INFLUENCE OF ROOT RESTRICTION ON CHLOROPHYLL AND CAROTENOIDS CONCENTRATIONS IN LEAVES OF FOUR PAPAYA (*Carica papaya* L.) GENOTYPES

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ABSTRACT

Changes in concentration of leaf pigments (chlorophyll and carotenoids) and its relation are good indicators of perturbations in plants caused by environmental factors. In this study, four papaya genotypes were evaluated: two from 'Solo' group (Sunrise Solo and Improved Sunrise Solo line 72/12) and two from "Formosa" group (Tainung 02 and Know-You 01) grown under field conditions in a ultisol at two distinct effective deepness (ED). The ED was determined using a penetrograph in a soil with average soil moisture of 11,2%. The area with ED of 0.35m that received a maximum force of 4.12 MPa for penetration was delimited as an area with restriction (WR) to root growth, while, the area with minimum ED of 0.60m that received a force lower than 2.30 MPa for penetration as an area with no restriction (NR). The concentration of chlorophyll *a*, *b*, *total (a+b)*, carotenoids and the chlorophyll *a/b* and the total chlorophyll (a+b)/carotenoids ratios were determined under field condition in four plants per genotype, in both ED, five months after transplant of the seedlings. The WR plants of Tainung 02 were the only genotype that showed significantly lower concentration of chlorophyll *a*, total chlorophyll *(a+b)*, and carotenoids, lower chlorophyll *total (a+b)/*carotenoids value and N and Fe concentration compared to NR plants. There was no significant difference in concentration of leaf pigments among plants of 'Solo' group genotypes grown in areas WR and NR. We conclude that concentration of leaf photosynthetic pigments was not a good indicator of the effective deepness stress.

Keywords: photosynthetic pigments, depth effective

RESUMO

INFLUÊNCIA DA RESTRIÇÃO MECÂNICA DA RAIZ SOBRE AS CONCENTRAÇÕES DE CLOROFILAS E CAROTENÓIDES EM FOLHAS DE QUATRO GENÓTIPOS DE MAMOEIRO (*Carica papaya* L.)

As alterações na concentração dos pigmentos fotossintéticos (clorofilas e carotenóides) e suas relações são considerados indicadores de distúrbios causados por fatores do ambiente em plantas. Neste estudo, quatro genótipos de mamão foram avaliados: dois pertencentes ao grupo 'Solo' (Sunrise Solo TJ e Sunrise Solo 72/12) e dois pertencentes ao grupo 'Formosa' (Tainung 02 e Know-You 01), sendo cultivados num Argissolo Amarelo, em condição de campo, em duas sub-áreas com profundidades efetivas (*PE*) distintas. A PE foi determinada com auxílio de um penetrógrafo a uma umidade média do solo de 11,2%. A sub-área *CR* (com restrição) apresentou profundidade efetiva média de 0,35 m, determinada até que se obtivesse um esforço máximo de 4,12 MPa para penetração, enquanto a sub-área *SR* (sem restrição) apresentou profundidade efetiva mínima de 0,60 m, determinada por um esforço menor que 2,30 MPa. Em condição de campo e em ambas as áreas, a concentração de clorofila *a*, *b*, total *(a+b)* e carotenoids e os valores da relação a/b e clorofila (a+b)/carotenóides foram determinadas em quatro plantas com 5 meses após o transplantio de cada genótipo. Em relação às plantas crescidas na sub-área SR, as plantas do genótipo Tainung 02, crescidas na sub-área CR, apresentaram valores reduzidos na concentração de clorofila a, total (a+b), carotenóides e na relação clorofila total (a+b)/carotenóides. Não houve diferenças significativas na concentração dos pigmentos fotossintéticos entre os genótipos do grupo 'Solo' em ambas as áreas estudadas. A concentração dos pigmentos fotossintéticos da folha não foi um bom indicador para o estresse causado pela profundidade efetiva.

Palavras-chave: pigmentos fotossintéticos, profundidade efetiva.

INTRODUCTION

The events associated with pigment destruction are numerous and have been discussed elsewhere (Hendry et al., 1987; Brown et al., 1991). Apart from net destruction at critical phases in the plant's life cycle, the loss of pigments during environmental stress or on premature senescence is a highly visible indicators of stress. In addition, the ratio of chlorophyll *a* to *b* in land plants has been used widely as an indicator of response to shade and as an early indicator of senescence (Brown *et al*., 1991). The ratio between chlorophyll and carotenoids has been much less widely used diagnostically, but Buckland et al., (1991) have found that this ratio is a sensitive indicator for distinction of natural full-term senescence and senescence due to environmental stress. Neverthless, changes in chlorophyll/carotenoids ratios are a potentially sensitive indicators of stress (Hendry & Price, 1993).

Soil physical limitation to root growth in plantations may arise from several sources. These include the existence of a horizon of high strength and soil compaction resulting from harvesting of a previous crop (Misra & Gibbons, 1996). Compact horizons that restriction of root growth may be naturally dense layer or fragipans, or result from the forces applied to the soil by implements or animals (Unger & Kaspar, 1994). High levels of soil compaction are common in heavily use recreation areas, construction sites, urban areas, timber harvesting sites, fruit orchards, agroforestry systems and tree nurseries (Kozlowski, 1999).

A compact zone at a shallow depth that prevents root penetration is highly detrimental to plant growth and yield when plants are not irrigated, especially when precipitation is infrequently, as in semi-arid and sub-humid regions (Unger & Kaspar, 1994). Under such conditions, plants rapidly deplete the plant-available soil water above the restricting zone, which results in severe plant water stress unless timely precipitation occurs (Barton *et al.*, 1966).

Perhaps certain chemicals messangers originating in the roots act as signal of root volume restriction (RVR) stress which influence shoot growth. It has been suggested that RVR induces a reduction in the supply of growth substances from roots to shoot (Carmi & Heuer; 1981; Lachno et al., 1982; Carmi, 1986; Kays et al, 1974; Hartung et al., 1994; Liu & Latimer, 1995; Carmi, 1995). Soil compaction also induces changes in the amounts and balances of growth hormones in plants, especially increases in abscisic acid and ethylene (Kozlowski, 1999).

Root restriction reduced plant dry weight, number of root apices, leaf number, shoot initiation, extension and dry weight, root length, leaf area and water uptake by 30-60% in peach seedlings (Richards & Rowe, 1977) and chlorophyll concentration in *spreading euonymus* (Dubik *et al.*, 1990) and alder seedlings (Tschaplinski & Blake, 1985).

The loss of photosynthetic pigments during environmental stress is a highly visible indicators of several events making then a useful tool to select a genotype which is more suitable to develop under a determined stress condition among a pool of genotypes.

The objective of this study was to determine the influence of soil mechanical resistance to root growth, on chlorophyll and carotenoids concentrations in leaves of four papaya genotypes, grown under field condition at two distinct effective deepness.

MATERIAL AND METHODS

Plant material and growth conditions

Under field conditions, four papaya genotypes, two from ‘Solo’ group (Sunrise Solo and Improved Sunrise solo line 72/12) and two from ‘Formosa’ group (Tainung 02 and Know-You 01) grown in ultisol at two distinct effective deepness (ED) at the Estação Experimental de Macaé - Empresa de Pesquisa Agropecuária do Estado do Rio de Janeiro/Brasil (PESAGRO-RIO) were analyzed. The ED was determined using a penetrographer SC-60, cone/axe standard ASAE, angle solid cone with 60^0, base area $0.000129m^2$ and 0.0095m diameter of the axe (Soilcontrol, Santo Amaro, São Paulo, Brazil), in a soil with average humidity of 11.2 ±± 2.50%. The area with ED of 0.35 ± 0.05 m (n=20) that received a maximum force of 4.12 MPa for penetration was delimited as an area with restriction (WR) to root growth, while, the area with minimum ED of 0.60 m (n=20) that received a force lower than 2.30 MPa for penetration as an area with no restriction (NR).

Fertilization, water management and cultural practices were made according to Marin *et al.*, (1993). The soil textural class, bulk density, particle density, porosity and macroporosity of the soil were classified according to EMBRAPA (1997) (Table 1).

TABLE 1. Textural class, bulk density, particle density, porosity and macroporosity of the soil in Macaé/RJ/Brazil.

Horizon	B_d^z (g cm^{-3})	P_{dr}^y (g cm^{-3})	Soil Porosity (%)	Soil Macroporosity ^{x} (%)
A^w (sandy-loam)	1.74	2.60	33.1	13.3
B^v (clay)	1.64	2.61	37.2	7.9

B_d^z = Bulk Density, P_d^y = Particle Density, Macroporosity^x (0.1atm), (sandy-loam, 58% coarse, 15% fine sandy, 07% silt and 20% clay)^w, (clay, 25% coarse, 19% fine sandy, 08% silt and 48% clay)^v, Laboratory of Soil Physics/ Universidade Federal de Viçosa - Viçosa/MG/Brazil.

RESULTS AND DISCUSSION

The concentration of leaf pigments (chlorophyll and carotenoids) and the chlorophyll a/b and total chlorophyll (a+b)/carotenoids ratios, in the four genotypes at the two distinct effective deepness are shown in figures 1 to 6. All genotypes did not show signioficant differences for the evaluated characteristics, except Tainung 02 which showed significant reduction of the values for *Chl a*, total *Chl (a+b)*, *Car* and the ratio of *Chl* (a+b)/*Car*, for the WR treatment. However, root restriction did not show significant effect on *Chl b* and *Chl a*/*Chl b* ratio in papaya trees. Similar results were observed by Dubik *et al.*, (1990) in *spreading euonymus* and by Tschaplinski & Blake, (1985) in alder seedlings for *Chl a* and total *Chl* in plants growing under root restriction condition. Wolf (1956) has suggested that *Chl a* is destroyed more rapidly during leaf senescence than *Chl b*.

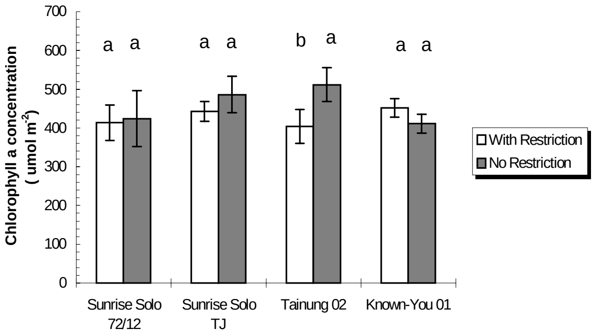

Figure 1. Chlorophyll *a* concentration in leaves of four papaya genotypes as influenced by root zone restriction. Vertical bars indicate standard error (n=4). Different letters show significant difference at 5% level (Duncan's multiple range test).

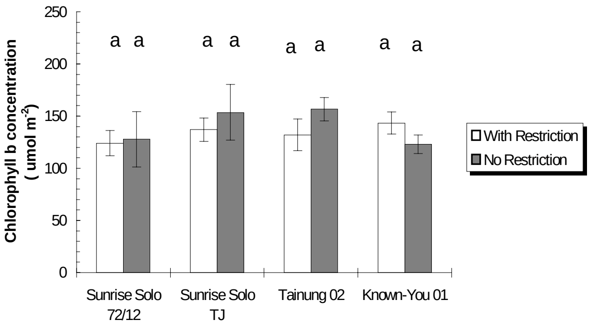

Figure 2. Chlorophyll *b* concentration in leaves of four papaya genotypes as influenced by root zone restriction. Vertical bars indicate standard error (n=4). Different letters show significant difference at 5% level (Duncan's multiple range test).

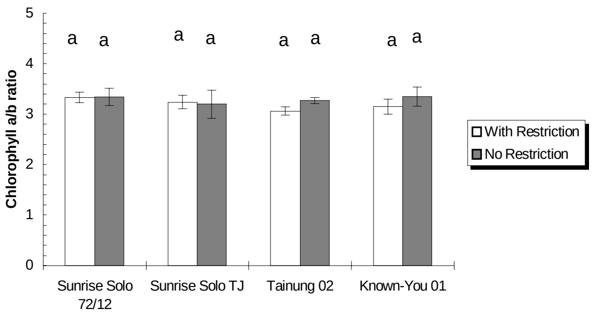

Figure 3. Chlorophyll (*a+b)* concentration in leaves of four papaya genotypes as influenced by root zone restriction. Vertical bars indicate standard error (n=4). Different letters show significant difference at 5% level (Duncan's multiple range test).

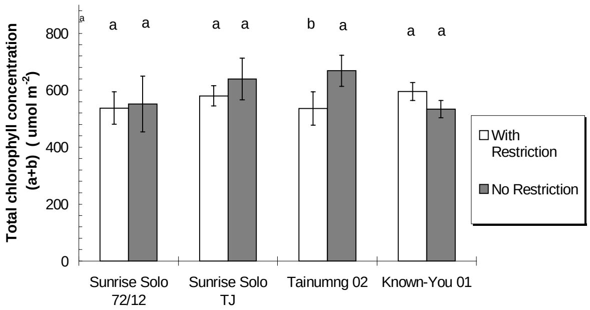

Figure 4. Chlorophyll *a/b* ratio concentration in leaves of four papaya genotypes as influenced by root zone restriction. Vertical bars indicate standard error (n=4). Different letters show significant difference at 5% level (Duncan's multiple range test).

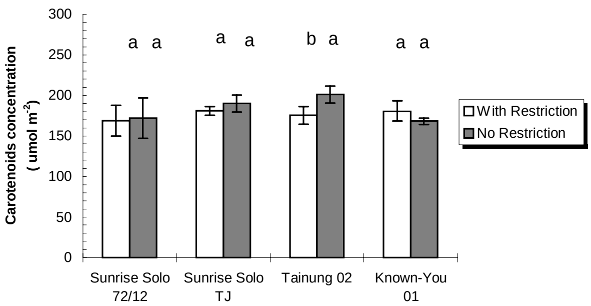

Figure 5. Carotenoids concentration in leaves of four papaya genotypes as influenced by root zone restriction. Vertical bars indicate standard error (n=4). Different letters show significant difference at 5% level (Duncan's multiple range test).

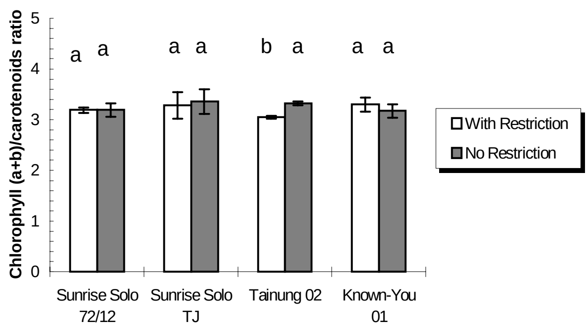

Figure 6. Chlorophyll (*a+b)*/Carotenoids concentration in leaves of four papaya genotypes as influenced by root zone restriction. Vertical bars indicate standard error (n=4). Different letters show significant difference at 5% level (Duncan's multiple range test).

There was no significant difference in concentration of leaf pigments among evaluated plants of 'Solo' group genotypes grown in areas WR and NR. Specially, Tainung

02 genotype cultivated in WR area, the results showed that root zone restriction imposed by soil impedance was an important stress factor. This genotype showed a more reduced total leaf number and total leaf area in WR area (Yamanishi et al, 1998).

It is not clear whether a reduction in concentration of *Chl a* and total *Chl* was caused by a reduction in synthesis or by an increase in degradation. Brown et al., (1991) and Hendry et al., (1987) related that senescence process reduce the concentration of chlorophyll and Matoo & Suttle (1991) mentioned that ethylene is the principal hormone involved in this process. Many reports (Kays et al, 1974; Sarquis et al, 1991, Hussain et al, 1999) indicate that nonwounding physical stress like soil impedance also increases ethylene production, which in turn acts as an endogenous growth regulator. Thus, we supposed that ethylene production by Tainung 02 genotype could be higher than in the others genotypes under WR. Future research on this genotype should be conducted in order to study the effects of the root mechanical restriction in relation to ethylene production.

The contents of protein, N and Fe in the papaya leaves of Tainung 02 were significantly lower than the other genotypes in area WR (Figures 7 and 8). The reduction in N and Fe could have accounted for the reduction in chlorophyll observed in Tainung 02, since these elements are important in chlorophyll and/or protein synthesis (Jacobson & Oertli, 1956; Marschner, 1995). Another possible cause for chlorophyll reduction in root-restricted-plants may have been a decrease in cytokinin synthesis (Adedipe & Fletcher, 1971; Blackman & Davies, 1985). In papaya plants, more investigations related to hormone effect are necessary.

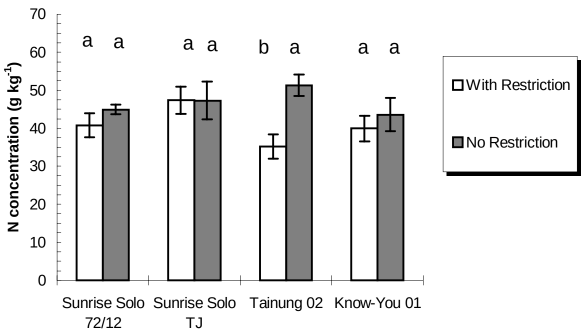

Figure 7. N concentration in leaves of four papaya genotypes as influenced by root zone restriction. Vertical bars indicate standard error (n=4). Different letters show significant difference at 5% level (Duncan's multiple range test).

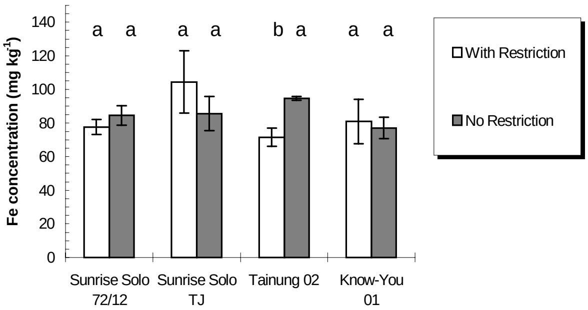

Figure 8. Fe concentration in leaves of four papaya genotypes as influenced by root zone restriction. Vertical bars indicate standard error (n=4). Different letters show significant difference at 5% level (Duncan's multiple range test).

CONCLUSION

The WR plants of Tainung 02 were the only genotype which showed significantly lower concentration of Chl a and Chl (a+b), carotenoids and Chl (a+b):Car ratio compared to NR one. Among the NR plants of 'Formosa' group, Tainung 02 showed significantly higher concentration of Chl a, Chl b, Chl (a+b) and Car compared to Know-You 01. There was no significant difference in concentration of leaf pigments among plants of 'Solo' group genotypes grown in areas WR and NR. However, the measurement of leaf pigment concentration was not a good indicator of stress by root restriction.

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