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Title: A Model of Foliar Growth in a Variety of Maqueño Banana.

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Graphical Abstract *(mandatory)*

Crecimiento foliar cada				
Días.	15	30	45	60
Área foliar.	0,08282	0,08718	0,11375	0,1304[illegible]

Table 1.1 Measurements of the foliar area for the planting material thermal chamber. The authors

Etapa.	1	2	3	[illegible]
Error.	00.00693	0.00300	0.00216	0.0[illegible]

Table 1.2 Errors in approaching the values of the model to the experimental values in the different calculation stages

Etapas.		1	2	3
Coeficientes.	a	0,00728	0,00753	0,00745
	b	0,07794	0,07197	0,05877
	c	0,15691	0,10797	0,12689

Table 1.3 Coefficients of the model function for each pair of experimental data

Óptimo.	Top - AF Posible
0,008353608	0,840664402
0,009936912	
0,162011163	

Table 1.4 Optimal coefficients that determine the tendency of the maximum growth of the foliar area

Abstract. *(mandatory)*
The growth of the foliar area is mainly for the plant development, particularly in Musaceae, which get sizes relatively bigger as compared to the other vegetable species. An estimate of the final behavior of the foliar area is made for a banana species, from experimental measurements carried out from the beginning of the plant development up to four months, considered in fifteen -day stages, using a model that describes the trend of final foliar growth which the plant can reach in the stage after the last experimental measurement. The first measurement is considered to run the model with each of the subsequent measurements. The model is selected in the class of functions of the type $A_{a,b,c}(t) = \frac{at^2}{bt^2+ct+1}$, from which those that have a non-sigmoid geometric behavior are discarded, imposing conditions on the coefficients, among which are subsequently selected from the experimental data, those that they accurately represent the process.

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Introduction *(optional), no page limit*

The growth of the foliar area is fundamental for the development of plants, particularly in musaceae, which get sizes relatively bigger as compared to the other vegetable species. Although they have a lesser amount, the growth of leaves in the banana plant is remarkable, and it may be noticed at first glance, through successive observation. According to what is next expressed, ´nutritional needs are determined through field tests, and through the foliar analysis in different stages of vegetative development`, (García Serrano P. et al. pp. 69, 2009). Beyond these assessments, it is possible to perform some kind of predictive analysis starting from experimental information.

Recent studies performed by (Freile Almeida J.A., Quilimbaqui Prado W.C., Cando Naranjo Y.G., 2020), measure the growth of several morphological parameters in one variety of banana, on different planting materials, and with organic fertilization; remarking, "as for the variable foliar area of the plant, statistically significant differences were found (*Tukey a* $P \leq 0.05$) only for the propagation material factor. In this case the plants treated in thermal chamber showed a greater average of foliar area with ($0{,}34\ m^2$), results higher than those of the material little corm ($0{,}2\ m^2$), corm ($0{,}07\ m^2$) and the corm fraction ($0{,}05\ m2$). In this sense an analysis is made, starting from the data reported above, concerning which can be the final behavior of the feature referred to, using one model of functions that describes the behavior of the experimental data, and suggests the final state of the leaf area, for the planting material *thermal chamber*, and therefore a reliable measurement of the space available for the photosynthesis.

Materials and Methods *(optional), no page limit*

Construction of the Model

In general the importance of the use of mathematical models, for problem solving in different knowledge areas, particularly in the agricultural sciences, is stressed by (Hershenfeld N., 1999). The growth of the area of a banana leaf, as it is for any other plant, reaches a given dimension, which is typical for each species. It means, at a certain moment of the development of the leaves, they reach a greater foliar size, with which they remain performing the functions of the plants´ physiology during the useful stage. The area growth should take place in a faster way in an initial stage and slower in the last stage of the development. This evolution may be described in terms of a certain class of functions of the type:

$$A_{a,b,c}(t) = \frac{at^2}{bt^2+ct+1} \quad (1)$$

excluding those having peculiarities, demanding the fulfillment of the condition, $c^2 - 4b < 0$, which allows to establish a connection between the parameters "b" and "c" in the rank $-2\sqrt{b} < c < 2\sqrt{b}$ with $b > 0$. Now, if foliar growth is linked to the presence of nitrogen in the soil, it is possible to establish a nitrogen–foliar area link. Taking into account that a given amount per square meter $N_0\ {}^{u}/_{m^2}$, is the right one for this nutrient; and that "n" m^2 is a higher margin for the area of the leafs, a rank may be established for placing the parameter "a", replacing in (1) the connection nitrogen–

foliar area these hypothesis, for a predetermined and evenly distributed amount of nitrogen in the soil (quantity of parts per million, per square meter) and a limit measurement of foliar area, it results,

$$0 < \frac{aN_0^2}{bN_0^2+cN_0+1} < n$$

$$0 < a < nb + n\left(\frac{c}{N_0} + \frac{1}{N_0^2}\right)$$

If the coefficient "c" is annotated higher $2\sqrt{b}$ it results in,

$$0 < a < n\sqrt{b}\left(\sqrt{b} + \frac{2}{N_0}\right) + \frac{n}{N_0^2} \qquad (2)$$

Taking then into account that the parameter "b" is in the interval $(0;+\infty)$ and that $n = 1\,m^2$ and $N_0 = 350$, it turns out that $a \in \left(0; b + 0{,}000016\sqrt{b} + 0{,}000008\right)$.

With the data provided in (Freile Almeida J.A., Quilimbaqui Prado W.C., Cando Naranjo Y.G., 2019), an exploration is made to find the limit tendency of foliar growth with the different measurements of a time period in sustained conditions of nitrogen concentration, determining the values of the three auxiliary variables "a", "b" and "c".

So that the model function does not oscillate, restricting even more the class (1), it is demanded that the first derivative does not get nullified on the right side of zero, set that represents the domain of the variable time. It would only be needed to justify that the numerator of $A'_{a,b,c}(N)$ does not get nullified since because of the connection between the parameters "b" and "c", the denominator is not non-existent. Being it,

$$A'_{a,b,c}(N) = \frac{acN^2+2aN}{(bN^2+cN+1)^2}$$

The numerator is equaled to zero as $acN^2 + 2aN = 0$. The initial nitrogen level in the soil called N_i, conditions the values of " a" and "c", therefore resulting $c \neq -\frac{2}{N_i}$. In a connection of the type $N(c)$ it is appropriate to demand that $N = -\frac{2}{c} > 500$, considering that this value of the variable nitrogen, is higher than the one required, in the conditions of a crop of whatever type; therefore, for the values of "c" negatives, $-\frac{2}{500} < c$, it means, $c > -0.004$. Finally the parameter "b" may be placed in the interval $[0; 1]$ in a standard form, since it is not conditioned by obtaining the model.

Results and Discussion *(optional), no page limit*

Once the parameters of the model function that represents the data are decided, and considering that the model separates from the experimental value of the area for two consecutive measurements in less than $4.5\,(10^{-3})\,m^2$ for each one, considering also that for the value calculated in each stage; the difference between the experimental and the estimated value, does not exceed in more than $9(10^{-3})\,m^2$ of the unit of measurement considered, which in each node, is lower than $50\,cm^2$ (Refer *to tables 1.1 – 1.2*); table *1.3* shows the coefficients of the model function for each one of the growth stages, considered respectively starting on day 15 until each one of the following measuring days considered in *table 1.1*.

Finally there is the selection of the coefficients of the model function for which the quotient $\frac{a}{b}$ is the highest one among those calculated for each pair of experimental measurements, since it represents the horizontal asymptote which marks out the growth of the variable foliar area, represented in *table 1.4*.

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These conditions allowed to determine that foliar area may grow up to $0{,}840664402\ m^2$, which represents approximately an increase of $5{,}08305\ \%$ in the highest measurement of the foliar area obtained in the last measurement, performed 120 days after sowing the planting material. This percentage value represents around $406{,}64402\ cm^2$ of the foliar area the plant may reach, in the stage subsequent to the last time when measurements were made.

Conclusions *(optional),*

The method put into practice allows estimating the leaf area growth in any plant, if the behavior of this feature in certain moments during the development of the plant is known. Similar analysis may be carried out for other morphological variables, since in general their quantitative behavior, tends to happen in a sigmoid form, showing different growth speeds at the beginning and at the final stage, during which it remains practically invariable. Subsequent studies may lead toward the search of nutrient concentrations like nitrogen, which guarantee the best morphological and fruit performance, since the studies referred to report a relative difference close to a $5\ \%$ in the foliar growth of the plants treated with the two different organic fertilizers used.

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