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APPLICATIONS OF A MODEL TO ESTIMATE FRUIT MASS OF *Pyrus communis* L.[1]

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The estimation of pear fruit mass from nondestructive diameter measurements is an important horticultural element. Fruit mass is a more acceptable absolute measure of fruit growth than diameter, but the latter can be be measured more easily. BOLLARD (*2*), working with apple fruits, has emphasized the need to measure volume or mass rather than diameter to properly express growth. Studying pear fruit mass involves harvesting and weighing the material, which is time consuming and destructive to the plant. This is especially a problem when performing growth analyses where individual trees must be sampled frequently and tracked over time.

An alternative to these methods is the use of regression models to correlate fruit mass with some dimension of the intact fruit (e.g. diameter). Such models may be applied using measurements obtained without damaging test fruits and they may be the only reasonable approach of fruit mass estimation when, as in commercial settings, destructive methods cannot be used. Thus, it is useful to be able to predict when pear fruits will

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meet the required market size specifications because of the demands of continuity of supply from supermarkets.

With regard to crop estimates, the special character of each cultivar must be taken into consideration. WINTER (*15*) reported that the fruit growth curve and the relationship between fruit mass and diameter of each particular cultivar were essential components in the application of mathematical models. Considering that initial fruit size differences result in substantial changes in fruit commercial sizes at harvest (*9*), these predictive models are also useful in the practice of fruit thinning. Trees are commonly thinned to regulate final fruit size because this allows control over carbohydrate partitioning. Especially with respect to economic considerations the alternation of light crops of usually large fruits with poor storage quality and heavy crops with too many undersized fruits is highly undesirable (*14*).

A background of the anatomical structure and physiological behaviour of the pear fruit is found in publications of HULME (*10*), BAIN (*1*), FAUST (*4*), MAGEIN (*12*) and GARRIZ et alii (*6, 7*).

The objective of this study was to develop a nondestructive method for determining fruit mass of *Pyrus communis* L. cv. 'Bartlett'from its initial growth to maturity. Our focus was on a model correlating fruit mass with diameter.

Materials and methods. A mature crop of 'Bartlett'pear trees on *P. communis* L. rootstock, planted at 5x4m spacing, was studied at the Experimental Farm of the Comahue National University, Rio Negro, Argentina, on a sandy loam soil. A full description of the soil is given by IRISARRI *et alii* (*11*). The orchard was kept weed-free, fertilized and sprayed for pest and disease control according to the local standard programme for pears. Trees were trained to a multiple leader.

Five trees were selected at random during the 1991/92, 1992/93 and 1993/94 growing seasons. One fruit on each of the four quadrants (N, S, E and W) was sampled at weekly intervals, starting in September, 21 days after full bloom (DFB) and ending in January, 142 DFB. Fruit mass (FM) was measured with an electronic scale (model Mettler P1210, Mettler Instrumente AG, Zurich, Switzerland) and fruit diameter (FD) with a Vernier caliper (model 30-410-5, General Supply Corporation, Jackson, Miss., U.S.A.). FD was the maximum width perpendicular to the main axe. Full blossom was estimated to be on September 20, 1991, September, 24, 1992 and September 15, 1993, respectively, for each successive season. A total of 898 fruits, ranging from small to large size, was measured.

Equations characterizing the two data sets were developed using SYSTAT procedure. Model suitability was evaluated using goodness-to-fit measures (*3*).

In addition, fruits were sampled in the 1994/95 growing season using the same procedure previously described, to test the accuracy of the models being developed.

Results and discussion. Using the criteria delineated we selected three adjustments, for the 1991/92, 1992/93 and 1993/94 growing seasons, and using all data combined, which are presented in Table 1. In all cases the following function provided the most satisfactory fit to the data with very high percentages of accounted variances (>97%):

$$y = a\,X^{b} \qquad \text{(I)}$$

(Y = FM; X = FD; e and b are constants). Table 1 also show the residual mean squares from fitting these models. All of the data were successfully fitted by a model that did not increase the residual mean square relative to the models corresponding to the 1991/92, 1992/93 and 1993/94 growing seasons. Differences between specific models for each year and the model using the combined adjustment were small, suggesting that it may be possible to use a general predictive model. The relationship between FM vs. FD at several developmental stages was then fitted to model.

$$Y = 0.8236\,X^{2.775} \qquad \text{(II)}$$

where Y = FM (g) and X = FD (cm). The value of the coefficient of determination for the curve was $r^2 = 0.98$.

For *Malus domestica* Borkh. cultivars 'Red Delicious'and 'Granny Smith', GARRIZ and DEL EGIDO (*5*) and GARRIZ *et alii* (*8*) developed similar empirical models to predict fruit weight from initial growth to maturity.

TABLE 1 - Regression models of fruit mass in grams (Y) and fruit diameter in centimeters (X) for 'Bartlett'pear trees over three growing seasons, df = degrees of freedom, r^2 = coefficient of determination

Growing season	Model	Residual mean square	df	r^2
1991/92	$Y=0.80091\,X^{2.750}$	0.186	278	0.97
1992/93	$Y=0.77336\,X^{2.800}$	0.208	276	0.98
1993/94	$Y=0.89404\,X^{2.746}$	0.136	338	0.99
Combined data	$Y=0.82360\,X^{2.775}$	0.180	896	0.98

The accuracy of predictions made using model (II), was tested on an independent crop grown at the Experimental Farm in the 1994/95 growing season (n = 200), to see how well a single general model performed. According to the statistical analysis (F test), the differences in mean-squared deviation between measured and calculated values were very small P ($\geq$ 0.05). The regression curve and the data for the 1994/95 growing season were plotted together to evaluate fit graphically (Figure 1). Both analyses indicate that FD can efficiently estimate the expected magnitude of FM.

According to WILLIAMS *et alii* (*14*), unless a certain minimum size is attained, the fruit will be given a lower grade and price. Therefore, resolution of model (II) is useful for estimating fruit mass from diameter measurements.

The results reported here showed that the regression of FM against FD for 'Bartlett'pear fruits was reasonably accurate, suggesting that it may be possible to use a robust general model. A similar work to obtain the seasonal fruit growth pattern of *Pyrus communis* L. cv. 'Bartlett'is being conducted. Further studies of this type may lead to practical ways to improve crop estimates in fruit trees.

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RESUMO

(APLICAÇÕES DE UM MODELO PARA ESTIMAR A MASSA DE FRUTOS *Pyrus communis* L.)

A estimativa não-destrutiva do peso de frutos é importante na Horticultura, particularmente, quando devem ser feitas repetidas medições na mesma árvore sem alterar-lhe o crescimento. O objetivo do presente estudo foi desenvolver um método para determinar a massa do fruto (FM) da pereira usando modelos que a correlacionam com o diâmetro máximo do fruto (FD), uma dimensão facilmente mensurável. Uma cultura de *Pyrus communis* L. cv. 'Bartlett'foi estudada na Fazenda Experimental da Universidade Nacional de Comahue, Argentina. Cinco árvores foram selecionadas ao acaso e os frutos foram amostrados em intervalos semanais, começando em setembro, 21 dias após o pleno florescimento

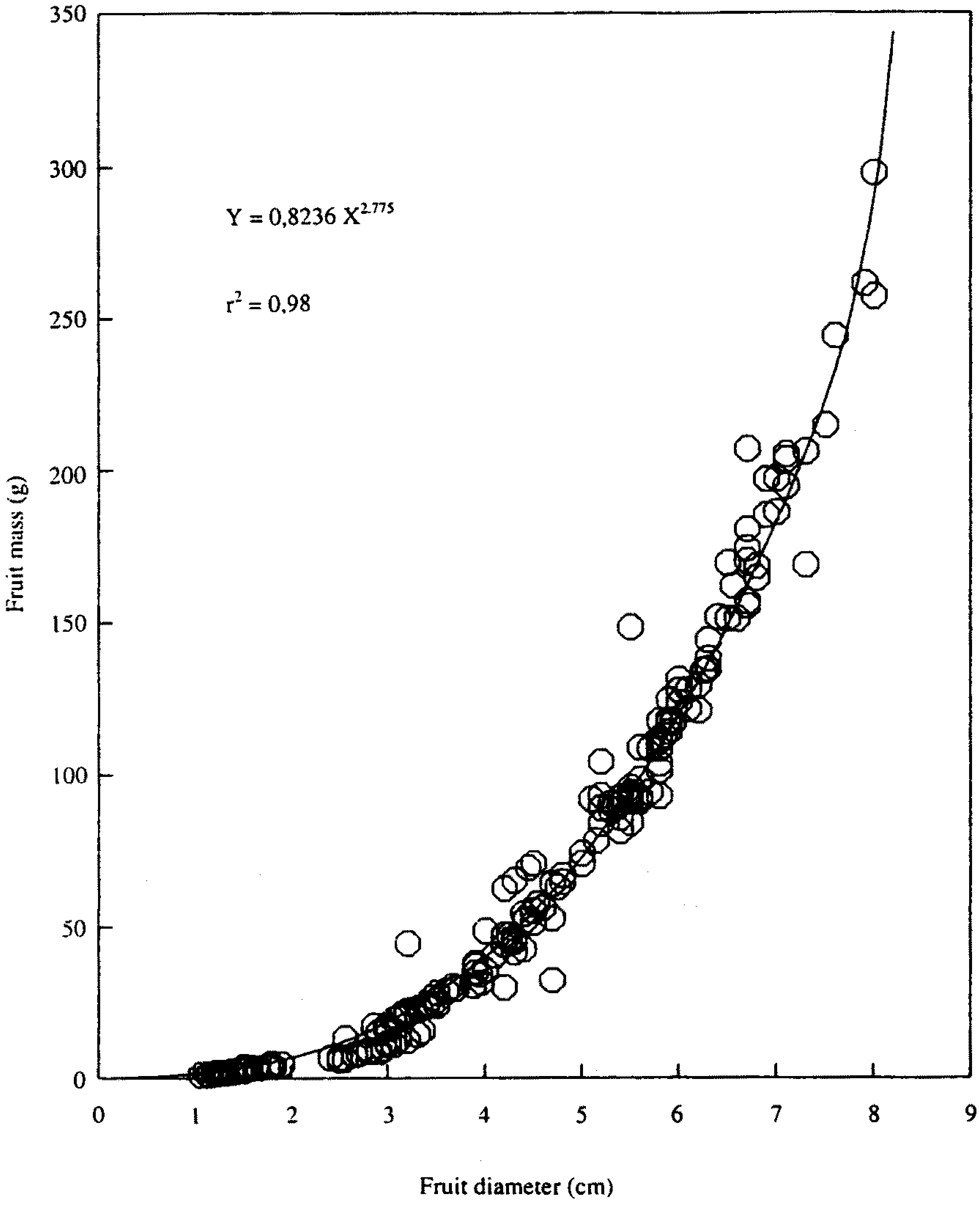

FIGURE 1 - Relationship between fruit mass and fruit diameter for 'Bartlett'pear trees. Data for the 1991/92, 1992/93 and 1993/94 growing seasons were fitted by the model (solid line). Symbols represent data measured on an independent crop (1994/95).

(DFB), e terminando em janeiro, 142 DFB, durante três estações de crescimento (1991/92,1992/93 e 1993/94). Equações de regressão foram desenvolvidas usando o procedimento SYSTAT. Os dados dos três anos foram amalgamados porque a análise mostrou que as suas curvas não diferiam. FN (Y, g) "versus" FD (X, cm) ajustou-se melhor ao modelo $Y = 0,8236\ x^{2,775}$ ($r^2 = 0,98$). A testagem do modelo numa outra cultura mostrou que as predições foram razoavelmente acuradas, parecendo indicar que pode ser possível o uso de um modelo geral para predição seguro.

CITED LITERATURE

1. BAIN, J. Some morphological, anatomical and physiological changes in the pear fruit (*Pyrus communis* var. Williams Bon Chrétien) during development and following harvest. *Australian Journal of Botany, 9*(2):99-123, 1961.
2. BOLLARD, E.G. The physiology and nutrition of developing fruits. In: Hulme, A.C., (ed.). *The biochemistry of fruits and their products.* Vol. I. London, Academic Press, 1970. p. 387-425.
3. DANIEL, C. & WOOD, F.S. *Fitting equations to data.* New York, John Wiley & Sons, 1980. 458 p.
4. FAUST, M. *Physiology of temperate zone fruit trees.* New York, John Wiley & Sons, 1989. 131 p.
5. GARRIZ, P.I. & DEL EGIDO, M.A. Modelos de predicción de calibres en frutos de manzano. *Fruticultura Profesional,* 38 (especial manzano): 141-144. 1991.
6. GARRIZ, P.I.; ALVAREZ H.L. & BARTUSCH, A.M. Efecto de la orientación en el árbol sobre la tasa de crecimiento de frutos de pera cv. Williams. In: REUNION NACIONAL DE FISIOLOGIA VEGETAL, XX. San Carlos de Bariloche, Argentina, 1993. *Abstracts,* San Carlos de Bariloche, SAFV, 1993. p. 122-123.
7. GARRIZ, P.I.; ALVAREZ, H.L. & COLAVITA, G.M. Dinámica de la abscisión en peras del cultivar Williams. In: CONGRESSO LATINOAMERICANO DE HORTICULTURA, VI, Huerta Grande, Argentina, 1994. *Abstracts*, Huerta Grande, CLH-AAH, 1994. p. 121.
8. GARRIZ, P.I.; BARTUSCH, A.M. & ALVAREZ, O.A. La relación peso-diámetro en los frutos de manzano cv. Granny Smith. In: CONGRESSO IBEROAMERICANO DE HORTICULTURA, I, Montevideo, Uruguay, 1992. *Abstracts,* Montevideo, COLHOR, 1992. p. 52.
9. GARRIZ, P.I.; DEL EGIDO, M.A. & BARTUSCH, A.M. Variaciones estacionales en el tamaño de los frutos de manzano cv. Red Delicious. *Rev. Ceres, 39*(225):405-413. 1992.
10. HULME, A.C. Some aspects of the biochemistry of apple and pear fruits. *Advances in Food Research, 8*:297-413. 1958.
11. IRISARRI, J.; APCARIAN, A.; BIANCO, H. & SCHMIDT, O. Mapa de suelos del Campo Experimental de la Facultad de Ciencias Agrarias. *Informe de la Cátedra de Edafologia.* Universidad Nacional del Comahue, Argentina, 1987. 50 p.
12. MAGEIN, H. La gestion du marché par la gestion du verger. *Le Fruit Belge, 442*:49-52. 1993.

13. TROMP, J. & WERTHEIM, S.J. Synthetic growth regulators: Mode of action and application in fruit production. In: COLLOQ. INTERNATIONAL POTASH INSTITUTE, 15th., Bern, 1980. *Proceedings* (*Physiological aspects of crop productivity*), Bern, Int. Potash Inst., 1980. p. 137-150.

14. WILLIAMS, M.W.; BILLINGSLEY, H.D. & BATJER, L.P. Early season harvest size prediction of 'Bartlett' pears. *Journal of the American Society of Horticultural Science, 94*(6):596-598, 1969.

15. WINTER, F. Fruta de pepita: Pronósticos de rendimiento según el método Bavendorf. *Corporación de Productores de Fruta de Rio Negro, 14:*6-17. 1987.