

MODEL FOR ESTIMATING OF SOME SHOOTS BIOMETRIC PARAMETERS IN THE CASE OF WOODY SPECIES

Simona ROSU¹, Mihai Valentin HERBEI², Florin SALA¹

Banat University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" from Timisoara, ¹Soil Science and Plant Nutrition; ²Remote Sensing and GIS

Corresponding author: florin_sala@usab-tm.ro

Abstract. The present study evaluated the relationship between dimensional parameters of annual growth of shoots in woody species. The biological material was represented by the species *Tilia cordata* L., from the area of the Cenad Forest Protected Area, Timis County, Romania. The length of the internodes (IL) and the diameter of the internodes (ID) were determined in relation to the position of the internodes on the shoot (IP). The length of the internodes (IL), in relation to their position on the shoot, was described by a polynomial equation of degree 3, in statistical safety conditions, according to $R^2 = 0.832$, $p = 0.00014$. The diameter of the internodes (ID), in relation to their position on the shoot (IP), was described by a polynomial equation of degree 2, in statistical safety conditions, according to $R^2 = 0.982$, $p < 0.001$. Within PCA, PC1 explained 63.002% of variance, and PC2 explained 36.998% of variance. Cluster Analysis led to the grouping of internodes based on Euclidean distances, in relation to the values of IL and ID parameters, in statistical safety conditions (Coph. Corr = 0.913). The highest degree of similarity was found in the case of internodes I7 and I8, in which case SDI = 0.2786. The regression analysis facilitated the obtaining of an equation that described the variation of the internode diameter (ID) in relation to the internode position (IP) and internode length (IL) analyzed simultaneously, in statistical safety conditions according to $R^2 = 0.995$, $p < 0.001$. 3D and isoquant models were obtained to represent the ID variation in relation to IP and IL. From the comparative analysis of the real data and the graphical representation of the models from the obtained equations, deviations of the ID values were found in the case of internodes I6, I7, I8 and I9 from the theoretical model. This can be associated with certain stress conditions generated by vegetation factors during the formation of the respective internodes. The approach can be extended to other arboreal or fruit species of economic interest.

Keywords: Biometric parameters, Cluster Analysis, growth model, PCA, shoot, woody species

INTRODUCTION

Shoots and plant stems present a variety of growth forms, in relation to the species, vegetation conditions and different stimuli or stressors (Chelakkot and Mahadevan, 2017).

Shoot morphology, structure, growth, biomass, orientation, and other parameters or characteristics of shoots, vary in relation to different influencing factors (Liu and Su, 2016).

Different parameters of the shoots were studied in relation to the mineral elements (Sugiura and Tateno, 2011; Sala and Blidariu, 2012), the maximum height and the height gradient (Osada, 2011; Sun et al., 2019a), the maturation of the shoots in plants (Poethig, 2013), root - shoots partitioning in relation to some mineral elements (eg Ca) in the apple (Kalsist et al., 2018), shoot in relation to tree wood (Rosati et al., 2018), root - shoot ratio for agricultural production (Bláha, 2019), biomass production (Cao et al., 2019).

Plant growth is a natural process that takes place in relation to specific factors of influence. Growth and position of shoots in different plant species was studied in relation to leaf area (Souza et al., 2009; van der Sande et al., 2015; Sun et al., 2019b), various elevations conditions (Wang et al., 2012), growth potential associated with periods of apple resource limitation (Reyes et al., 2016), light conditions (Liu and Sub, 2016; Saouab and Amraoui, 2020), fruiting in some fruiting species in orchards (de Oliveira et al., 2017), soil moisture (Scharnweber et al., 2020).

Based on studies in oak, Herrmann et al. (2015) considered that endogenous rhythmic growth was regulated by internal clocks rather than by the availability of resources.

Due to the importance of knowledge of shoot growth, understanding of influencing factors, different models of shoot maturation have been developed in relation to vegetative phases (Poethig, 2013), in relation to plant height and certain associated traits (Gleason et al., 2018), biomass variation in shoots (64 arboreal species), in relation to elevation gradient (Sun et al., 2019a), growth of shoots in hybrid Rosa in relation to the position of shoots / shoot bending (Zhang et al., 2020), in relation to C allocation (Habiyaemye et al., 2021).

Chelakkot and Mahadevan (2017), based on their studies, formulated mathematical models regarding the growth of shoots from a quantitative biophysical perspective, and Kaitaniemo et al. (2020) used and demonstrated the effectiveness of power-law models (as allometric equations) in the study of tree growth in trees (*Betula pendula* Roth).

The present study evaluated the growth of shoots based on biometric parameters, with reference to the length and diameter of the internodes in relation to their position on the shoot in the case of a woody specie.

MATERIAL AND METHODS

The study evaluated the relationship between the dimensional parameters of the internodes on the annual shoots and formulated a model for estimating the relationships of their interdependence and growth of the shoots. The biological material was represented by the species *Tilia cordata* L., and came from the Protected Area of Cenad Forest, Timiș County, Romania, figure 1. The shoots samples (4 shoots) were taken in July, 2021.

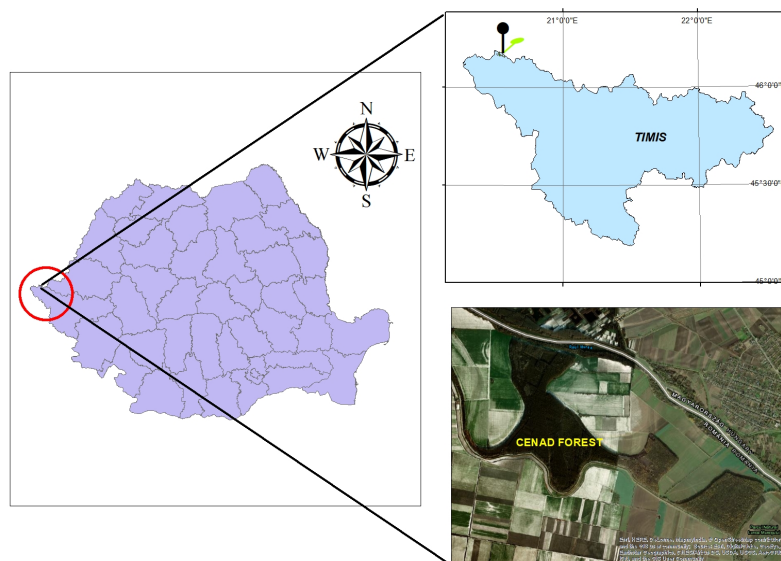


Figure 1. Sampling area, Cenad Forest Protected Area, Timis County, Romania (9)

Determinations (in number of 120) were made regarding the position of the internodes on the shoot (IP), the length of the internodes (IL) and the diameter of the internodes (ID). The values of the IL parameter were obtained by measurement, accuracy ± 0.5 mm. The diameter of the internodes (ID) was measured with an electronic caliper, with an accuracy of ± 0.001 mm.

Statistical analysis and processing of experimental data was done with the statistical mode of EXCEL, PAST software (Hammer et al., 2001), and Wolfram Alpha (2020). Regression analysis, PCA, and Cluster Analysis were performed. To evaluate the statistical safety of the obtained results were used ANOVA-test, p, Coph. corr.

RESULTS AND DISCUSSIONS

The values of the Statistical Analysis regarding the parameters of characterization of the internodes on the shoot, internode length (IL) and internode diameter (ID), *Tilia cordata* L., resulted in the study are presented in table 1.

Table 1. Statistical characterization values of the shoots parameters, *Tilia cordata* L.

Statistical Parameters	Internode length (IL)	Internode diameter (ID)
Min	3.50	3.68
Max	11.50	11.07
Mean	8.60	7.99
Std. error	0.5689	0.6360
Variance	4.8552	6.0667
Median	9.2	9.12
Coeff. var	25.61152	30.82695

The length of the internodes (IL), in relation to their position on the shoot (IP), was described by a polynomial equation of degree 3, relation (1), in statistical safety conditions, according to $R^2 = 0.832$, $p = 0.00014$, $F = 18.134$. The graphical distribution of IL in relation to IP is shown in figure 2.

$$IL = -0.01353x^3 + 0.22x^2 - 0.5234x + 7594 \quad (1)$$

where: *IL* – internode length; *x* – internode position on the shoot (IP).

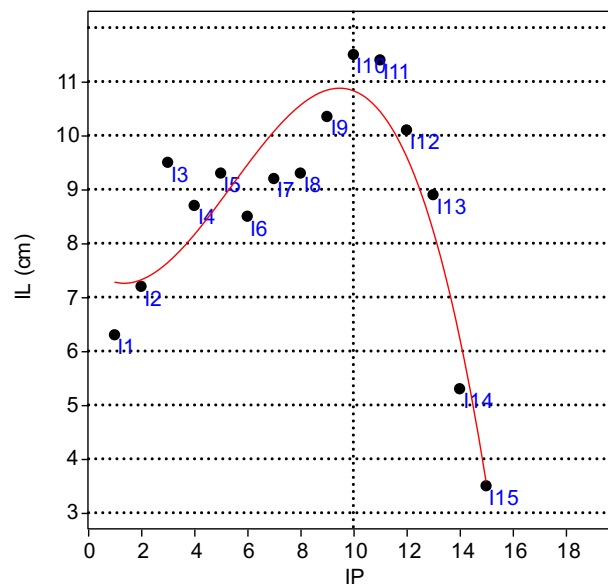


Figure 2. Graphic distribution of IL values in relation to IP and graphical expression of the model of equation (2), *Tilia cordata* L.

The diameter of the internodes (ID), in relation to their position on the shoot, was described by a polynomial equation of degree 2, relation (2), in statistical safety conditions, according to $R^2 = 0.982$, $p < 0.001$, $F = 337.82$. The graphical distribution of ID in relation to IP is shown in figure 3.

$$ID = -0.02918x^2 - 0.06747x + 10.94 \quad (2)$$

where: *ID* – internode diameter (mm); *x* – internode position on the shoot (IP).

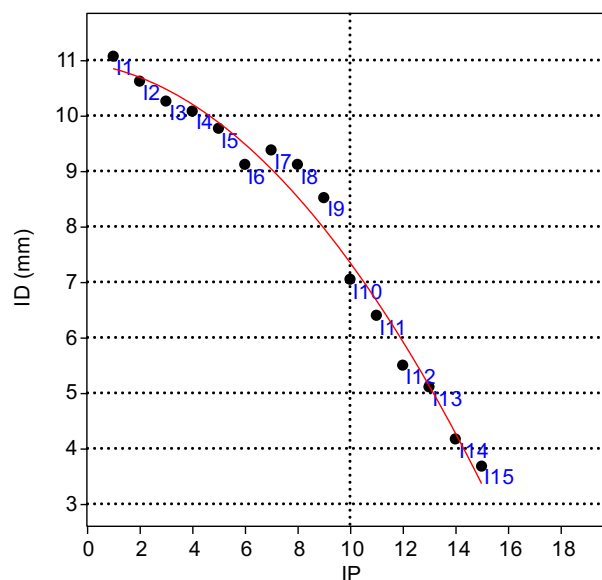


Figure 3. Graphic distribution of ID values in relation to IP and graphical expression of the model of equation (2), *Tilia cordata* L.

According to PCA, the distribution diagram of the internodes in relation to IL and ID parameters, as biplot, was obtained. PC1 explained 63.002% of variance, and PC2 explained 36.998% of variance. The association of the internodes with positions I3, I4, I5, I6, I7, I8 and I9 with the two parameters, IL and ID, was found. From the analysis of the graphical distribution in figure 4, a deviation from the graphical expression of equation (2) of the internodes I6, I7, I8 and I9 was found. It is possible that during the formation and growth of these internodes, certain environmental factors (humidity, temperature) had restrictive values, in relation to the requirements of normal vegetation.

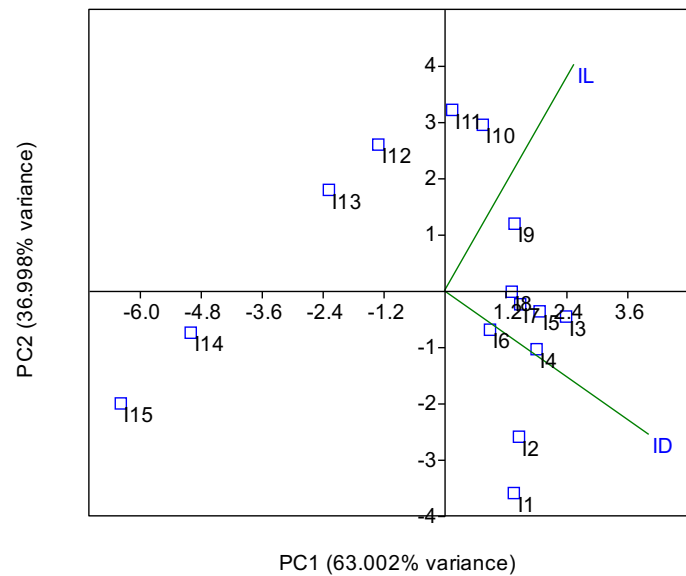


Figure 4. PCA diagram regarding the distribution of internodes in relation to ID and IP (as biplot), *Tilia cordata* L.

Cluster Analysis led to the grouping of internodes based on Euclidean distances, in relation to the values of IL and ID parameters, in statistical safety conditions (Coph. Corr = 0.913), figure 5. The formation of two distinct clusters, C1 and C2, was found. Cluster C1 comprises two internodes I14 and I15, with the lowest values for the analyzed parameters.

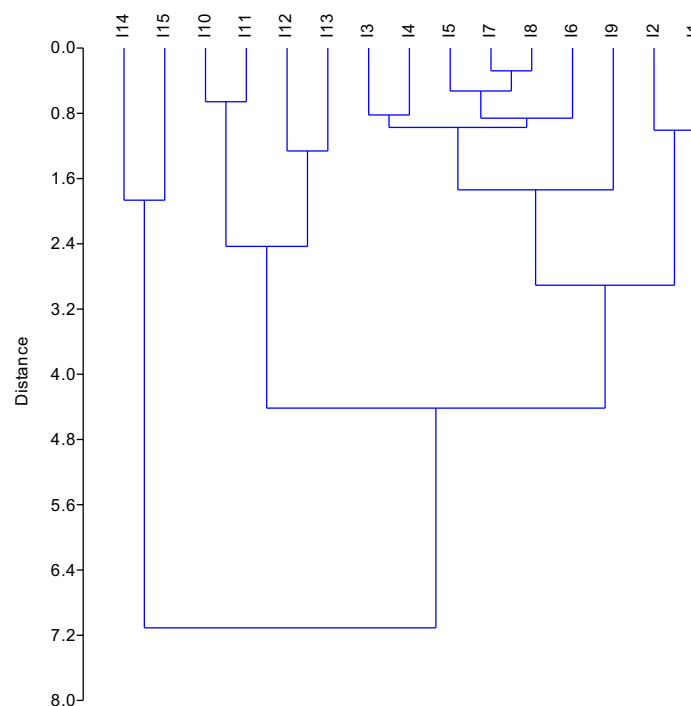


Figure 5. Internode grouping dendrogram based on similarity in relation to IL and ID values, *Tilia cordata* L.

Cluster C2 comprises several sub-clusters. From the analysis of the internode association, it was found the grouping (I1_I2), as internodes at the base of the shoot, within a C2-1 sub-cluster. Another group comprises the internodes [(I10_I11), (I12_I13)] within a C2-3 subcluster, as internodes towards the top of the shoots. In relation to the IL and ID values, some of the internodes were grouped on the basis of similarity within a C2-2 subcluster, as a predominantly position in the middle of the shoots [(I3_I4); I5, (I7_I8), I6; I9]. Similar to figure 2, of the PCA diagram, and within the CA dendrogram, the association of the internodes I6, I7, I8, I9 was found, which showed deviations from the distribution of the model given by equation (2). In fact, the highest degree of similarity was found in the case of internodes I7 and I8, in which case SDI = 0.2786, table 2.

Table 2. SDI values in relation to the parameters of the internodes studied in the shoots, *Tilia cordata* L.

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15
I1		1.0062	3.3009	2.5962	3.2696	2.9398	3.3565	3.5781	4.7859	6.5727	6.9151	6.7428	6.5024	6.9721	7.9027
I2	1.0062		2.3280	1.5942	2.2655	1.9849	2.3532	2.5807	3.7858	5.5888	5.9539	5.8843	5.7663	6.7240	7.8647
I3	3.3009	2.3280		0.8200	0.5292	1.5164	0.9297	1.1574	1.9365	3.7821	4.3023	4.7977	5.1848	7.3978	8.9049
I4	2.5962	1.5942	0.8200		0.6754	0.9806	0.8602	1.1321	2.2707	4.1256	4.5643	4.7892	4.9740	6.8182	8.2462
I5	3.2696	2.2655	0.5292	0.6754		1.0308	0.4026	0.6500	1.6325	3.4983	3.9708	4.3443	4.6771	6.8819	8.4100
I6	2.9398	1.9849	1.5164	0.9806	1.0308		0.7467	0.8000	1.9449	3.6448	3.9760	3.9578	4.0299	5.8943	7.3887
I7	3.3565	2.3532	0.9297	0.8602	0.4026	0.7467		0.2786	1.4360	3.2740	3.7041	3.9830	4.2805	6.5080	8.0610
I8	3.5781	2.5807	1.1574	1.1321	0.6500	0.8000	0.2786		1.2093	3.0207	3.4363	3.7073	4.0299	6.3642	7.9520
I9	4.7859	3.7858	1.9365	2.2707	1.6325	1.9449	1.4360	1.2093		1.8664	2.3658	3.0303	3.7055	6.6652	8.3874
I10	6.5727	5.5888	3.7821	4.1256	3.4983	3.6448	3.2740	3.0207	1.8664		0.6577	2.0887	3.2440	6.8363	8.6808
I11	6.9151	5.9539	4.3023	4.5643	3.9708	3.9760	3.7041	3.4363	2.3658	0.6577		1.5811	2.8132	6.4948	8.3551
I12	6.7428	5.8843	4.7977	4.7892	4.3443	3.9578	3.9830	3.7073	3.0303	2.0887	1.5811		1.2618	4.9809	6.8463
I13	6.5024	5.7663	5.1848	4.9740	4.6771	4.0299	4.2805	4.0299	3.7055	3.2440	2.8132	1.2618		3.7207	5.5861
I14	6.9721	6.7240	7.3978	6.8182	6.8819	5.8943	6.5080	6.3642	6.6652	6.8363	6.4948	4.9809	3.7207		1.8655
I15	7.9027	7.8647	8.9049	8.2462	8.4100	7.3887	8.0610	7.9520	8.3874	8.6808	8.3551	6.8463	5.5861	1.8655	

The regression analysis evaluated the variation relation of a parameter of the internodes, namely the diameter (ID), in relation to the position of the internodes on the shoot (IP) and the length of the internodes (IL), in the case of shoots of *Tilia cordata* L.

The diameter of the internodes (ID) in relation to the internode position (IP) and the internode length (IL) was described by equation (3), in statistical safety conditions according to $R^2 = 0.995$, $p < 0.001$, $F = 458.7842$. The graphical distribution of the ID values in relation to IP (x = axis) and IL (y-axis) is shown in 3D form in figure 6 and in isoquant form in figure 7.

Both from the analysis of equation (3) and from the 3D model of ID variation in relation to the two factors (IP and IL) it was found that internode position (IP) had a minimal influence on the diameter of the internodes (ID), and the variation of this parameter was mainly due to the length of the internode (IL).

$$ID = ax^2 + by^2 + cx + dy + exy + f \quad (3)$$

where: ID - internode diameter (mm);

x – IP – internode position; y – IL – internode length (cm);

a, b, c, d, e, f – coefficients of the equation (3);

a= -0.0094735;

b= -0.0942188;

c= 0.1101841;

d= 2.2165227;

e= -0.0559396;

f= 0

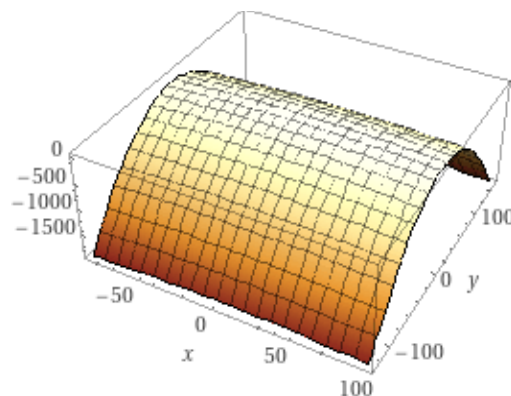


Figure 6. 3D model of ID variation in relation to IP (x-axis) and IL (y-axis), *Tilia cordata* L.

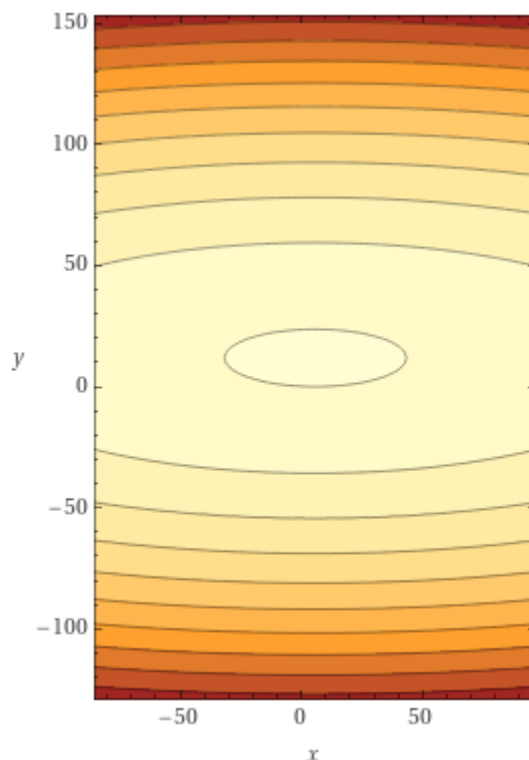


Figure 7. Model in the form of isoquants, for ID variation in relation to IP (x-axis) and IL (y-axis), *Tilia cordata* L.

The knowledge of the variation of the shoots is of interest and has been studied from various perspectives, biological and ecological, in the case of some species from natural areas (Wang et al., 2012; Desprez-Loustau et al., 2016; Valladares et al., 2016).

In the case of cultivated species, aspects of the growth and development of shoots are of high interest from the perspective of fruit tree breeding programs, cultivation technologies and production (Dalla Costa et al., 2017; De Oliveira et al., 2017; Anderson et al., 2021).

For fruit species (fruit trees, fruit shrubs) may be useful information in relation to maintenance pruning during the active vegetation period, watering, fertilization, foliar treatments (Nielsen et al., 1999; Koutinas et al., 2010). Also, for these species, the information is useful in relation to the production estimation, respectively with current maintenance and harvesting works in relation to the fruit species (Yadav et al., 2002; Onishi et al., 2019; Anderson et al., 2021). Shoot and leaf samples are recommended for assessing nutritional status (Sala, 2011) and have been used to develop models for apple fruit quality (Jivan and Sala, 2014), to determine the degree of pathogenic attack by imaging analysis (Drienovsky et al., 2017).

Studies of shoots based on models of variation of some parameters, or growth models, in relation to different influencing factors, are of interest from the perspective of knowing some variables that influence the formation and growth of shoots, quantification of variation in relation to them, and management measures.

CONCLUSIONS

The regression analysis facilitated the obtaining of some equations, as models that described the variation of the shoots parameters studied, in conditions of statistical safety.

The obtained models, such as equations, as well as 3D or isoquant graphic models, can be used to estimate dimensional parameters in shoots, to estimate shoot growth, the influence of environmental factors on growth processes, and other studies and models can be developed associated with them, in relation to the degree of wood maturation, or specific works to control the growth of wood species.

The approach model used in this study can be extended to different forest species, but also to species of economic interest, such as fruit species (fruit trees and shrubs), vines, or ornamental tree species.

ACKNOWLEDGEMENT

The authors thanks to the GEOMATICS Research Laboratory, BUASMV "King Michael I of Romania" from Timisoara, for the facility of the software use for this study.

BIBLIOGRAPHY

1. Anderson N.T.; Walsh K.B.; Wulfsch D. - Technologies for forecasting tree fruit load and harvest timing-from ground, sky and time. *Agronomy* 2021, 11, 1409. <https://doi.org/10.3390/agronomy11071409>
2. Bláha L. - Importance of root-shoot ratio for crops production. *Journal of Agronomy & Agricultural Science* 2019, 2, 012. doi:10.24966/AAS-8292/100012
3. Cao X.; Shen Q.; Shang C.; Yang H.; Liu L.; Cheng J. - Determinants of shoot biomass production in mulberry: combined selection with leaf morphological and physiological traits. *Plants* 2019, 8(5), 118. <https://doi.org/10.3390/plants8050118>
4. Chelakkot R.; Mahadevan L. - On the growth and form of shoots. *Journal of the Royal Society Interface* 2017, 14(128), 20170001. <https://doi.org/10.1098/rsif.2017.0001>
5. Dalla Costa, L.; Malnoy M.; Gribaudo I. - Breeding next generation tree fruits: technical and legal challenges. *Horticulture Research* 2017, 4, 17067. <https://doi.org/10.1038/hortres.2017.67>
6. De Oliveira P.D.; Marodin G.A.B.; de Almeida G.K.; Gonzatto M.P.; Darde D.C. - Heading of shoots and hand thinning of flowers and fruits on 'BRS Kampai' peach trees. *Pesquisa Agropecuária Brasileira* 2017, 52(11), 1006-1016. <https://doi.org/10.1590/S0100-204X2017001100006>
7. Desprez-Loustau M.L.; Aguayo J.; Dutech C.; Hayden K.J.; Husson C.; Jakushkin B.; Marçais B.; Piou D.; Robin C.; Vacher C. - An evolutionary ecology perspective to address forest pathology challenges of today and tomorrow. *Annals of Forest Science* 2016, 73, 45-67. <https://doi.org/10.1007/s13595-015-0487-4>
8. Drienovsky R.; Nicolin A.L.; Rujescu C.; Sala F. - Scan Sick & Healthy Leaf - A software application for the determination of the degree of the leaves attack. *Research Journal of Agricultural Science* 2017, 49(4), 225-233.
9. ESRI. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute, 2011.
10. Gleason S.M.; Stephens A.E.A.; Tozer W.C.; Blackman C.J.; Butler D.W.; Chang Y.; Cook A.M.; Cook J.; Laws C.A.; Rosell J.A.; Stuart S.A.; Westoby M. - Shoot growth of woody trees and shrubs is predicted by maximum plant height and associated traits. *Functional Ecology* 2018, 32(2), 247-259. <https://doi.org/10.1111/1365-2435.12972>
11. Habiyaemue J.D.; Herrmann S.; Buscot F.; Goldmann K. - Temporal changes and alternating host tree root and shoot growth affect soil microbiomes. *Proceedings* 2020, 66, 35; doi:10.3390/proceedings2020066035
12. Hammer Ø.; Harper D.A.T.; Ryan P.D. - PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* 2001, 4(1), 1-9.
13. Herrmann S.; Recht S.; Boenn M.; Feldhahn L.; Angay O.; Fleischmann F.; Tarkka M.T.; Grams T.E.; Buscot F. - Endogenous rhythmic growth in oak trees is regulated by internal clocks rather than resource availability. *Journal of experimental botany* 2015, 66(22), 7113-7127. <https://doi.org/10.1093/jxb/erv408>
14. Jivan C.; Sala F. - Relationship between tree nutritional status and apple quality. *Horticultural Science* 2014, 41(1), 1-9. <https://doi.org/10.17221/152/2013-HORTSCI>
15. Kaitaniemi P.; Lintunen A.; Sievänen R. - Power-law estimation of branch growth. *Ecological Modelling* 2020, 416, 108900. <https://doi.org/10.1016/j.ecolmodel.2019.108900>
16. Kalcsist L.; van der Heijden G.; Waliullah S.; Giordani L. - S-ABA-induced changes in root to shoot partitioning of root-applied ⁴⁴Ca in apple (*Malus domestica* Borkh.). *Trees* 2019, 33, 433-442. <https://doi.org/10.1007/s00468-018-1789-6>
17. Koutinas N.; Pepelyankov G.; Lichev V. - Flower induction and flower bud development in apple and sweet cherry. *Biotechnology & Biotechnological Equipment* 2010, 24(1), 1549-1558, doi:10.2478/V10133-010-0003-9
18. Liu W.; Su J. - Effects of light acclimation on shoot morphology, structure, and biomass allocation of two *Taxus* species in southwestern China. *Scientific Reports* 2016, 6, 35384. <https://doi.org/10.1038/srep35384>
19. Neilsen G.H.; Neilsen D.; Peryea F. - Response of soil and irrigated fruit trees to fertigation or broadcast application of nitrogen, phosphorus, and potassium. *HortTechnology* 1999, 9(3), 393-401. <https://doi.org/10.21273/HORTTECH.9.3.393>
20. Onishi Y.; Yoshida T.; Kurita H.; Fukao T.; Arihara H.; Iwai A. - An automated fruit harvesting robot by using deep learning. *Robomech Journal* 2019, 6, 13. <https://doi.org/10.1186/s40648-019-0141-2>
21. Osada N. - Height-dependent changes in shoot structure and tree allometry in relation to maximum height in four deciduous tree species. *Functional Ecology* 2011, 25(4), 777-786. <https://doi.org/10.1111/j.1365-2435.2011.01833.x>
22. Poethig R.S. - Vegetative phase change and shoot maturation in plants. *Current Topics in Development Biology* 2013, 105, 125-152. doi: 10.1016/B978-0-12-396968-2.00005-1
23. Reyes F.; DeJong T.; Franceschi P.; Tagliavini M.; Gianelle D. - Maximum growth potential and periods of resource limitation in apple tree. *Frontiers in Plant Science* 2016, 7, 233. <https://doi.org/10.3389/fpls.2016.00233>
24. Rosati A.; Paoletti A.; Hariri R.A.; Famiani F. - Fruit production and branching density affect shoot and whole-tree wood to leaf biomass ratio in olive. *Tree Physiology* 2018, 38(9), 1278-1285.

- <https://doi.org/10.1093/treephys/tpy009>
25. Sala F. - Agrochimie. Editura Eurobit, Timisoara, 2011, pp. 476-481.
 26. Sala F.; Blidariu C. - Macro- and micronutrient content in grapevine cordons under the influence of organic and mineral fertilization. Bulletin UASVM Horticulture 2012, 69(1), 317-324. doi:<http://dx.doi.org/10.15835/buasvmcn-hort:8535>
 27. Saouab F.-E.; Amraoui M.B. - Short shoot growth and reproduction response to light conditions vary with order branching in the proximal part of *C.atlantica* Crown. International Journal of Forestry Research 2020, 2020, 8383010. <https://doi.org/10.1155/2020/8383010>
 28. Scharnweber T.; Smiljanic M.; Cruz-García R.; Mantley M.; Wilmking M. - Tree growth at the end of the 21st century - the extreme years 2018/19 as template for future growth conditions. Environmental Research Letters 2020, 15(7), 074022. <https://doi.org/10.1088/1748-9326/ab865d>
 29. Souza J.P.; Prado C.H.B.A.; Albino A.L.S.; Damascos M.A. - Shoot-foliage relationships in deciduous, semideciduous, and evergreen cerrado tree species. Brazilian Journal of Plant Physiology 2009, 21(1), 75-86. <https://doi.org/10.1590/S1677-04202009000100009>
 30. Sugiura D.; Tateno M. - Optimal leaf-to-root ratio and leaf nitrogen content determined by light and nitrogen availabilities. PLoS ONE 2011, 6(7), e22236. <https://doi.org/10.1371/journal.pone.0022236>
 31. Sun J.; Wang M.; Lyu M.; Niklas K.J.; Zhong Q.; Li M.; Cheng D. - Stem diameter (and not length) limits twig leaf biomass. Frontiers in Plant Science 2019a, 10, 185. doi: 10.3389/fpls.2019.00185
 32. Sun J.; Wang M.; Lyu M.; Niklas K.J.; Zhong Q.; Li M.; Cheng D. - Stem and leaf growth rates define the leaf size vs. number trade-off. AoB Plants 2019b, 11(6), plz063. <https://doi.org/10.1093/aobpla/plz063>
 33. Valladares F.; Laanisto L.; Niinemets Ü.; Zavala M.A. - Shedding light on shade: ecological perspectives of understorey plant life. Plant Ecology & Diversity 2016, 9(3), 237-251. <https://doi.org/10.1080/17550874.2016.1210262>
 34. Van der Sande M.T.; Zuidema P.A.; Sterck F. - Explaining biomass growth of tropical canopy trees: the importance of sapwood. Oecologia 2015, 177, 1145–1155. <https://doi.org/10.1007/s00442-015-3220-y>
 35. Wang Y.; Čufar K.; Eckstein D.; Liang E. - Variation of maximum tree height and annual shoot growth of smith fir at various elevations in the Sygera Mountains, Southeastern Tibetan Plateau. PLoS ONE 2012, 7(3), e31725. <https://doi.org/10.1371/journal.pone.0031725>
 36. Wolfram, Research, Inc., Mathematica, Version 12.1, Champaign, IL (2020).
 37. Yadav I.S.; Rao N.K.S.; Reddy B.M.C.; Rawal R.D.; Srinivasan V.R.; Sujatha N.T.; Bhattacharya C.; Rao P.P.N.; Ramesh K.S.; Elango S. - Acreage and production estimation of mango orchards using Indian Remote Sensing (IRS) satellite data. Scientia Horticulturae 2002, 93, 105-123. [https://doi.org/10.1016/S0304-4238\(01\)00321-1](https://doi.org/10.1016/S0304-4238(01)00321-1)
 38. Zhang N.; van Westreenen A.; Evers J.B.; Anten N.P.R.; Marcelis L.F.M. - Quantifying the contribution of bent shoots to plant photosynthesis and biomass production of flower shoots in rose (*Rosa hybrida*) using a functional-structural plant model. Annals of Botany 2020, 126(4), 587-599. <https://doi.org/10.1093/aob/mcz150>