

Modelling Growth of the Primary Shoot of Rose

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Abstract

In propagation of rose by leafy stem cuttings, the area of the original leaf is a visible quality determinant of cuttings because it influences rooting (number and dry weight of roots) and length and dry weight of the primary shoot. In this paper a simple photosynthesis-based model is presented to predict elongation of the primary shoot of rose planting material derived from single node leafy stem cuttings. The model describes shoot elongation in response to changes in the original leaf area of cuttings during the first 11 weeks following severance. The model reasonably predicted primary shoot elongation but underestimated shoot length when leaf area was reduced by about 70% or when the complete leaf was removed at 7, 14 or 21 days after severance. The model accurately predicted carbohydrate accumulation during the first 3 weeks after severance. Simulations support the hypothesis that post-severance photosynthesis rather than the initial carbohydrate reserve level is the major determinant of primary shoot growth of single node leafy stem cuttings of rose.

INTRODUCTION

Homogeneous planting material with a well developed root system and primary shoot is a major guarantee of uniform and fast establishment of a rose crop after being planted in the greenhouse.

In the commonly used rose bending production system the primary shoot of the planting material is very important because it influences future growth of bottom breaks after bending. Kool (1996) showed that larger source capacity of the primary shoot of young rose plants, would result in faster development rate and larger weight of bottom breaks which is known to influence flower production (Zieslin et al., 1973). In the case of the still non-commercial, intensive single-stem rose production system, where each young plant is supposed to result in a harvestable stem (Bredmose, 1998; Chao et al., 1998) the importance of the primary shoot is even larger because its length and dry weight directly determines the quality of the flowering shoot. Thus, the ability to control and predict growth of the axillary primary shoot of rose planting material is an important aspect in rose production.

In propagation, the area of the original leaf of single node leafy stem cuttings of rose is considered a quality determinant of planting material because variation in dry weight of roots and length of the primary shoot (Fig. 1) could be mainly ascribed to variations in the area of the original leaf and possibly to changes in the carbohydrate availability (Costa and Challa, 2002). Identically, Marcelis-Van Acker and Leutscher (1993) found that double-node and double leaf cuttings would result in heavier young plants, with a longer primary shoot and larger leaf area compared to single node/leaf cuttings.

It has been also reported for rose plants that the leaf underneath an outgrowing axillary bud is the main source of carbohydrates for the shoot (Mor and Halevy, 1979; Van Labeke et al., 2001) and that rose shoot growth is mainly dependent on the assimilate supply available during growth (Marcelis-Van Acker, 1994; Bredmose, 1998).

Our aim is to develop a simple photosynthesis-based model to predict growth

(elongation) of the primary shoot of rose planting material in relation to changes in the leaf area (photosynthetic capacity) of the original leaf of cuttings. The basic hypothesis is that the original leaf of cuttings influences growth of the axillary primary shoot primarily via assimilate supply.

MATERIAL AND METHODS

Experiments

Mother plants of *Rosa hybrida* Madelon[®] were grown in a greenhouse and single node leafy softwood stem cuttings with an original leaf of 5 leaflets were also propagated and grown in the greenhouse as described by Costa and Challa (2002).

Treatments: Cuttings were defoliated to different degrees by removing from the original leaf: no leaflet (control), 1 leaflet, 3 leaflets or the entire leaf at 0, 7, 14 or 21 days after severance. Leaflets were removed in a basipetal order, starting at the terminal leaflet. The treatments resulted in average leaf areas of 58, 39 and 14 cm² for cuttings with 5, 4, and 2 leaflets respectively. Fifteen days after severance, cuttings were potted in 10-cm diameter plastic pots containing a commercial potting mixture (pH=6.0; EC=0.7 dS m⁻¹) and placed inside the propagation benches. Plants were hardened-off for 21 days before being moved to another greenhouse compartment with a day/night temperature set at 18°C/16°C respectively. The photoperiod was extended to 18 hours with high-pressure sodium lamps (Phillips SON/T Agro, 400 W) providing (a minimum) light intensity of about 50 μmol m⁻² s⁻¹ (PPF) at plant level. Plants were placed on aluminium benches and grown until flower break and lateral buds of the primary shoot started to sprout. Plant density was 51 plants m⁻² until week 7 and 32 plants m⁻² afterwards.

Measurements: Total leaf area (LI-3100 area meter; Li-Cor Inc., Lincoln, NE, USA), dry weight of roots, of the primary shoot (leaves and stem), and of the original stem segment of cuttings were determined 10 weeks after severance. The length of the primary shoot was measured every week between the end of week 4 and end of week 10 (Fig. 1). Carbohydrates were determined as described by Costa et al. (2001).

Major Assumptions and Parameters of the Model

The model assumes that until 40 days after severance, only the original leaf of cuttings results in net photosynthesis. The young and in some cases partly unfolded leaves of a young primary shoot represent a sink rather than a source (Mor and Halevy, 1979). According to previous literature a young shoot, up to 10-20 cm long, can be considered as a net sink (Mor and Halevy, 1979; Van Labeke et al., 2001). Another major assumption is that roots start growing earlier than the axillary primary shoot. Dry weight partitioning to roots starts at 7 days after severance, whereas partitioning to the shoot starts at 11 days after severance as observed in previous experiments (Costa and Challa, 2002). Partition of dry weight to the shoot was estimated at 88% and growth rate of roots is calculated as 10% of the shoot's growth rate.

The length of the primary shoot and the new formed leaf area were estimated from the simulated dry weight of the primary shoot according to the formulae presented in Table 1. The maximum elongation rate was estimated as the derivative of a Gompertz curve fitted to the measurements of the shoot length of the control (Fig. 1A). The maximum elongation rate was then converted into the maximum growth rate according to the relation between length and dry weight (Table 1).

Simulations started always at severance (week 0) and were extended until end of week 11 (one week more than the duration of the measurements). Because leaf removal (original leaf area = 0 cm²) during the first week of propagation resulted in the loss of cuttings by stem black rot (Costa and Challa, 2002) no simulation was conducted for that situation.

Simulations were conducted using the Powersim Studio 2003 package (Power Sim Software AS). The relational diagram is presented in Fig. 2.

RESULTS

Shoot Elongation

The model could accurately predict elongation of the primary shoot in the control situation (Fig. 3). However, when the original leaf area was reduced by 70% the model strongly underestimated elongation.

The model did not predict accurately the effect of the time of leaf removal on the elongation of the primary shoot (Fig. 4). The simulated elongation started fast and before the measured elongation. However, leaf removal stopped primary shoot elongation (at least for some time) whereas in reality the shoot continued elongating (Fig. 4).

Carbohydrate Dynamics

Simulations for cuttings with a leaf area of 58 cm² (control) show that carbohydrates accumulate until the end of week 3 which is in agreement (also quantitatively) with measurements (Fig. 3). This increase in the carbon pool is followed by a fast decrease until end of week 6, which occurs simultaneously with the elongation of the primary shoot. The carbohydrate pool increases again after week 6 as a consequence of the net photosynthetic activity of the new leaves of the primary shoot and the reduced maximum growth rate. Simulations also show that cuttings with smaller leaf area (39 or 14 cm²) accumulate less carbohydrates (Fig. 3).

Increasing the initial concentration of carbohydrates in cuttings with a leaf area of 14 cm² by 300% from 0.06 to 0.25 mg mg⁻¹ dry weight (amount measured in 5 leaflets cuttings filled with starch at 3 weeks after severance) increased growth of the preliminary shoot by only 30% (Fig. 5A). This contrasts with the effect of increasing photosynthesis per unit of leaf area by only 50% which resulted in a about 100% increase of the shoot length (Fig. 5A) and also strongly increased the available pool of carbohydrates (Fig. 5B).

DISCUSSION AND CONCLUSIONS

The model predicts elongation of the primary shoot of cuttings with considerable accuracy but only when no reduction of the original leaf area occurred. As cuttings accumulate carbohydrates in leaves during the first weeks of propagation (Fig. 3), it is possible that gross photosynthesis per unit of leaf area is negatively affected. When assuming a 50% higher photoassimilation (1.2 mg CO₂ cm⁻² day⁻¹) for cuttings with 14 cm² of leaf area the simulated values obtained for shoot elongation were closer to the measured values (Fig. 5A). Therefore, gross photosynthesis per unit leaf area may be higher in smaller leaf cuttings due to the absence of feedback inhibition of photosynthesis by carbohydrate accumulation (Stitt, 1991) or because smaller leaf cuttings are less prone to water stress (Loach, 1988).

The underestimation of the shoot length when the original leaf was removed at different moments of propagation (Fig. 4) may be because new leaves of the primary shoot start to become sources earlier in that situation or because other factors (e.g. hormones) (Dieleman, 1998) may overrule the effect of photosynthate supply/availability on bud outgrowth when drastic reduction of the leaf area occurs.

The simulations showed that cuttings with smaller leaf area (specially the ones with 14 cm²) accumulate less carbohydrates (Fig. 3). This agrees with measurements done at the rooting zone of cuttings until 11 days after severance and showing that cuttings with an intact leaf (5 leaflets) accumulated more carbohydrates than cuttings with only 2 leaflets (Costa et al., 2001).

Increasing the initial carbohydrate reserves had only a small positive effect on the simulated elongation of the primary shoot in cuttings with a leaf with 14 cm². This means that the carbohydrate pool present at severance has only a minor effect on further growth of cuttings if compared to the effect of post-severance photosynthesis. The role of the initial reserves in single leaf stem cuttings of rose is mainly to guarantee survival during the first days of propagation (Costa, 2002).

The applicability of the proposed model should be increased by including climate

factors (CO₂, light intensity, temperature) which do also influence growth of rose cuttings.

Literature Cited

- Bredmose, N.B. 1998. Growth, Flowering and Postharvest performance of single-stemmed Rose (*Rosa hybrida* L.) plants in response to light quantum integral and plant population density. *J. Amer. Soc. Hort. Sci.* 123:569-576.
- Cannell, M.G.R. and Thornley, J.H.M. 2000. Modelling the components of plant respiration: some guiding principles. *Ann. Bot.* 85:45-54.
- Chao, K., Gates, R.S. and Anderson, R.G. 1998. Knowledge-based control systems for single stem rose production. Part I: Systems analysis and design. *Trans. ASAE* 41:1153-1161.
- Costa, J.M. 2002. The role of the leaf in growth dynamics and rooting of leafy stem cuttings of rose. Ph.D. Dissertation, Wageningen Univ., the Netherlands.
- Costa, J.M. and Challa, H. 2002. The effect of the original leaf of rooting and initial growth of planting material of rose. *Sci. Hort.* 95:111-121.
- Costa, J.M., Challa, H., Van Meeteren, U. and Van de Pol, P.A. 2001. Photosynthates: mainly stored and yet limiting in propagation of rose cuttings. *Acta Hort.* 547:167-174.
- Dieleman, J.A. 1998. Cytokinins and bud break in rose combination plants. Ph.D. Dissertation, Wageningen Univ., The Netherlands.
- Kool, M.T.N. 1996. System development of glasshouse roses. Ph.D. Dissertation, Wageningen Univ., The Netherlands.
- Gijzen, H. 1992. Simulation of photosynthesis and dry matter production in greenhouse crops. Simulation report CABO.
- Lieth, J.H. and Pasian, C.C. 1993. Development of a crop simulation model for cut-flower roses. *Acta Hort.* 328:179-184.
- Loach, K. 1988. Water relations and adventitious rooting. p.102-116. In: T.D. Davis, B.E. Haissig and N. Shankla (eds.), *Adventitious root formation in cuttings*, Discorides Press, Portland, Oregon.
- Marcelis-Van Acker, C.A.M. and Leutscher, K.J. 1993. Effect of the type of cutting on heterogeneity and growth of *Rosa hybrida* cv. 'Motrea' and *Schefflera arboricola* cv. 'Compacta'. *Sci. Hort.* 54:59-67.
- Marcelis-Van Acker, C.A.M. 1994. Effect of assimilate supply on development and growth potential of axillary buds in roses. *Ann. Bot.* 73:415-420.
- Mor, Y. and Halevy, A.H. 1979. Translocation of ¹⁴C assimilates in roses. *Physiol. Plant.* 45:177-182.
- Stitt, M. 1991. Rising CO₂ levels and their potential significance for carbon flow in photosynthetic cells. *Plant Cell Env.* 14:741-762.
- Van Labeke, M.C., Dambre, P., Bodson, M. and Pien, H. 2001. Developmental changes in carbohydrate content in young rose shoots (*Rosa hybrida* 'Frisco'). *Acta Hort.* 547:193- 201.
- Zieslin, N., Halevy, A.H. and Biran, I. 1973. Sources of variability in greenhouse flower production. *J. Am. Soc. Hort. Sci.* 98:321-324.

Tables

Table 1. Parameter values and model equations (DW = dry weight).

Parameter values:	
Initial DW	350 mg
Initial carbohydrate concentration	0.06 mg/mg DW (average amount for the leaf and stem parts of a single node leafy stem cutting at severance; Costa, 2002)
Leaf Gross rate photosynthesis (Pg)	0.84 mg CO ₂ cm ⁻² day ⁻¹ (for cuttings propagated at 85 μmol m ⁻² s ⁻¹ and 18 h photoperiod; Costa, 2002)
Conversion efficiency	0.7 g DW g ⁻¹ CH ₂ O (Gijzen, 1992)
Specific leaf area (SLA)	0.025 m ² g ⁻¹
Primary shoot leaf weight ratio (LWR)	0.6
Equations:	
Total Respiration (R _t)	R _t = Growth respiration (R _g) + Maintenance respiration (R _m) (R _g) = 35% of daily Pg (Cannell and Thornley, 2002) (R _m) = 1% of Total DW (Lieth and Pasian, 1993)
Primary shoot length	1E-10*DWSshoot ³ – 5E-06*DWSshoot ² + 0.031*DW
Primary shoot leaf area	SLA*LWR*Shoot DW

Figures

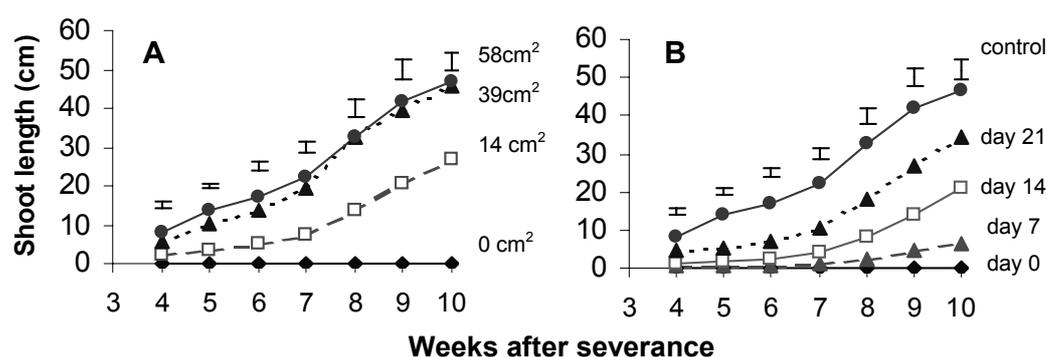


Fig. 1. Effects of (A) the leaf area (58 cm² (= control), 39 cm², 14 cm² and 0 cm²) and (B) timing of leaf removal (days 0, 7, 14 or 21 after severance) on the growth of the primary shoot of single node leafy stem cuttings of *Rosa hybrida* Madelon[®] after severance. Vertical bars indicate least significant differences at 5% level.

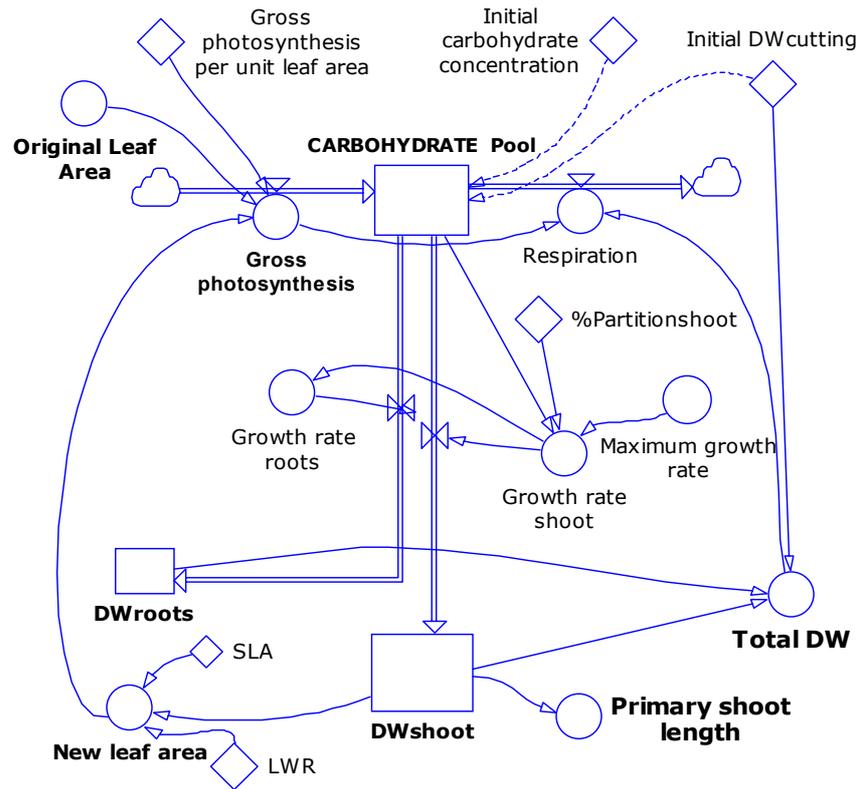


Fig. 2. PowerSim relational diagram showing the main relations between the original leaf (area) of cuttings, the carbohydrate pool and growth (elongation) of the primary shoot.

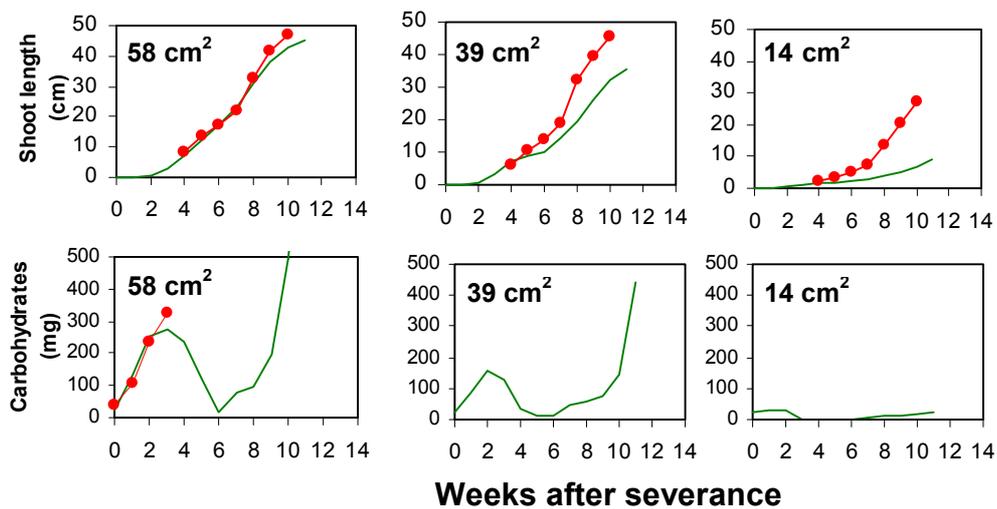


Fig. 3. Primary shoot elongation and carbohydrate dynamics (observed (—●—) and predicted (—)) for young rose plants *Rosa hybrida* Madelon[®] derived from of single node leafy stem cuttings with an original leaf of 58 cm², 39 cm² or 14 cm² plotted against the number of weeks after severance.

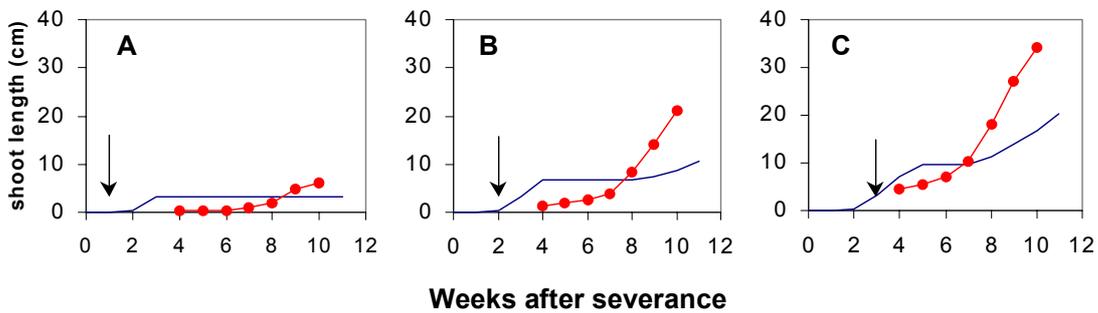


Fig. 4. Length of the primary shoot (observed (—●—) and predicted (—)) for young plants of *Rosa hybrida* Madelon[®] derived from single node leafy stem cuttings with the original leaf removed on day 7 (A), day 14 (B) or day 21 (C) of propagation. Arrow indicates the moment of removal.

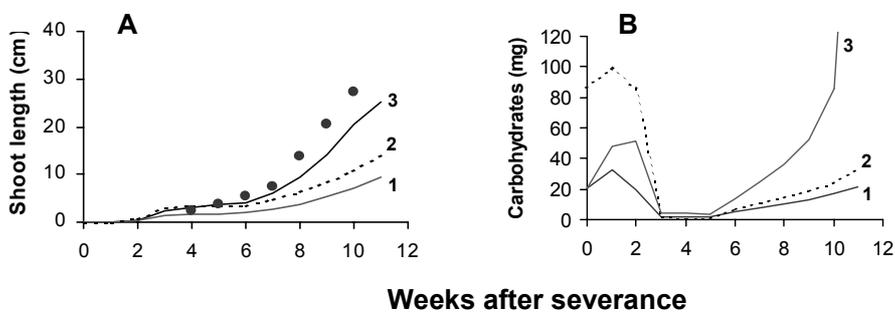


Fig. 5. Observed (symbols) and predicted (lines) values for (A) length of the primary shoot and (B) carbohydrate storage in young plants of *Rosa hybrida* Madelon[®] derived from single node leafy stem cuttings with a leaf area of 14 cm² with **1**) initial carbohydrate pool of 0.06 mg CH₂O mg⁻¹ DW and Pg = 0.84 mg CO₂ m⁻² s⁻¹; **2**) initial carbohydrate pool of 0.25 mg CH₂O mg⁻¹ DW and Pg = 0.84 mg CO₂ m⁻² s⁻¹ and **3**) initial carbohydrate pool of 0.06 mg CH₂O mg⁻¹ DW and Pg = 1.2 mg CO₂ m⁻² s⁻¹.

