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Effect of Leaf Water Potential on Cold Tolerance of C*offea arabica L.*

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ABSTRACT

Young coffee plants from cultivar Mundo Novo of Coffea arabica were grown without irrigation for 32 consecutive days, to evaluate the effect of leaf water potential on damage caused by low temperatures, under controlled conditions. A wide range of leaf water potentials were evaluated, from – 0.45MPa (wet soil) at the beginning of the experimental period, to – 4.8MPa (severe leaf wilting) at the end. Results showed that under moderate water stress, there was a higher frequency of undamaged plants and lower frequency of severely damaged plants. These results help explain part of the regional variability observed after a frost and stress the importance of new studies associating cold and drought tolerance in coffee.

Key words: Cold tolerance, coffee, leaf water potential, water stress

INTRODUCTION

The frosts that occur in the coffee regions of Brazil are primarily caused by cold air masses that strike the region during the winter time. It is not uncommon to occur precipitation before frost episodes (Gomes et al., 1979; Caramori and Manetti Filho, 1993, Caramori et al., 2000). Water status of the coffee plants during frost occurrence is quite variable, depending on soil water balance prior to the arrival of the cold front and the amount of precipitation occurred. After the passage of the cold front, under conditions of clear sky and low atmospheric humidity, heat loss by irradiation during the night is very high and radiative frosts are likely to occur (Caramori et al., 2000).
All coffee cultivars of the species *Coffea arabica* grown in southern Brazil have low variability for cold tolerance (Androcioli Filho et al., 1986). This is due to the fact that coffee originated in the tropical regions of Africa, were this species grows naturally under woods. Damages in general occur when temperatures at leaf level are between -3^{o}C and -4^{o}C (Camargo and Salati, 1966; Ferraz, 1968) and become more severe with the time of exposition to low temperatures (Manetti Filho and Caramori, 1986). Many physical and physiological factors have caused great variability on damages by frosts in coffee plantations. Caramori and Sera (1979) and Manetti Filho et al. (1984) observed higher leaf damage caused by radiative frost on cultivar Catuai in the field, compared to the cultivar Mundo Novo. Among the factors involved on this susceptibility, the dwarf habit of Catuai was identified as one of the most important. Nevertheless, under field conditions it has been observed that Catuai vegetates more intensely during the winter and this could cause a reduction on sap concentration, causing higher susceptibility

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to frost. Observations made with coffee plantlets grown in pots under controlled conditions (Chaves and Manetti Filho, 1990) provided evidence that plantlets fertilized with potassium were less damaged by frost. Under field conditions, it has been observed that frost damages are lower when plants are under some degree of water stress, probably due to the increase of sap concentration. In other species, the increase of cold tolerance related to water stress has been exhaustively reported. For example, Benzioni et al. (1992) reported a higher rate of bud survival following frost on jojoba (*Simmondsia shinensis*) submitted to water stress, compared to irrigated plants. In species that undergo through dormancy during the winter, water deficit works as a stimulus for cold hardening (Anisko and Lindstrom, 1996; Ceccardi et al., 1995). There are no references in the literature about the effects of water deficit on the magnitude of damage caused by low temperatures in *Coffea*. Therefore, with the aim of help elucidating this subject, the present paper reports the results of an investigation about the effect of water deficit imposed to young coffee plants on the severity of damage caused by low temperature under controlled conditions.

MATERIALS AND METHODS

The experiments were performed with young coffee plants of the cultivar Mundo Novo LCP 376/4 with five pairs of leaves. Plantlets were produced in the nursery according to the normal technical recommendations for the coffee crop (Instituto Brasileiro do Café, 1981). About three hours before the beginning of the first test, all plants were abundantly irrigated and kept without irrigation for the remaining of the experimental period under nursery conditions, fully exposed to sunlight. During the night and in daily periods with risk of precipitation, the plants were covered with plastic sheets to prevent hydration. A wide range of leaf water potential was obtained throughout the experimental period of 32 days during the months of June and July by imposing natural dehydration to the plants. A total of 22 tests were performed during this period. Six plants were evaluated in each test. Immediately after the beginning of each test, the plants to be evaluated were transferred to the laboratory. One of the leaves of the second pair from the tip was taken to measure leaf water potential using a Schollander chamber.

The cold chamber used to simulate low temperatures was adapted and previously described by Manetti Filho and Caramori (1986). It basically contains a refrigeration unit with a thermostat, a rectangular box of galvanized steel recovered with a 2cm layer of styrofoan with an ethanol solution at 19% and a suction pump of 0.12 CV to agitate and homogenize the solution. Temperature within the solution was monitored with six thermocouple sensors of cooper-constantan distributed in the box and connected to an automatic recorder. In order to prevent direct contact of the plants with the ethanol solution, they were placed within plastic bags and sealed with a plastic welding device. Excess of air within the bags was extracted with a vacuum pump of 0.26MPa immediately after sealing and the plants were totally immersed in the solution.

Starting at ambient temperature (about 20°C in the laboratory), the temperature was gradually forced to drop up to –3°C and kept at this level for about 90 minutes, with an oscillation of ± 0.5°C. Then, the plants were taken from the solution and exposed to ambient temperature. The period necessary to lower the temperature to –3°C was approximately six hours. Figure 1 illustrates the typical curve of temperature during the tests. Differences among monitored points within the solution were less than 0.5°C for all tests performed. Temperature stabilization around –3°C was forced by manual control of the thermostat, which caused an internal oscillation between –2.5°C and –3.5°C during the last 90 minutes of each test.

Damage evaluation was performed as described by Soderholm and Gaskins (1960) and Androcioli Filho et al. (1986). One day after each test, the percentage of leaf area damaged was visually scored by four independent evaluators and an average score for each plant was obtained. Based on the average values obtained by each evaluator, the plants were grouped in classes of damage according to the following scale:

I. Without visible damage
II. Light damage (maximum of 25% of leaf damage)
III. Moderate damage (between 25% and 50% of leaf damage)
IV. Severe damage (between 50% and 75% of leaf damage)

V. Very severe damage (above 75% of leaf damage).

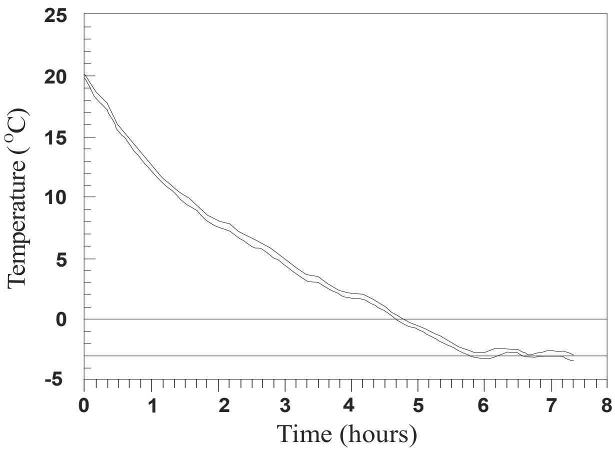

Figure 1 - Typical curve of temperature within the cold chamber. The two solid lines represent upper and lower limits of internal temperature oscillation for all tests.

RESULTS AND DISCUSSION

Table 1 shows the distribution of plants in classes of damage according to leaf water potential. A wide range of leaf water potential was observed during the 32 days of test. The plants with wet soil had leaf water potential higher than –0.8MPa. Symptoms of leaf wilting were only visible below –2MPa, and severe wilting was observed in the plants with leaf water potentials lower than –3.5MPa.

There was clear evidence that a higher number of plants with severe damage (classes IV and V) occurred under higher water potentials (above –1.3MPa). On the other hand, the frequency of plants without visible damage or with light damage (classes I and II) increased as leaf water potential decreased. Under very low leaf water potential (below –4MPa), there was indication that damages started to increase, probably due to cellular damage caused by severe water deficit.

The results presented in this paper suggest that, when frosts occur under natural conditions, it is expected that there will be more severe damages on well hydrated coffee plants. Therefore, the regional variability on damage extent after frost could be related to the degree of hydration of leaf tissues and consequently, to the dilution of the cell solution. These results support theories that associate tolerance to low temperatures with drought tolerance (Levitt, 1972; Street and Öpic, 1974).

Table 1 - Number of coffee plants in different classes of damage according to leaf water potential (**Ψ**), after being submitted for 90 minutes to –3°C under controlled conditions.

-Ψ (MPa)	**Classes of damage***					**Total of Plants Evaluated**
	I	**II**	**III**	**IV**	**V**	
0,45 a 0,70	0	0	1	5	3	9
0,75 a 1,00	0	2	2	10	4	18
1,05 a 1,30	2	5	2	5	0	14
1,35 a 1,60	0	3	2	2	0	9
1,65 a 1,90	1	4	4	0	0	9
1,95 a 2,20	5	6	1	2	0	14
2,25 a 2,50	2	3	6	0	0	11
2,55 a 2,80	6	8	0	0	0	14
2,85 a 3,10	2	5	0	0	0	7
3,15 a 3,40	1	4	0	0	0	5
3,45 a 3,70	0	3	1	0	0	4
3,75 a 4,00	0	3	1	0	0	4
4,05 a 4,30	0	2	2	0	0	4
4,35 a 4,60	0	1	3	1	0	5
4,65 a 4,80	0	0	2	2	1	5

** I – Without visible damage; II – Maximum of 25% of leaf damage; III – Between 25% and 50% of leaf damage; IV – Between 50% and 75% of leaf damage; V – Above 75% of leaf damage.*

Normally, the species of *Coffea* that are more tolerant to drought such as *Coffea racemosa*, have mechanisms of osmotic adjustment that reduce the use of water during the winter. This mechanism causes an increase on the concentration of the cell solution that may also increase tolerance to frost. This opens a new perspective for plant breeders that could try to associate these characteristics and develop new coffee cultivars more tolerant to low temperatures. Nevertheless, other factors may be involved on the mechanism of cold tolerance of coffee plants with higher water stress. This was demonstrated by Guinchard et al. (1997) in plants of *Trifolium repens* cv. Huia that had only 30 to 40% of the variation of osmotic potential explained by the variation of free sugars, suggesting that other components rather than carbohydrates might participate in osmotic regulation. Therefore, there is a need of further studies to elucidate the mechanisms involved on higher cold tolerance of coffee plants submitted to water deficit.

RESUMO

Mudas de cafeeiros da cultivar Mundo Novo de *Coffea arabica* foram mantidas sem irrigação em viveiro, por um período de 32 dias consecutivos, com o objetivo de se avaliar o efeito do potencial de água na folha nos danos causados por baixas temperaturas, sob condições controladas. As plantas avaliadas apresentaram potenciais de água nas folhas entre –0,45MPa (solo encharcado) no início do período experimental e –4,8MPa (murchamento severo das folhas) na fase final. Os tratamentos com baixas temperaturas consistiram em submeter as plantas de café protegidas com sacolas plásticas seladas durante 90 minutos a -3^{o}C ± 0,5^{o}C, dentro de um banho de solução etanólica. A avaliação dos danos foliares foi feita visualmente por quatro avaliadores independentes, um dia após a submissão às baixas temperaturas. Os resultados mostraram que, sob estresse hídrico moderado, houve maior frequência de plantas não danificadas e menor freqüência de plantas com danos severos. Plantas muito hidratadas sofreram danos severos com maior frequência. Estes resultados podem explicar parte da variabilidade regional nos danos de geadas e destacam a importância de novos estudos associando tolerância ao frio com tolerância à seca.

REFERENCES

Androcioli Filho, A.; Siqueira, R.; Caramori, P. H.; Pavan, M. A.; Sera, T. and Soderholm, P. K. (1986), Frost injury and performance of coffee at 23^{o}S in Brazil. *Exp. Agric.,* **22** (1), 71-74.

Anisko, T. and Lindstrom, O. M. (1996), Cold hardiness of evergreen azaleas is increased by water stress imposed at three stages. *J. Am. Soc. Hortic. Sci.,* **121** : (2), 296-300.

Benzioni, A.; Palzkill, D. A. and Nelson, J. M. (1992), Flower bud dormancy, ABA concentration, and survival during frost of jojoba genotypes under water stress. *J. Am. Soc. Hortic. Sci.*, **117** : (6), 976-980.

Camargo, A. P. and Salati, E. (1966), Determinación de la temperatura letal para hojas de café en noches de heladas. Lima, Peru. *Café*, **8** : (3), 12-15.

Caramori, P. H. and Sera, T. (1979), Influência do porte do cafeeiro no dano provocado por geada. In: 7º Congresso Brasileiro de Pesquisas Cafeeiras, Araxá, MG. *Resumos...* Rio de Janeiro : IBC-GERCA. pp. 133-134.

Caramori, P. H. and Manetti Filho, J. (1993), *Proteção dos cafeeiros contra geadas*. Londrina : IAPAR. (Circular; 79). 28 pp.

Caramori, P. H.; Manetti Filho, J.; Morais, H. and Leal, A.C. (2000), *Geada* - Técnicas para proteção dos cafezais. Londrina : IAPAR. (Circular; 112). 35 pp.

Ceccardi, T. L.; Heath, R. L. and Ting, I. P. (1995), Low-temperature exotherm measurement using infrared thermography. *HortScience*, **30** : (1), 140-142.

Chaves, J. C. D. and Manetti Filho, J. (1990), Danos de geadas em cafeeiros submetidos a adubação potássica e calagem. In: 16º Congresso Brasileiro de Pesquisas Cafeeiras, Espírito Santo do Pinhal, SP. *Resumos...*, Rio de Janeiro, IBC. pp. 86.

Ferraz, E. C. (1968), *Estudo sobre o momento em que a geada danifica as folhas do cafeeiro*. (Tese de Doutorado). Piracicaba : ESALQ-USP. 59 pp.

Gomes, J.; Chaves, J. C. D.; Caramori, P. H. and Sera, T. (1979), *Manejo do cafezal sob condições de geada*. Londrina : IAPAR. (Informe da Pesquisa; 15). 23 pp.

Guinchard, M. P.; Robin, C.; Grieu, P. and Guckert, A. (1997), Cold acclimation in white clover subjected to chilling and frost: changes in water and carbohydrates status. *Europ. J. Agron.*, **6** : (3-4), 225-233.

Instituto Brasileiro do Café (1981), *Cultura de Café no Brasil* - Manual de Recomendações. 4th ed. Rio de Janeiro : Instituto Brasileiro do Café. 485 pp.

Levitt, J. (1972), *Responses of plants to environmental stresses.*Nova York : Academic Press. 697 pp.

Manetti Filho, J. and Caramori, P. H. (1986), Desenvolvimento de uma câmara fria para simulação de temperaturas baixas. *Pesq. Agropec. Bras.*, **21**: (10), 1005-1008.

Manetti Filho, J.; Caramori, P. H. and Sereia, V. J. (1984), Efeitos da geada nas cultivares Mundo Novo e Catuaí. In: 11º Congresso Brasileiro de Pesquisas Cafeeiras, Londrina, PR. *Resumos...* Rio de Janeiro : IBC-GERCA. pp. 39.

Soderholm, P. K. and Gaskins, M. H. (1960), Evaluation of cold resistance in the genus *Coffea*. *Am. Soc. Hort. Sci., Caribeean Region*, **4**, 8-15.

Street, H. E. and Öpic, H. (1974), *Fisiologia das angiospermas – crescimento e desenvolvimento.* São Paulo : Polígono. 332 pp.

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