index du taux de croissance de la culture, permettant une meilleure connaissance du rapport entre les techniques agronomiques et la réponse du blé.*

Mots-clés : *Analyse de croissance, rotation des cultures, engrais azoté, blé dur.*

Introduction

The study of the crop total dry matter dynamics accumulation is an important investigation tool for the determination of a better agronomic management. Application of this methodology can give a valid contribution to the understanding of the relations between agronomic and environmental factors and crop yield. Total dry matter accumulation trend, as described by a mathematical function adapted to the experimental data, allows an easier interpretation of the phenomenon, using growth adopted function parameters.

The functional approach allows, moreover, a clearer and immediate interpretation of the accumulation trend, that is determined by all experimental data, removing therefore the unfailing oscillations (Evans, 1972); this approach is also useful for an easier comparison between the different studied treatments (Vannella, 2002).

In the latter decades, many authors proposed different growth functions (Venus and Causton, 1979; Hunt and Venus, 1981), some of which were characterized from parameters with a clear biological significance. In this research the function suggested by Vannella (2002) was used, modifying the Richards function (1959) and introducing new parameters characterized by a specific biological meaning.

The aim of this paper is to evaluate, on durum wheat, the effects of crop rotation and nitrogen fertilization on the dry matter accumulation dynamics.

Materials and methods

The trial was carried out during 2000-01 and 2001-02 on the Experimental Farm Sparacia (AG, 37°37'N, 13°42'E) of the Department ACEP of Palermo University, site representative for durum wheat cultivations in the inland hilly Sicily, characterized by a sub arid climate with a yearly rainfall mean of about 500 mm concentrated in the fall-winter period, with minimum and maximum temperature means respectively of 9 and 21 °C. The trial was carried out on a Eutric Vertisol, representative of the pedotype of the area, according to World Reference Base on Soil Resources (WRB), set on a slight slope.

The trial consisted of a split-split-plot design with three replications in which four durum wheat varieties (Appio = V1, Creso = V2, Valbelice = V3, Simeto = V4), three nitrogen fertilization (N0 = control, N60 = 60 kg/ha, N120 = 120 kg/ha) and two crop rotations (wheat-legume = W-L, continuous wheat = W-W) were combined.

The durum wheat sowing took place on 9 December 2000 in the first year and in the second on 1 January 2002 using 350 germinable seeds/m^2 in rows 25 cm apart. The nitrogen fertilizer was applied, in both years; 50% of the amount at sowing time and the other 50% at tillering stage.

Plant sampling was carried out in six different stages: tillering, stem elongation, booting, flag leaf, kernel filling and ripening. Upon sampling after separation of the leaves, stems and ears, biomass accumulation was determined.

To describe the biomass accumulation trend the following function was used:

$$Y = a[1 + (m - 1)e^{c(1-x/q}]^{1/(1-m)}$$

where:

Y = biomass value (kg/ha)
a = theoretical yield attainable
m = defined interval 0 < m < 1 and 1 < m
c = determines the trend of the absolute growth rates (AGR)
q = coordinate of the inflexion point

Results

The ANOVA, carried out for individual year and periods of sampling, emphasized main and interaction effects on dry matter accumulation, with the exception, in the first year, of the tillering, stage where crop rotation and nitrogen fertilization rates were not significant. In the second year only C x N interaction at grain filling stage was not significant (Tables 1 and 2). The parameters showed different trends in the two-years trial. In the first year, the crop rotation with legume (W-L) showed a higher accumulation of total dry matter (t.d.m.), in comparison to continuous wheat (W-W), whereas in the second year higher accumulation of t.d.m. was observed in W-W (Figs 1a and 2a). The highest values of the parameter "a" were observed, in the first year, in W-L (a = 16115.9) that reached, about 10 days before W-W, the maximum increase of dry matter accumulation (parameter "Q"; Table 3). Varieties also showed significant differences for biomass accumulation. In the first year, variety V3 showed a marked difference from the others ("a" = 15206.7 kg/ha), and 29-days of the maximum increase of dry matter accumulation anticipation in comparison to V4 (Figs 1b and 2b). The trend of biomass accumulation in relation to the different N-treatments, in the two years, was markedly different. In the first year a strong differentiation was observed in the fertilization treatments from 100 days after sowing, whereas, in 2001-02 biomass accumulation was similar for both nitrogen treatments (Figs 1c and 2c).

Table 1. Analysis of variance of dry matter at the different stages (2000-01)

	Tillering	Stem elon.	Booting	Flag leaf	Filling grain	Ripening	Area Leaf
Crop rotation (C)	NS	**	**	**	**	**	**
Variety (V)	**	**	**	**	**	**	**
C x V	**	**	**	**	**	**	**
Nitrogen (N)	NS	**	**	**	**	**	**
C x N	**	**	**	**	**	**	**
V x N	**	**	**	**	**	**	**
C x V x N	**	**	**	**	**	**	**

**Values significantly different at P ≤ 0.01; NS: not significant.

Table 2. Analysis of variance of dry matter at the different stages (2001-02)

	Stem elon.	Booting	Flag leaf	Filling grain	Ripening	Area Leaf
Crop rotation (C)	**	**	**	**	**	**
Variety (V)	**	**	**	**	**	**
C x V	**	**	**	**	**	**
Nitrogen (N)	**	**	**	**	**	**
C x N	**	**	**	NS	NS	**
V x N	**	**	**	**	**	**
C x V x N	**	**	**	**	**	**

**Values significantly different at P ≤ 0.01; NS: not significant.

The analysis of the growth functions parameters evidenced values of horizontal asymptote that in some cases, for the first year, resulted more than twice those calculated in the second year. In the first year, the highest "q" values may also be observed. The parameter values, in the two years, were probably determined by the different thermopluviometric trend; in the first year, in fact, it was characterized by an higher rainfall amount (+150 mm with respect to the pluriannual mean) and by a better distribution of the rain over the growing season, in 2001-02, instead, the rainfall was rather low (320 mm) and irregularly distributed, not adequately satisfying crop water requirements. This circumstance determined a considerable reduction of the specific rates of growth and a low accumulation period, as emphasized from the crop growth rate (CGR) trends reported in Figs 3a, 3b, 3c, 4a, 4b, and 4c. The unsatisfactory water availability could also explain the non-significant interaction C x N, in the second year and in the last two samplings. The higher water availability, during early development stages in the first year, determined differences in the biomass accumulation trends. The CGR higher values, the slower and gradual reduction of the growth rates, after the achievement of the maximum speed of accumulation, explain the higher values of the parameter "a" reported in W-L and in N60 and N120 nitrogen rates.

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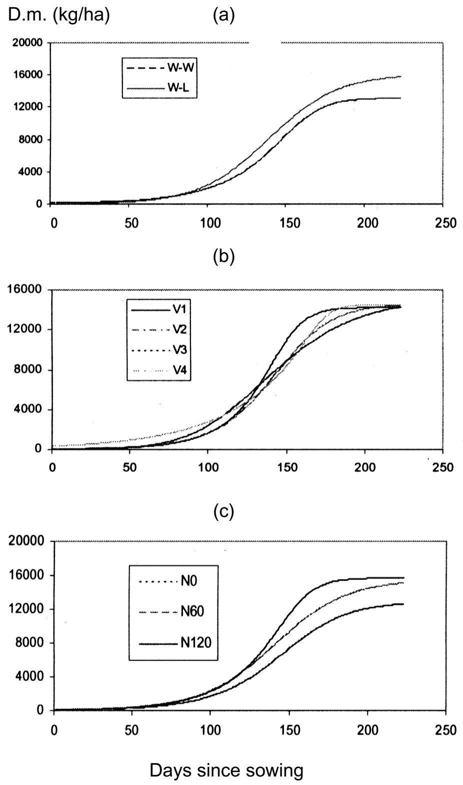

Fig. 1. Dry matter accumulation over crop rotation (a), over varieties (b) and over nitrogen rates (c) (2000-01).

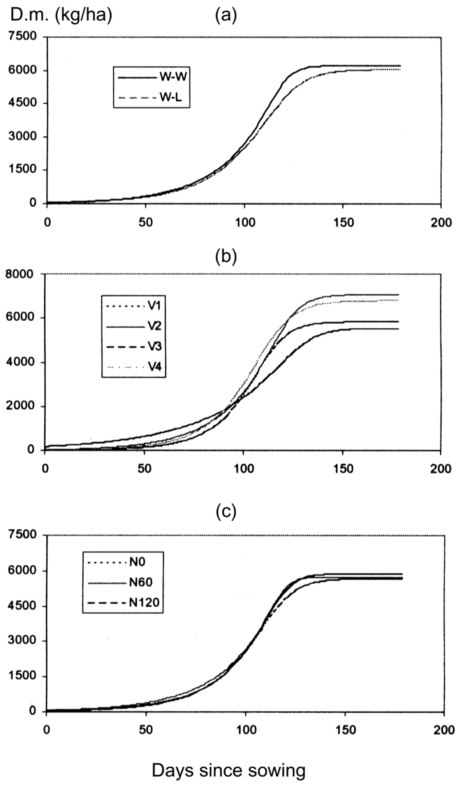

Fig. 2. Dry matter accumulation over crop rotation over crop rotation (a), over varieties (b) and over nitrogen rates (c) (2001-02).

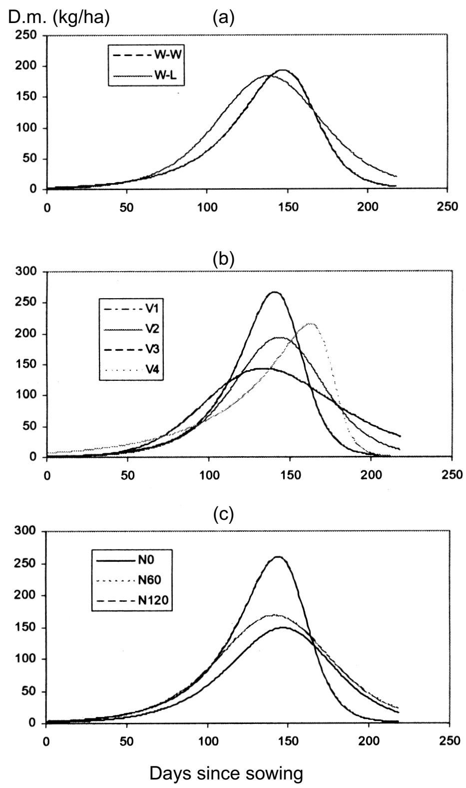

Fig. 3. CGR in relation to crop rotation (a), to variety (b) and to nitrogen rates (c) (2000-01).

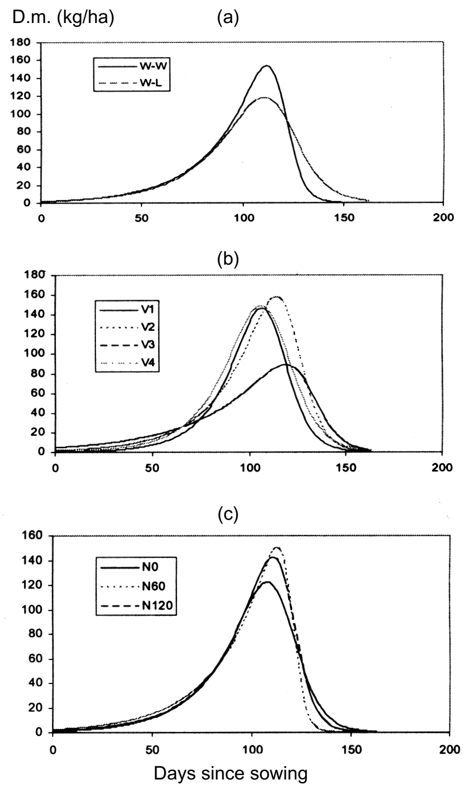

Fig. 4. CGR in relation to crop rotation (a), to variety (b) and to nitrogen rates (c) (2001-02).