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Yield components in *Hevea brasiliensis*—theoretical considerations

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Abstract. A theoretical analysis of yield components of *Hevea brasiliensis* is attempted in this paper. The effect of the major yield components, i.e. initial flow rate per unit length of tapping cut, length of the cut, percentage rubber content and plugging index on rubber yield is represented by the formula

$$y = \frac{F \cdot l \cdot C_r}{p}$$

Variation in yield within and between clones can be ascribed to variation to any one of the above components. The importance of high growth rate for maintaining high yield throughout the life cycle of the tree is theoretically elucidated. While the present contention of a theoretical maximum yield of 9.5 t ha^{-1} with a stand of 350 trees is questioned, the theoretical possibility of attaining that yield by increasing the stand per ha to 600 is analysed.

Key-words: Hevea brasiliensis; Euphorbiaceae; para rubber; yield components; potential yield

Introduction

Quantitative analysis is a valuable method of examining the components of yield of any crop. In the case of *Hevea brasiliensis* complete characterization of yield components is still lacking, but a theoretical examination is useful for identifying areas where knowledge and data are lacking, and may also stimulate new ideas and experimental approaches. Such an examination is presented here.

Theoretical aspects

The yield of rubber (y) obtained from a tree each time it is tapped is determined by the volume (V) of latex collected and its rubber content (C_r, % rubber content w/v):

$$y = \frac{V \cdot C_r}{100} \quad (1)$$

The volume of latex depends on the rate and the duration of flow. Milford, Paardekooper & Yee (1969) have proposed a plugging index (p), to measure the extent of latex vessel plugging during flow. This is calculated as

$$p = \frac{100\, F_I}{V} \quad (2)$$

where F_I is the average flow rate per min during the first 5 min after tapping.

The initial flow rate (F_I), is determined by the length of the tapping cut and the average flow rate per unit length. The length (l) of the tapping cut is related to the girth of the tree, which in turn reflects growth rate. The flow rate per unit length of the cut on the other hand will be determined by the number and diameter of latex vessels and by turgor pressure. As these are influenced by different physiological characteristics it is useful to consider them separately.

The average initial flow rate per cm of tapping cut is given by

$$F = F_I / l \quad (3)$$

so that

$$V = \frac{100\, F \cdot l}{p} \quad (4)$$

and

$$y = \frac{F \cdot l \cdot C_r}{p} \quad (5)$$

These relationships indicate that the yield of rubber from a tree, per tap, is proportional to the initial flow rate, the length of the tapping cut and the rubber content of the latex and inversely proportional to the plugging index. All the internal and external factors influencing yield must exert their effects through one of the above components. This is supported by experimental evidence. Yield has been found to be positively correlated to the initial flow rate (Paardekooper & Samosorn, 1969) and negatively correlated to plugging index (Milford *et al.*, 1969). Sethuraj, Sulochanamma & George (1974b) found initial flow rate to be a clonal characteristic.

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Variations in yield

The contribution of each of the components of yield may vary from clone to clone. For example, the differences in yield between two trees, whether belonging to the same or different clones, can be analysed in terms of the following formula:

$$\Delta y = \frac{F_I(1)\cdot l(1)\cdot C_r(1)}{p(1)} - \frac{F_I(2)\cdot l(2)\cdot C_r(2)}{p(2)} \quad (6)$$

where the figures 1 and 2 in parentheses denote the different trees. The reasons for the difference in yield from a tree per tap in different years can be similarly expressed.

The yield of rubber per unit land area per annum (Y) is determined by the average rubber yield per tree per tap ($\bar{y}$), the number of trees (N) and number of tappings per annum (n_t), i.e.,

$$Y = \bar{y}\, N \cdot n_t \quad (7)$$

There is a tendency for average yield per tap ($\bar{y}$) to decrease as n_t increases.

Relationship between the total biomass production and yield

Of the assimilate produced in any period by a tree, part is utilized for the biosynthesis of rubber and a part of the rubber synthesized in latex vessels may be extracted by tapping. The ratio of annual rubber yield to annual dry matter production (including rubber extracted) is defined as the harvest index (I_H). In calculating the partition coefficient or harvest index, only the rubber extracted through tapping is considered:

$$I_H = \frac{2.25\, \bar{y}\cdot n_t}{W} \quad (8)$$

where $\bar{y}\cdot n_t = y_t$ and W is the total annual dry matter production per tree, including the rubber extracted. The factor 2.25 accounts for the high calorific value of rubber (Templeton, 1969). W may be partitioned into

$$W = G + 2.25 \cdot y_t \quad (9)$$

where G is the total dry matter production per annum, excluding rubber extracted. This would be equivalent to the annual increment in shoot and root dry weight.

Under a particular system of tapping F_I, l and C_r are determined by clonal characteristics and cannot be altered at will. The plugging index (p) can, however, be lowered to a considerable extent by the use of yield stimulants. This results in higher y_t which in turn will increase the I_H, although this is recognized as a heritable clonal characteristic (Subramanian, Narayana & Ng, 1971). However, we should note that a harvest index of more than 0.3 is considered detrimental to the growth of the tree.

I_H per tree *per se* is not an indicator of yield. Two clones with the same yield may differ in I_H, if the growth rates are different. For a given y_t, a clone with a higher G is preferable, as a sustained growth rate is necessary for high rates of girth increase, which is one of the factors influencing the cumulative yield over the economic lifespan of the tree. When considering maximum yield potential, the fact that it may not be practicable to develop clones with an I_H of more than 0.6 should be considered. The I_H varied from 0.07 to 0.52 among the twenty-eight clones studied by Templeton (1969). He also reported that clones of higher productivity exhibited a more intense depression in growth rate (G). Sethuraj *et al.* (1974a) have proposed a girth increment index (I_G) to characterize the yield potential of clones in relation to girth increment:

$$I_G = \frac{\Delta_g y_t}{10} \quad (10)$$

where Δ_g is the annual girth increment. Ten kilograms of rubber yield per tree per annum was taken as a standard and hence the figure 10 in the denominator.

Clones with high I_G show high sustained growth rate irrespective of high yield; a very desirable character.

Theoretical maximum potential yield

Templeton (1969) has estimated a maximum potential yield of 9500 kg ha^{-1} by the ninth year of tapping, assuming the combination of $W = 60$ kg during the second year of tapping, $I_H = 0.5$ and a normal stand of 350 trees ha^{-1}. He further assumed that the yield during the ninth year might be three times that in the second year of tapping. It has been established (Wycherly, 1976) that the growth rate after the trees are opened for tapping shows a declining trend with age. The increase in yield with age is mainly a function of a better partitioning coefficient, i.e., high I_H. As the I_H of 0.5 assumed was high, even for the second year of tapping, a three-fold yield increase in the ninth year as compared to the second year is not theoretically possible, so the assumptions on which the computation of a maximum potential yield of 9500 kg ha^{-1} are based must be questioned. The maximum annual dry matter production recorded for trees after 5 years of tapping is only about 60 kg ha^{-1}; assuming an I_H of 0.5 and a stand of 350 trees ha^{-1}, the maximum yield obtainable is only 4666 kg ha^{-1}. Even assuming $W = 100$ kg and $I_H = 0.5$ the maximum yield which could be obtained is only 7777 kg ha^{-1}. The total dry matter production per ha can, however, be increased by increasing the number of trees per ha, although the dry matter production per tree may be reduced. Assuming a stand of 600 trees ha^{-1}, an annual dry matter production of 60 kg per tree and I_H of 0.6 the yield obtainable from 1 ha would be about 9600 kg. The total biomass production with such a growth rate would be 36 t ha^{-1} year^{-1}. This is within the realm of theoretical possibility. Assuming an average radiation (PAR) of 200 cal cm^{-2} d^{-1} and 200 effective days with 100% light interception in a year, the potential dry matter production, calculated by the formula of Penning de Vries, Brunsting & van Laur (1974) would be 83.2 t ha^{-1} year^{-1}.

By adopting a suitable exploitation method, or stimulation, the latex extraction can be manipulated to maintain a high I_H. The objective of the future breeders should be therefore to combine the characters of high girth increment index and high yield per tap (y).

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