Application of Vis/Nir Spectroscopy to Establish Peach Ripening as Affected by Rootstock

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Abstract

The objective of this paper was to monitor peach ripeness of "Chimarrita" and "Maciel" cultivars, grafted on different rootstocks, using the flesh-flesh firmness parameter, as an indicator of harvest time through equipment based on Vis/Nir spectroscopy. The orchard was installed in 2005, was "V" system trained with spacing of 5.0 x 1.5 m, and the cultivars were grafted on seven rootstocks: "Capdeboscq", "Flordaguard", "Nemaguard", "Okinawa", "Tsukuba", "Umezeiro" and "Viamão". After harvesting, the fruits were evaluated by the NIR CASE spectrophotometer, establishing categories of flesh-flesh firmness, between 40N and 60N for fruits consumed in a long term and <40N for immediate consumption. The analyzed rootstocks alter the peach ripeness of the "Chimarrita" and "Maciel" cultivars. The "Umezeiro" rootstock induced early harvest for the "Chimarrita" cultivar. The "Nemaguard"/ "Maciel" combination provides fruits with a superior harvest period than the other ones evaluated. The Vis/Nir Spectroscopy is a useful tool to monitor the harvest of "Chimarrita" and "Maciel" cultivars.

INTRODUCTION

Rootstocks might influence several tree and fruit characteristics exploiting the orchard ability as far as production and fruit quality are concerned. In addition, some rootstocks stand out for excellence for certain aspects (Schäfer, et al., 2001).

Changes in flesh fruit firmness have been a reliable way to describe the changes occurring during maturation and to forecast physical damage on peaches. The fruit softening is a physiological process that occurs during maturation in the plant storage period, and in general in thethe post-harvest management operation (Kader, 1992; Crisosto et al., 2001; Metheney et al., 2002). In most of previous studies, flesh fruit firmness was measured by the traditional destructive method using a reduced sample of fruit that might not be fully representative of the batch of considered fruits.

Currently, many non-destructive systems are being used in the harvesting and post-harvesting and in laboratory analysis (Aweta, 2010; Greefa, 2010; Sinclair, 2010) to monitor the ripeness and evaluate fruit quality. Many researchers have compared several evaluation methods for flesh firmness, as acoustic, Vis/Nir, among others, for apple, avocado, melon, nectarine and mango (De belie et al., 2000; Shmulevich, 2003). In Brazil, the use of these techniques for fruit quality analysis is becoming popular since the technique is relatively easy to use (Lu, 2007) and also allow to be used both in the field with hand-on instruments, in packing houses or in dedicated laboratories (Herold et al., 2005).

Among these techniques, one of the most used is the visible spectroscopy (VIS) of the near-infrared (NIR), which is presented as a promising and rapid technology in the evaluation of various internal features of the fruit. The spectroscopic explores properties of light, by measuring the energy generated by the interaction of the sample molecules with a spectrum of variable length (Osborne, 2000).

This technique, allows fast measurements (Huang et al., 2008), does not require any sample preparation, has the potential to estimate simultaneously various quality attributes (Huang et al., 2008), it allows repeated measurements on the same sample, and it does not require reagentsfor extraction (Nicolaï et al., 2006).

Firmness measurement and low temperature during postharvest might control ripeness evolution . The knowledge of these attributes provide useful information for post-harvest fruit management(Crisosto and Thompson, 2002). Monitoring the ripeness of fruits is crucial to meet the demands of the market, offering products ready to eat.

The objective of this paper was to monitor with a Vis/NIRs device the peach ripeness of "Chimarrita" and "Maciel" cultivars using the flesh-flesh firmness parameter, as an indicator of harvest time.

MATERIALS AND METHODS

"Chimarrita" and "Maciel" peaches cultivars plants were grafted on different rootstocks ("Capdeboscq", "Flordaguard", "Nemaguard", "Okinawa", "Tsukuba", "Umezeiro" and "Viamão") in a didactic orchard of the Agriculture Center of Palma, Federal University of Pelotas (UFPel), Pelotas/RS Brazil. The orchard was realized in 2005, trees were "V" system trained at a distance of 5.0 x 1.5 m. Trials were carried out in 2009/2010 seasons. , All the fruits carried in a plant with different composition of cultivar/rootstock were harvested at three different date and at each date all the fruits were harvested. After harvesting, the fruits were evaluated in the fruit laboratory of UFPel, Pelotas/RS. The NIR-Case® spectrophotometer (Imola, Italy) was used for the evaluation of fruits. This device measure through the light transmittance mode. The light source consists of eight halogen lamps, and the wavelength varies between 600 and 1000 nm. The measuring time varies between 6 milliseconds and 2 seconds. The equatorial zone of the fruit, in two diametrically opposite sides (A and B side), to obtain two repetitions per fruit was taken for measuremt. It was used the equipment already calibrated for "Maciel", flesh firmness (MR-multiple regression 0.86) and soluble solids (MR 0.94), and for "Chimarrita", flesh firmness (MR 0.9) and soluble solids (MR 0.85) (Fachinello et al., 2010).

According to the research done by Crisosto et al., (2001); Thompson and Crisosto, (2004); Metheney et al., (2002), the flesh-flesh firmness was considered the most appropriate parameter to determine the ripeness period and to establish the harvest time for peaches, being this parameter used in this research to monitor the ripeness of fruits.

From the consulted literature and considering the importance of the proper harvesting time for a long-term and immediate market of the fruits, categories of flesh firmness, between 40N and 60N for fruits to be consumed in the long term and <40N for immediate consumption were established., The best harvest period, was established on the percentage of fruit allocated in those categories during the harvest period, taking as reference the presence of fruit in percentage in the studied categories.

Data were expressed as bar graphs reporting the percentage of fruit within the range of flesh-flesh firmness corresponding to the long-term and immediate market. Thereafter, the grouping of rootstocks was analyzed, taking into account the dates of harvest through the euclidean distance and the clustering through the methods for the distances average, and a graphical representation done through a dendrogram. The cophenetic correlation between the similarity matrix and the cophenetic matrix to verify if the dendrogram is consistent with the original data, with data standardization was also carried out. The software used was STATISTICA 6.0.

Formula for data standardization: **FP = X - x / SD**, where X = value for surveillance, X = average and SD = standard deviation

Euclidean distance formula: $[(Z_1(A) - Z_1(B))^2 + (Z_2(A) - Z_2(B))^2 + Z_3(A) - Z_3(B)^2]^{1/2}$ for all pairs of rootstocks, where Z = harvest dates and A and B= rootstock

RESULTS AND DISCUSSION

Studies by Crisosto et al. (2001) and (2004), pointed out that a threshold level of flesh-flesh firmness from 18 to 35N in peaches is considered an optimal value for consumption, so in the present research, the fruit classified in <40N were considered ready to be consumed while those from 40 to 60N were considered for long-term consumption. According to the same authors, these thresholds of flesh-flesh firmness indicate critical changes during postharvest ripeness and high susceptibility fo the fruit to be to damage by injuries.

The cluster analysis can be an interesting tool to identify similarities between individuals; it is widely used in genetic improvement, and it could be applied to an exploratory analysis of the influence of rootstocks on the canopy cultivars used. The formation of clusters is based on a similarity matrix done through the calculation of distances, in this case, Euclidean, originating the cophenetic matrix, which will originate the dendrogram, that is the form of representation of these groups.

Therefore, according to Cruz and Carneiro (2003), the Pearson coefficient of linear correlation between the elements of the dissimilarity matrix (distances matrix between rootstocks, obtained from the original data) and the elements of the cophenetic matrix (distances matrix between rootstocks, obtained from the dendrogram) called cophenetic correlation coefficient may be used to evaluate the consistency of the standard group of hierarchical clustering methods, so that this values close to an unity indicate better performance. With the data obtained from this research, the cophenetic correlation coefficients indicate a good representation through the dendrogram of the original data for "Chimarrita" and "Maciel" cultivars in the long term and immediate consumption (0.95 and 0.88 – "Chimarrita" and 0.78 and 0.87 – "Maciel").

The figure 1A shows the percentage of fruit with flesh-flesh firmness between 40 and 60N during the harvest period. With the aid of cluster analysis from the euclidean distance in figure 1B, disregarding the greatest distances (2.0 cutoff point), it can be defined that the "Chimarrita"/"Umezeiro" (group 2) combination is distant from other combinations (group 1), with a lower percentage of fruit with flesh-flesh firmness between 40 and 60N, for as it is observed in Figure 3A, these fruits are already in a more advanced ripeness stage than the other rootstocks ones.

In figure 2A, it is observed the percentage of fruit with <40N flesh-flesh firmness during the harvest period. With the aid of cluster analysis from the euclidean distance in figure B, disregarding the greatest distances (2.0 cutoff point), it can be defined four groups with similar characteristics in the evolution of fruits ripeness. "Chimarrita" on

“Capdeboscq”, “Okinawa” and “Viamão” (group 1) could be harvested in the period of 7 to 10 of December 2009. “Chimarrita” on “Nemaguard” (group 2) could be harvested in three periods. “Flordaguard” and “Tsukuba” (group 3) induced low percentages of fruit for immediate consumption throughout the whole studied period, and these rootstocks might be responsible for the ripeness delay of “Chimarrita” . However, “Umezeiro” cultivar (group 4), as mentioned earlier, induced a faster ripeness in “Chimarrita” and also concentrate the harvest period.

The data presented here demonstrate that the fruit ripeness in “Chimarrita” is rootstock dependent, it can be clearly observed that the “Umezeiro” rootstock induces faster ripeness of “Chimarrita”, and in a shorter period of time as compared to the others. It also induces shorter vegetative cycle and is able to dwarf plants, providing a lower canopy volume, and, thus, exposing to sunlight the fruits, providing physical and chemical changes more quickly.

As a consequence the knowledge of the characters induced by rootstocks is of great importance since it might allow to choose the most appropriate for a particular growing region. This information corroborates the claims of Loreti (2008), in which the knowledge of bioorganic characteristics of rootstocks helps technicians and fruit growers to choose appropriate rootstocks.

In figure 3A, it is observed the percentage of fruit with flesh firmness between 40 and 60N during the harvesting period, and all combinations root/rootstock can be harvested on the first date except the “Maciel”/“Tsukuba”. With the aid of the cluster analysis from the euclidean distance in figure 3B, ignoring the largest distances (2.0 cutoff point), four groups with some characteristics in common can be defined: “Maciel”/“Capdeboscq” and “Maciel”/“Nemaguard” (group 1) have a more widely distributed harvest during the period than the other combinations, as for “Maciel”/“Tsukuba” (group 2), they have the highest percentage of fruit with flesh firmness between 40 and 60N in the second harvest date compared to the other groups. For “Flordaguard”, “Okinawa” and “Viamão” (group 3), the fruit harvest is concentrated between 22 and 28 of December 2009. The “Maciel”/ “Umezeiro” (group 4) combination shows a higher percentage of fruit for consumption in the long term (40 and 60N) than other combinations, between 22 and 28 of December 2009, but the last date has yet a percentage of approximately 20%. Picolotto et al (2009), also claims that the quality of fruits, as compared to the flesh firmness, is changed by the “Capdeboscq”, “Tsukuba” and “Okinawa” rootstocks, and the largest vigor, for “Chimarrita”. Studies done by Giorgi et al. (2005) and Remorini et al. (2008) also show the key role of the rootstock in this ripeness index.

In figure 4A, it was observed the percentage of fruit with <40N flesh firmness during the harvest period. With the aid of cluster analysis in figure B, disregarding the greatest distances (2.0 cutoff point), it can be defined that the “Maciel” fruits, grafted on “Capdeboscq”, “Flordaguard”, “Okinawa”, “Aberystwyth” (group 1), could be harvested from the second harvest date; this fact shows that there is a concentration of harvest time for fruits for immediate consumption (<40N). However, on “Nemaguard” (group 2), fruits can be harvested on three dates, showing simultaneous presence of fruits in different ripeness stages, requiring multiple transfers, and on “Umezeiro” and “Tsukuba” (group 3), they could be harvested only on January first, 2010.

CONCLUSIONS

On the basis of the obtained results it can be concluded that the studied rootstocks might influence the ripeness of peach of “Chimarrita” and “Maciel” . The “Umezeiro” rootstock induced early harvest in “Chimarrita” . The “Nemaguard” rootstock induced an extension of the harvest period in “Maciel”.

As a general conclusion it can be stated that the Vis/Nir spectroscopy is a useful tool to monitor the fruit harvest in “Chimarrita” and “Maciel”.

Literature Cited

Aweta – Organização internacional de tecnologia para frutas, vegetais e flores 2010. Disponível em:< http://www.aweta.nl/index.html> Acesso em 24/06/2010.

Chitarra, M.I.F.; Chitarra, A.B. Pós-colheita de frutos e hortaliças: fisiologia e manuseio. Lavras: ESAL-FAEPE, 2005. 785 p.

Crisosto, C.H., Slaughter, D., Garner, D., Boyd, J.,. Stone fruit critical bruising thresholds. Journal American Pomology Society 55, 76–81, 2001

Crisosto, C.H., Garner, D., Crisosto, G.M., Bowerman, E.,. Increasing ‘Blackamber’ plum (*Prunus salicina* Lindell) consumer acceptance. Postharvest Biology Technology 34, 237–244, 2004.

Cunha Junior, L. C.; Durigan, M. F. B.; Mattiuz, Martins, R. N.; Durigan, J. F. Caracterização da curva de maturação de pêssegos 'Aurora-1', na região de Jaboticabal-SP. Revista Brasileira de Fruticultura [online]. 2007, vol.29, n.3, pp. 661-665. ISSN 0100-2945.

Cruz, C.D.; Carneiro, P.C.S. Modelos biométricos aplicados ao melhoramento genético. Viçosa: UFV, 2003. 585p.

DE Belie, N., Schotte, S., Lammertyn, J., Nicolai, B., DE Baerdemaeker, J., 2000. Firmness changes of pear fruit before and after harvest with acoustic impulse response technique. Journal Agronomy Engenier Res. 77, 183–191.

Fachinello, J.C.; Machado, N.P.; Betemps, D.L.; Galarça, S.P.; Azevedo, F.Q.; Schneeder, E.P. Maturation of Peaches by Near Infrared Spectroscopy (NIR). Congresso Internacional de Horticultura. Livro de resumos, p:170, Lisboa, Portugal 2010.

Giorgi, M.; Capocasa, F.; Scalzo, J.; Murri, G.; Battino, M.; Mezzetti, B. The rootstock effects on plant adaptability, production, fruit quality, and nutrition in the peach (cv. Suncrest). Scientia Horticulturae, v.107, p.36-42, 2005.

GREEFA – equipamentos 2010. Disponível em:<http://www.greefa.nl/> Acesso 24/06/2010.

Herold, B., Truppel, I., Zude, M. and Geyer, M., 2005. Portable sensor equipment for fruit maturity monitoring in apple orchard. Information and Technology for Sustainable Fruit and Vegetable Production FRUTIC 05: 347-354.

Huang, H., Yu, H., Xu, H. and Ying, Y., 2008. Near infrared spectroscopy for on/in-line monitoring of quality in foods and beverages: A review. Journal of Food Engineering, 87: 303-313.

Kader, A.A. (Ed.), 1992. Postharvest Technology of Horticultural Crops, 2nd ed. University of California Division of Agri. and Natural Resources, Publ., p. 3311.

Kluge, R. A.; Nachtigal, J.C.; Fachinelo, J.C.; Bilhava, A. B. Fisiologia e manuseio pós-colheita de frutas de clima temperado. Campinas: Livraria e Editora Rural, 2002. 214 p.

Loreti, F. Porta-enxertos para a cultura do pessegueiro do terceiro milênio. Revista Brasileira Fruticultura, Jaboticabal - SP, v. 30, n. 1, p. 274-284, 2008.

Lu, R., 2007. Nondestructive measurement of firmness and soluble solids content for apple fruit using hyperspectral scattering images. Sens. & Instrument Food Quality 1: 19-27.

Metheney, P.D., Crisosto, C.H., Garner, D., 2002. Developing canning peach critical bruising thresholds. Journal American Pomology Society 56 (2), 75– 78.

Nicolaï, B., Lammertyn, J., Veraverbeke, E. A. and Jancsók, P., 2005. Non-Destructive Techniques for Measuring Quality of Fruit and Vegetables. Proceedings of 5th International Postharvest Symposium. Mencarelli, F. & Tonutti (eds.) Acta Horticulturae – ISHS 682 (2), Verona, Itália, 1333-1339.

Nicolaï, B. M., Beullens, K., Bobelyn, E., Hertog, M. L. A. T. M., Schenk, A., Vermeir, S. and Lammertyn,J., 2006. Systems to characterize internal quality of fruit and vegetables. Proceedings of the 4th International Conference on Managing quality in chains – The Integrated view on fruits and vegetables quality, Purvis, A. C., McGlasson, W. B. & Kanlayanarat, S. (eds.) Acta Horticulturae –ISHS 712, Bangkok, Thailand, 59-65.

Nicolaï, B. M., Beullens, K, Bobelyn, E., Peirs, A., Saeys, W., Theron, K. I. & Lammertyn, J., 2007. Nondestructive measurement of fruit and vegetable quality by means of NIR spectroscopy: A review. Postharvest Biology and Technology 46: 99-118.

Osborne, B. G., 2000. Near-infrared spectroscopy in food analysis. In Encyclopedia of Analytical Chemistry. Meyers, R. A. (ed.) John Wiley & Sons Ltd, Chichester, 1-14 pp.

Picolotto, L.; Manica-Berto, R.; Pasa, M.S.; Schmitz, J.D.; Prezotto, M.; Betemps, D.; Bianchi, V. Fachinello, J.C. . Características vegetativas, fenológicas e produtivas do pessegueiro cultivar Chimarrita enxertado em diferentes porta-enxertos. Pesquisa Agropecuária Brasileira [online]. 2009, vol.44, n.6, pp. 583-589. ISSN 0100-204X.

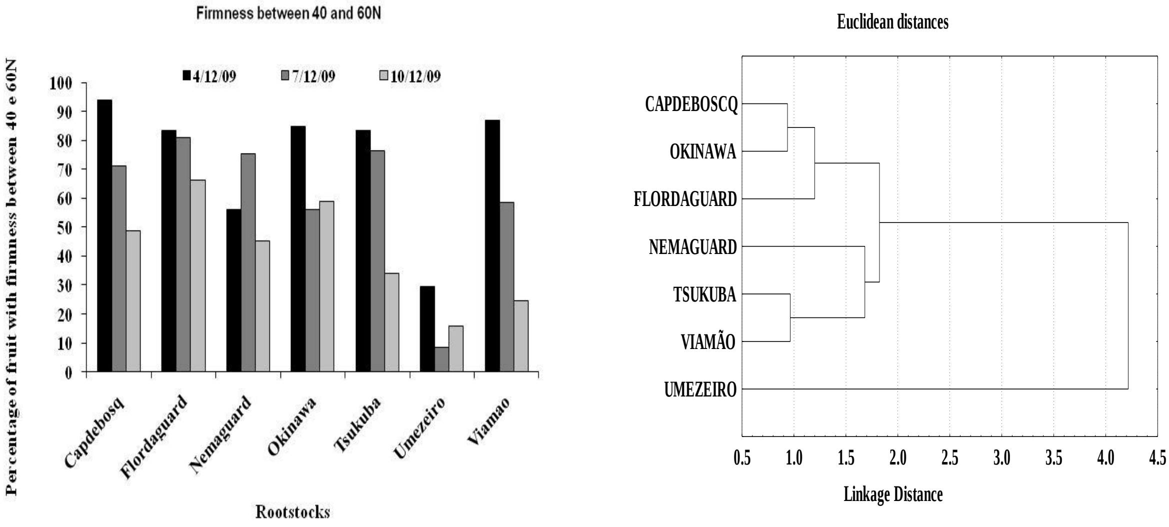
Remorini, D.; Tavarini, S.; Degl'innocentI, E.; Loreti, F.; Massai, R.; Guidi, L. Effect of rootstocks and harvesting time on the nutritional quality of peel and flesh of peach fruits. Food Chemistry, n.110, p.361-367, 2008.

SINCLAIR – equipamentos 2010. Disponível em:<http://www.sinclair-intl.com/> Acesso em: 24/06/2010.

Shmulevich, I., 2003. Nondestructive texture assessment of fruits and vegetables. Acta Horticulturae 599, 289–296.

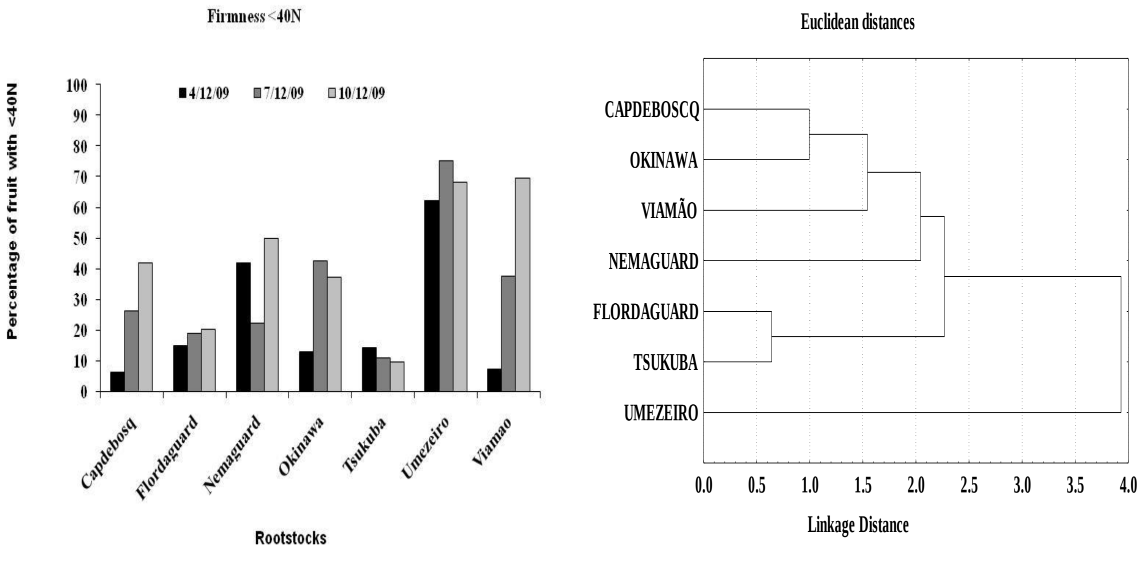
Thompson, J.F., Crisosto, C., 2002. Handling at destination markets. In: Kader, A.A. (Ed.), Postharvest Technology of Horticultural Crops, 3rd ed. DANR Publication, p. #3311, Chapter 21.

Figures



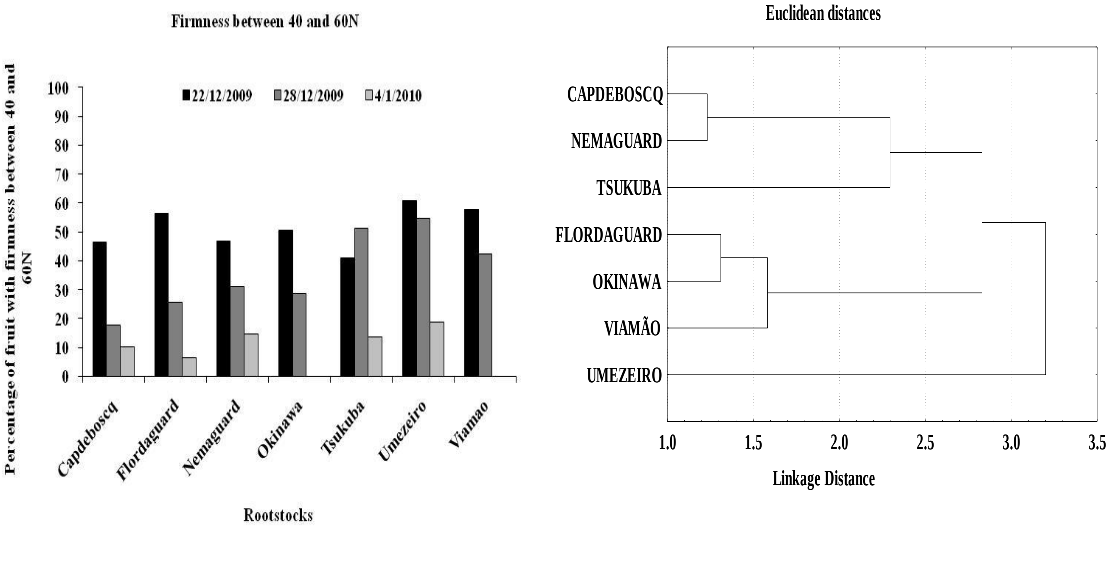
A B

Fig. 1. Percentage of fruit with flesh firmness between 40 and 60N (A) and euclidean distance (B) of peaches of "Chimarrita" cultivar grafted on different rootstocks in three harvest dates.



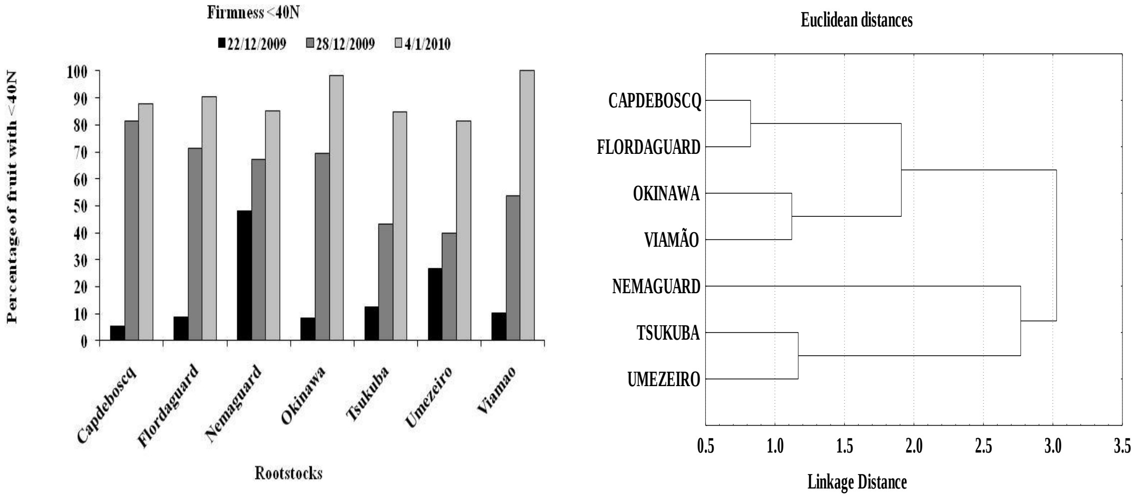
A B

Fig. 2. Percentage of fruit with flesh firmness less than 40N (A) and euclidean distance (B) of peaches of "Chimarrita" cultivar grafted on different rootstocks in three harvest dates.



A B

Fig. 3. Percentage of fruit with flesh firmness between 40 and 60N (A) and euclidean distance (B) of peaches of "Maciel" cultivar grafted on different rootstocks in three harvest dates.



A B

Fig. 4. Percentage of fruit with flesh firmness with less than 40N (A) and euclidean distance (B) of peaches of "Maciel" cultivar grafted on different rootstocks in three harvest dates.