Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 21, Issue 3, 2021
PRINT ISSN 2284-7995, E-ISSN 2285-3952

VARIATION OF SOME PHYSIOLOGICAL INDICES AND FRUITS BIOMETRIC PARAMETERS IN RELATION TO APPLE FOLIAR FERTILIZATION

Florin SALA

Banat University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" from Timisoara, Soil Science and Plant Nutrition, Timișoara, 300645, Romania
Email: florin_sala@usab-tm.ro

Corresponding author: florin_sala@usab-tm.ro

Abstract

The present study evaluated the variation of some physiological indices and biometric parameters of the fruits under the influence of foliar fertilization in apple. The plantation was of semi-intensive type, in non-irrigated conditions; the 'Florina' apple cultivar was studied. The products Biocomplex 900, Foliarel, Megafol, Uvafol, Waterfert and calcium chloride were used. The combination of fertilizer resources resulted in 8 experimental variants (V2 - V9), tested compared to a control variant (V1). Physiological indices (leaf area - LA, chlorophyll - Chl) and biometric parameters (fruit diameter - FD, fruit weight - FW) were evaluated. LA values ranged from 28.24 cm^2 (V1) to 34.37 cm^2 (V5). Chlorophyll content varied between 28.24 SPAD units (V1) and 49.99 SPAD units (V9). Fruits diameter (FD) varied between 52.48 mm (V1) and 64.15 mm (V9). Fruit weight (FW) recorded values between 96.10 g (V1) and 117.32 g (V9). The regression analysis led to equations that described the variation of FD and FW in relation to LA and Chl, in statistical safety conditions ($p < 0.001$). 3D and isoquant graphs models described the distribution of FD and FW values in relation to LA and Chl. Within PCA, PC1 explained 93.304% of variance, and PC2 explained 5.6066% of variance. The cluster analysis led to the dendrogram, in statistical safety conditions, Coph.corr = 0.788. The highest level of similarity was recorded between variants V5 and V8 (SDI = 0.7787), followed by variants V7 and V8 (SDI = 1.6693), respectively by V7 and V9 (SDI = 1.8845).

Key words: *apple, biometric parameters, foliar fertilizer, model, physiological indices*

INTRODUCTION

The apple (*Malus domestica* L.) is one of the main fruit species, cultivated in various areas worldwide, by the large number of genotypes, and the high interest of apples [39].

From single trees, cultivated in gardens as a hobby, or for decorative purposes, to super-intensive plantations, in areas dedicated to apple cultivation, with computer technologies and artificial intelligence (AI) for the management of horticultural farms, apple is of great importance.

Apples are an important product in human nutrition and on the fruit market [42]. Food plays an important role in the quality of life, and apples have an important contribution in this regard [5].

Apples have a high content of minerals, vitamins, amino acids, bioactive substances, polyphenols, etc. [21]. Apples are important as fresh fruits, fresh juices [4], [20], for industrialization [6], cosmetics [44], [31], [34], pharmaceutical industry [4], [33], [20].

In relation to the destination of apple production, plantation management has an important role [16], [32], [18].

Apple quality management has been studied and evaluated in relation to different cultivated genotypes [3], [1], [8], soil type and climatic conditions [26], [7], [19], irrigation systems [13], [12], [22], fertilizers and soil or foliar fertilization [29], [43], [24], [11], [36].

Apple production has been studied in relation to various ecological, economic and social factors in order to optimize plantation management, fruit quality and fruit market [37], [30], [35], [23], [28], [45].

The study and analysis of horticultural areas, such as plantations, need to be done both on a small scale, plant organs or individual plants [38], [10], [2], [25], [14], as well as on a large scale, plots, farms, areas, etc. [15], [47], [46] in order to choose the appropriate germplasm [9], [27], [40], and the formulation of optimal farm management solutions for quality production.

The present study evaluated the influence of foliar fertilizer resources on physiological indices and biometric parameters in apple, 'Florina' cultivar.

MATERIALS AND METHODS

The study evaluated the variation of some physiological indices and biometric parameters of apple fruit quality, in relation to foliar fertilization.

The experiment was organized within the Horticultural Center of BUASVM Timisoara, during 2012-2014. The 'Florina' apple cultivar was studied.

The plantation was organized in a semi-intensive, non-irrigated system. Soil was covered with vegetal carpet between rows with repeated mowing and maintained by herbicide on the tree rows, figure 1. Six different foliar fertilizer resources were used. Foliarel fertilizer was applied evenly on all variants. On the common Foliarel level, were applied: Biocomplex 900, Megafol, Uvafol and Waterfert. Additionally, calcium was applied in the form of calcium chloride ($CaCl_2$) and 8 fertilized variants (V2-V9) resulted, figure 1. For the comparison, a control variant was used, without fertilization (V1).

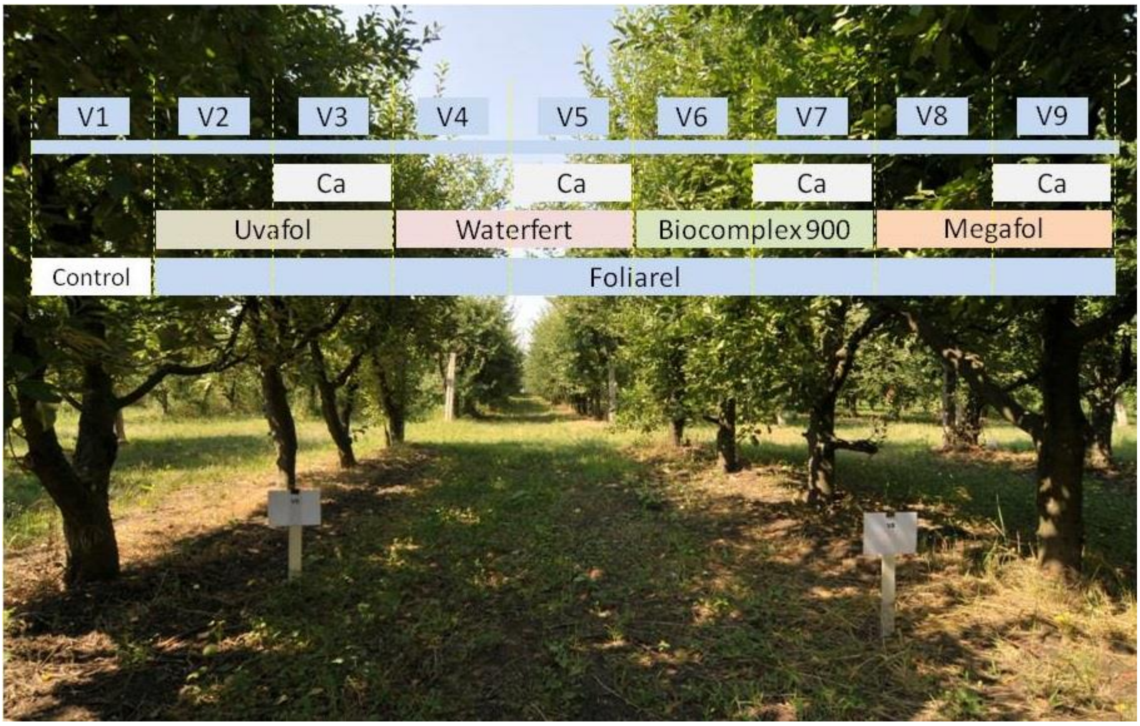

Fig. 1. Aspect from the experimental field, 'Florina' apple cultivar, and experimental variants
Source: author's image (Original).

The treatments were applied with an atomizer for the uniform distribution of the solutions. Foliar fertilizers were applied in two treatments, at the beginning of fruit formation (treatment I) and at an interval of 15 days (treatment II).

Trees vegetation condition and fruit quality parameters were evaluated, under the influence of the applied fertilization. As physiological indices leaf area - LA, and chlorophyll content – Chl were studied. The fruits were evaluated based on biometric parameters (fruit diameter - FD, fruit weight - FW).

Leaf area (LA) was determined based on leaf size (length, width), and correction coefficient (KA_F), relation (1).

$$LA = L \times w \times KA_F \qquad (1)$$

where:
LA – leaf area (cm^2);
L – leaf length (cm);
W – leaf width (cm);

KA_F – correction coefficient for 'Florina'.

The chlorophyll content (Chl) was determined by the non-destructive method with a portable chlorophyll meter (Spad 502 Plus). The diameter of the fruit (FD) was measured with an electronic calliper, with an accuracy of ± 0.001 mm. The weight of the fruit (FW) was determined by weighing with a laboratory balance, accuracy ± 0.005 g.

The increase in fruit quality was analyzed as an effect of foliar fertilizer-generated increase (FF-GI) and in relation to calcium supplementation (calcium-generated increase, Ca-GI).

The quality increase on each parameter studied (FD and FW) was reported compared to the control variant (V1), and on pairs of variants in relation to the application or not of calcium (V2/V3; V4/V5; V6/V7; V8/V9).

Appropriate mathematical and statistical tools were used to find models to describe the variation of quality parameters in relation to physiological indices (regression analysis), as well as to evaluate multiple solutions for similar results (PCA and cluster analysis).

Correlation analysis and ANOVA test were also used. To assess the safety of the data and the results obtained, the parameter p, the standard error (SE), and the coefficients r, R^2, Coph.corr., were used.

The RMSEP parameter, relation (2), was also used to assess the level of safety in predicting the values of biometric parameters based on the values of physiological indices.

$$RMSEP = \sqrt{\frac{1}{n}\sum_{j=1}^{n}\left(y_j - \hat{y}_j\right)^2} \quad (2)$$

PAST software [17], Wolfram Alpha software (2020) [41], and specific mathematical modules in EXCEL were used for data analysis and graph generation.

RESULTS AND DISCUSSIONS

The foliar fertilizer resources applied, within the 8 fertilized variants, generated a specific variation of the studied physiological indices, leaf area (LA), and chlorophyll (Chl). The LA values varied between 28.24 cm^2 for the control variant (V1) and 34.37 cm^2 for the V5 variant. The chlorophyll content varied between 28.24 SPAD units in the control variant and 49.99 SPAD units in the V9 variant (Table 1).

Fruits biometric parameters, fruit diameter (FD) and fruit weight (FW) registered a certain variation, associated with the vegetative status of the trees on the experimental variants. Fruit diameter (FD) recorded values between 52.48 mm for the control variant (V1) and 64.15 mm for the V9 variant. Fruit weight (FW) recorded values between 96.10 g for control variant (V1) and 117.32 g for variant V9 (Table 1).

Table 1. Values of physiological indices and biometric parameters in apple, 'Florina' cultivar, in relation to foliar fertilizers

Experimental variants	LA	Chl	FD	FW
	(cm^2)	(SPAD units)	(mm)	(g)
V1	28.24	44.67	52.48	96.10
V2	31.04	47.14	58.09	98.45
V3	33.23	48.73	59.09	103.63
V4	30.65	46.25	60.63	104.38
V5	34.37	48.40	62.60	113.19
V6	29.05	46.74	61.15	111.33
V7	34.34	49.23	63.85	115.48
V8	31.84	47.03	62.46	113.32
V9	33.63	49.99	64.15	117.32
SE	±0.75	±0.55	±1.20	±2.56

Source: Original data from experimental variants.

The applied foliar fertilization generated increases of fruit quality, in terms of diameter and weight, the values of the recorded increase (Δs) on each variant and index/ parameter studied, being shown in Figure 2.

Different levels of correlation were found between the physiological indices and biometric parameters studied. Very strong correlations were recorded between LA and Chl (r = 0.900) and between FD and FW (r = 0.925). Moderate correlations were recorded between FW and Chl (r = 0.705), between FD and LA (r = 0.720), and between FD and Chl (r = 0.769). A weak correlation was recorded between FW and LA (r = 0.634).

Based on the regression analysis, equations were obtained that described the variation of the biometric parameters of fruit quality in relation to the studied physiological indices.

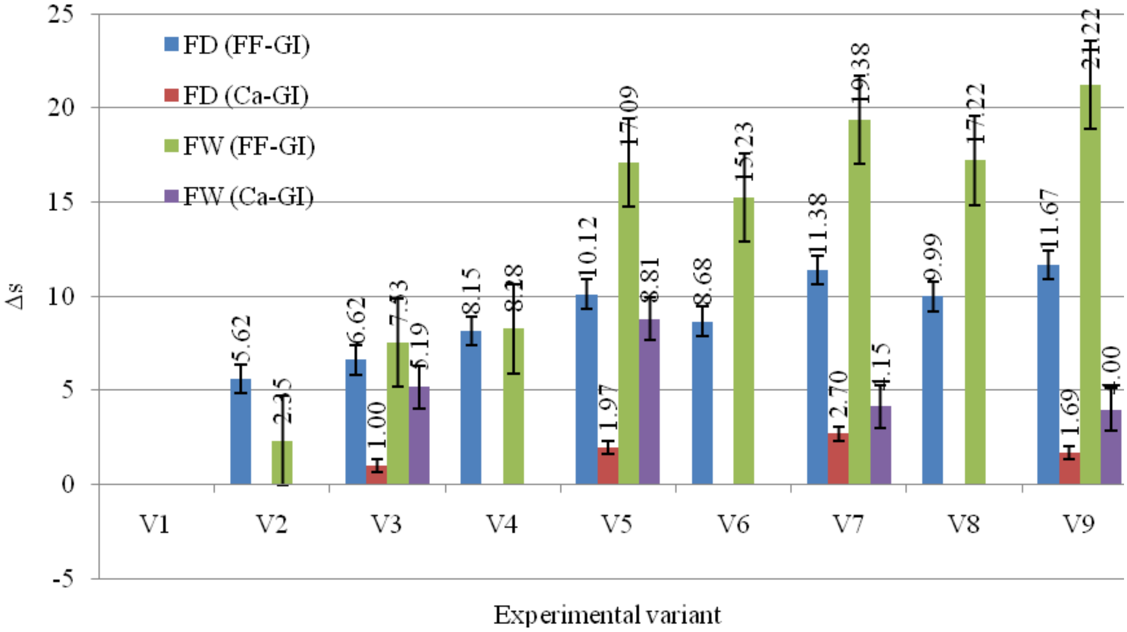

Fig. 2. The increase registered in relation to the foliar fertilization of the apple, 'Florina' apple cultivar
Source: original graph, generated based on the calculated experimental values.

The variation of the fruit diameter (FD) according to LA and Chl was described by equation (3), in conditions of statistical safety (R^2 = 0.0.999, p <0.001).

The ANOVA test confirmed the statistical safety of the values of the equation (3) parameters, as follows, p = 0.03365 for a; p = 0.0069 for b; p = 0.0077 for c; p = 0.0089 for d; p = 0.0085 for e. The graphical distribution of FD according to LA and Chl is presented in Figure 3 as a 3D model, and in Figure 4 as isoquants form.

$$FD = ax^2 + by^2 + cx + dy + exy + f \qquad (3)$$

where:
FD - fruits diameter;
x – LA – leaf area;
y – Chl – chlorophyll content;
a, b, c, d, e, f – coefficients of the equation (3);
a= 0.765196005349097;
b= 1.22091847116479;
c= 63.0043218922929;
d= -40.7376835167938;
e= -2.34095352623526;
f= 0

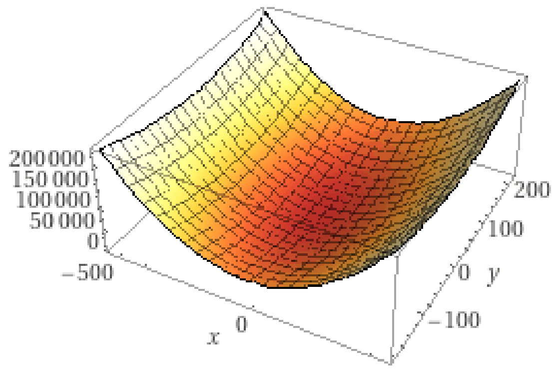

Fig. 3. 3D model of FD variation in relation to LA (x-axis) and Chl (y-axis), 'Florina' apple cultivar
Source: original graph generated based on experimental data.

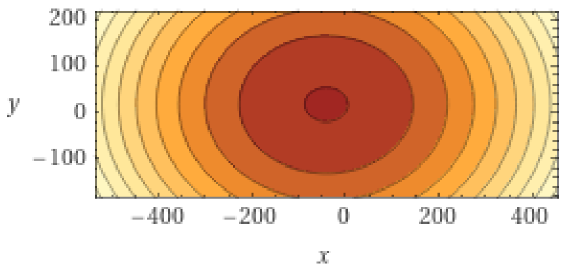

Fig. 4. Model in the form of isoquants for the distribution of FD in relation to LA (x-axix) and Chl (y-axix) in apple, 'Florina' cultivar
Source: original graph generated based on experimental data.

The variation of fruit weight (FW) according to LA and Chl was described by equation (4), in statistical safety conditions (R^2 = 0.0.998, p <0.001). The ANOVA test partially confirmed the statistical certainty of the values of the parameters of equation (4). The graphical distribution of FW in relation to LA and Chl is presented in the form of a 3D model in Fig. 5 and in the form of isoquants in Fig. 6.

$$FW = ax^2 + by^2 + cx + dy + exy + f \qquad (4)$$

where:
FW - fruits weight;
x – LA – leaf area;
y – Chl – chlorophyll content;
a, b, c, d, e, f – coefficients of the equation (4);
a= 1.8423127376365;
b= 1.84122208234375;
c= 71.5311783170931;
d= -46.3203844806745;
e= -3.96213398889279;
f= 0

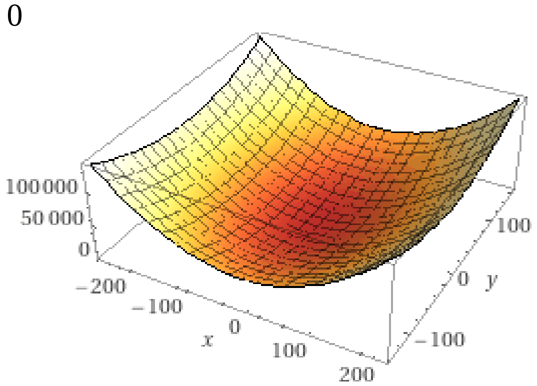

Fig. 5. 3D model of FW variation in relation to LA (x-axis) and Chl (y-axis), 'Florina' apple cultivar
Source: original graph generated based on experimental data.

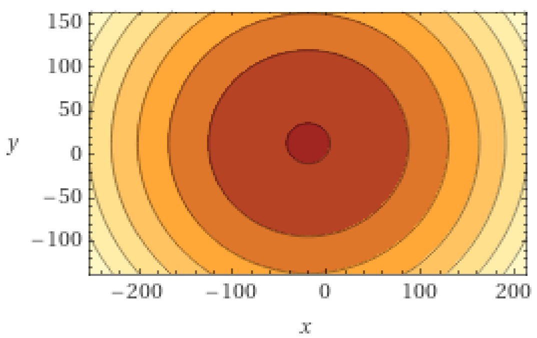

Fig. 6. Model in the form of isoquants for the distribution of FW in relation to LA (x-axix) and Chl (y-axix) in apple, 'Florina' cultivar
Source: original graph generated based on experimental data.

PCA led to the diagram in Figure 7, with variants distribution according to the indices and parameters studied. PC1 explained 93.304% of variance, and PC2 explained 5.6066% of variance.

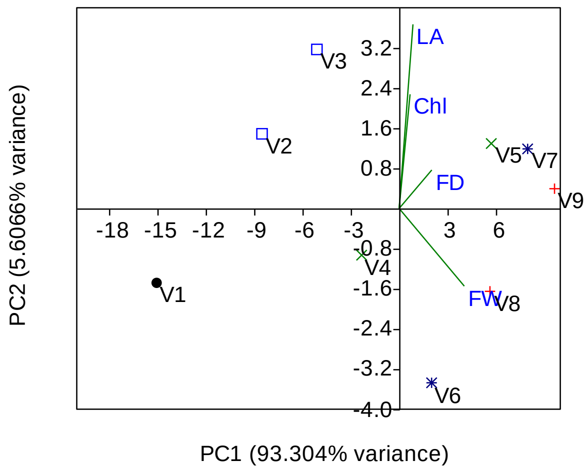

Fig. 7. PCA diagram of variant distribution in relation to physiological indices and biometric parameters in apple, 'Florina' cultivar, under the influence of foliar fertilization
Source: original graph generated based on experimental data.

The cluster analysis led to the dendrogram in Figure 8, in statistical safety conditions, Coph.corr = 0.788.

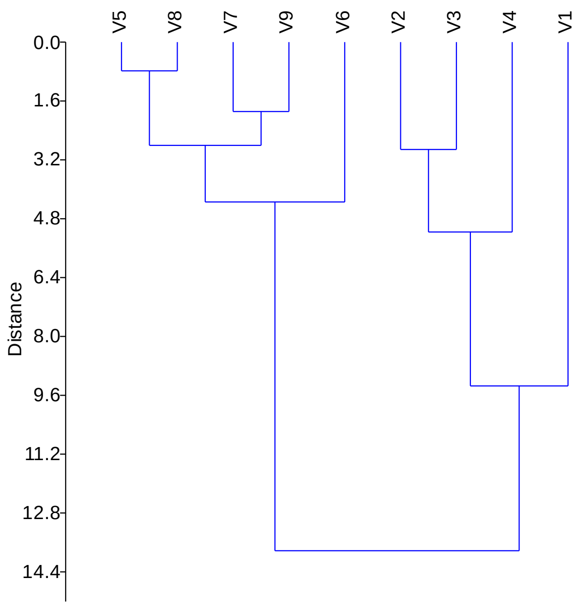

Fig. 8. Cluster diagram based on Euclidean distances, generated in relation FW and FD, 'Florina' apple cultivar
Source: original graph generated based on experimental data.

In relation to the fruits biometric parameters, the variants were grouped in two distinct clusters. A C1 cluster included variants V1 - V4, between which a high degree of similarity was found at V2 and V3 (SDI = 2.9177), and V4 was associated with them, followed by V1.

Cluster C2 included variants V5 - V9, between which different levels of similarity were registered. The highest level of similarity was recorded between variants V5 and V8 (SDI = 0.7787), followed by variants V7 and V8 (SDI = 1.6693), respectively by V7 and V9 (SDI = 1.8845), Table 2

Table 2. SDI values for experimental variants, 'Florina' apple cultivar

	V1	V2	V3	V4	V5	V6	V7	V8	V9
V1		6.4961	8.9585	12.58	19.713	17.099	21.906	20.279	23.598
V2	6.4961		2.9177	6.6011	13.862	11.491	16.056	14.511	17.853
V3	8.9585	2.9177		3.7168	10.978	8.5742	13.176	11.613	14.958
V4	12.58	6.6011	3.7168		7.264	4.9582	9.4611	7.9106	11.252
V5	19.713	13.862	10.978	7.264		2.7835	2.2003	0.77878	4.0068
V6	17.099	11.491	8.5742	4.9582	2.7835		4.8782	3.2144	6.5007
V7	21.906	16.056	13.176	9.4611	2.2003	4.8782		1.6693	1.8845
V8	20.279	14.511	11.613	7.9106	0.77878	3.2144	1.6693		3.3446
V9	23.598	17.853	14.958	11.252	4.0068	6.5007	1.8845	3.3446	

Source: original data calculated based on experimental results.

The estimation of the fruit quality parameters through equations (3) and (4) obtained from the regression analysis, was appreciated based on the RMSEP parameter; RMSEP = 1.63047 in the case of predicted FD, respectively RMSEP = 4.4560 in the case of predicted FW.
Based on the values of equations (3) and (4), the optimal values for x (LA) and y (Chl) were calculated, in relation to the fruits quality biometric parameters studied (FD and FW). Thus, in the case of FD, the values x_{opt} = 33.55 cm^2 (LA), and y_{opt} = 48.85 SPAD units (Chl) were found. In the case of FW, the values x_{opt} = 37.50 cm^2 (LA), and y_{opt} = 52.93 SPAD units (Chl) were found.
From the analysis of the values of equations (3) and (4), as well as from the 3D graphical distribution of the parameters FD and FW, it was found that the foliar surface (LA) showed a much wider variation, compared to Chl, in relation to ensuring FD and FW values, under the experimental conditions. This aspect recommends attention to the maintenance works of the trees in ensuring an optimal ratio between vegetative growth and fruiting, because the LA variation both by individual values and in the whole tree structure, contributes a lot to the variation of fruit quality parameters; a significant part of the water and nutrients being allocated to vegetative growth.
The association level of the variants in the dendrogram (Figure 8), and the values of the SDI indices (Table 2) provided information about the treatments that led to similar results, regarding the biometric parameters of fruit quality. If we take into account the availability of fertilizer products, or the costs of treatments, the farmer can choose those options that lead to similar results, in accordance with the specifics of the plantation, the destination of production (consumption, industrialization etc.), and also the market or profitability.
Such studies are important, because they offer multiple solutions, from which those the best options can be chosen, from a technical and economic point of view.

CONCLUSIONS

The foliar fertilizer resources used determined a specific variation of the physiological indices (LS and Chl) and of the biometric quality parameters (FD and FW) studied in the 'Florina' apple cultivar.
The regression analysis facilitated the obtaining of some models of the quality parameters (FD and FW) variation in relation to the physiological indices (LA and Chl),

under the influence of foliar fertilization. The obtained models are in the forms of equations, and 3D and isoquants graphic representation, in statistical safety conditions.

Among the multiple solutions obtained by foliar fertilization, the cluster analysis facilitated the identification of variants that generated similar results, with practical importance for choosing the optimal solution in relation to the fruits production system.

ACKNOWLEDGEMENTS

The author thanks to the Horticultural Research Center of the Banat University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" from Timisoara, Romania which facilitated this research.

REFERENCES

[1]Agnolet, S., Ciesa, F., Soini, E., Cassar, A., Matteazzi, A., Guerra, W., Robatscher P., Storti, A., Baric, S., Via J.D., Oberhuber, M., 2017, Dietary elements and quality parameters of 34 old and eight commercial apple cultivars grown at the same site in South Tyrol, Italy, Erwerbs-Obstbau, 59**:**171-183.
[2]Belhassine, F., Martinez, S., Bluy, S., Fumey, D., Kelner, J.-J., Costes, E., Pallas, B., 2019, Impact of within-tree organ distances on floral induction and fruit growth in apple tree: Implication of carbohydrate and gibberellin organ contents, Front. Plant Sci., 10:1233.
[3]Blažek, J., Hlušičková, I., 2007, Orchard performance and fruit quality of 50 apple cultivars grown or tested in commercial orchards of the Czech Republic, Hort. Sci. (Prague), 34(3):96-106.
[4]Boyer, J., Liu, R.H., 2004, Apple phytochemicals and their health benefits, Nutr. J., 3:5.
[5]Butu, M., Rodino, S., 2019, 11 - Fruit and Vegetable-Based Beverages - Nutritional properties and health benefits, Natural Beverages, 13:303-338.
[6]Campos, D.A., Gómez-García, R., Vilas-Boas, A.A., Madureira A.R., Pintado, M.M., 2020, Management of fruit industrial by-products - A case study on circular economy approach, Molecules, 25(2):320.
[7]Dalhaus, T., Schlenker, W., Blanke, M.M., Bravin, E., Finger, R., 2020, The effects of extreme weather on apple quality, Sci. Rep., 10:7919.
[8]Danková, V., Šubrtová, M., Suran, P., Zelený, L., 2021, Evaluation of internal quality of apple selections and cultivars bred in Holovousy, Acta Hortic., 1307:435-440.
[9]Dobrei, A., Dobrei, A.G., Nistor, E., Iordanescu, O.A., Sala, F., 2015, Local grapevine germplasm from Western of Romania - an alternative to climate change and source of typicity and authenticity, Agric. Agric. Sci. Procedia, 6:124-131.
[10]Drienovsky, R., Nicolin, A.L., Rujescu, C., Sala, F., 2017, Scan Sick & Healthy Leaf – A software application for the determination of the degree of the leaves attack, Res. J. Agric. Sci., 49(4):225-233.
[11]Dzanagov, S.Kh., Gazdanov, A.V., Lazarov, T.K., Basiev, A.E., Kanukov, Z.T., 2021, Fertilizers effect on yield and apples' fruits quality on leached chernozem. IOP Conf. Series: Earth and Environmental Science, 624:012201.
[12]Faghih, S., Zamani, Z., Fatahi, R., Liaghat, A., 2019, Effects of deficit irrigation and kaolin application on vegetative growth and fruit traits of two early ripening apple cultivars, Biol. Res., 52:43.
[13]Fallahi, E., Neilsen, D., Neilsen, G.H., Fallahi, B., Shafii, B., 2010, Efficient irrigation for optimum fruit quality and yield in apples, HortScience, 45(11):1616-1625.
[14]Ge, L., Zou, K., Zhou, H., Yu, X., Tan, Y., Zhang, C., Li, W., 2021, Three dimensional apple tree organs classification and yield estimation algorithm based on multi-features fusion and support vector machine, Inf. Process. Agric., article in press, https://doi.org/10.1016/j.inpa.2021.04.011.
[15]Govedarica, M., Ristic, A., Herbei M.V., Sala, F., 2015, Object oriented image analysis in remote sensing of forest and vineyard areas, Bulletin UASVM Horticulture, 72(2):362-370.
[16]Granatstein, D., Sánchez, E., 2009, Research knowledge and needs for orchard floor management in organic tree fruit systems, Int. J. Fruit Sci., 9(3):257-281.
[17]Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001, PAST: Paleontological statistics software package for education and data analysis, Palaeontol. Electron., 4(1):1-9.
[18]Herz, A., Cahenzli, F., Penvern, S., Pfiffner, L., Tasin, M., Sigsgaard, L., 2019, Managing floral resources in apple orchards for pest control: Ideas, experiences and future directions, Insects, 10:247.
[19]Hua, L., Gao, J., Zhou, M., Bai, S., 2021, Impacts of relative elevation on soil nutrients and apple quality in the Hilly-Gully Region of the loess plateau, China, Sustainability, 13:1293.
[20]Hyson, D.A., 2011, A comprehensive review of apples and apple components and their relationship to human health, Adv. Nutr., 2(5):408-420.
[21]Islam, J., Kabir, Y., 2019, 5 - Effects and mechanisms of antioxidant-rich functional beverages on disease prevention, Functional and Medicinal Beverages, 11:157-198.
[22]Jiang, X., He, L., 2021, Investigation of effective irrigation strategies for high-density apple orchards in Pennsylvania, Agronomy, 11:732.
[23]Li, M., Guo, J., Xu, C., Lei, Y., Li, J., 2018, Identifying climatic factors and circulation indices related to apple yield variation in main production areas of China, Glob. Ecol. Conserv., 16:e00478.
[24]Liakos, V., Smith, E., Fountas, S., Nanos, G., Kalfountzos, D., Gemtos, T., 2020, On-farm evaluation of variable rate fertilizer applications using yield-based

mathematical formulae in a Greek apple orchard, Int. J. Fruit Sci., 20(Is2):S48-S65.

[25]Locatelli, G., Pio, R., Bisi, R.B., Souza, F.B.M., Viana, M.T.R., Farias, D.H., Castro, E.M., Zambon, C.R., 2019, Leaf anatomy of apple trees during seasonal periods under subtropical conditions**,** HortScience, 54(11):1887-1895.

[26]Manandhar, S., Pandey, V.P., Kazama, F., 2014, Assessing suitability of apple cultivation under climate change in mountainous regions of western Nepal, Reg. Environ. Change, 14**:**743-756.

[27]Marconi, G., Ferradini, N., Russi, L., Concezzi, L., Veronesi, F., Albertini, E., 2018, Genetic characterization of the apple germplasm collection in Central Italy: The value of local varieties, Front. Plant Sci., 9:1460.

[28]Naderi, S., Raini, M.G.N., Taki, M., 2020, Measuring the energy and environmental indices for apple (production and storage) by life cycle assessment (case study: Semirom county, Isfahan, Iran), Environmental and Sustainability Indicators, 6:100034.

[29]Nava, G., Dechen, A.R., Nachtigall, G.R., 2007, Nitrogen and potassium fertilization affect apple fruit quality in Southern Brazil, Commun. Soil Sci. Plant Anal., 39(1-2):96-107.

[30]Ntakyo, P.R., Mugisha, J., Elepu, G., 2013, Socio-economic factors affecting apple production in Southwestern Uganda, Afr. Crop Sci. J., 21(4):311-321.

[31]Palermo, V., Mattivi, F., Silvestri, R., Regina, G.L., Falcone, C., Mazzoni, C., 2012, Apple can act as anti-aging on yeast cells, Oxid. Med. Cell. Longev., 2012:491759.

[32]Porcel, M., Andersson, G.K.S., Pålsson, J., Tasin, M., 2018, Organic management in apple orchards: Higher impacts on biological control than on pollination, J. Appl. Ecol., 55(6):2779-2789.

[33]Soler, C., Soriano, J.M., Mañes, J., 2009, Apple-products phytochemicals and processing: A review, Nat. Prod. Commun., 4(5):659-670.

[34]Stojilković, D., Tadić, V., Stanković, M., Roganović, S., Arsić, I., 2018, Standardized extract of wild apple fruit in alkyl-polyglucoside-based cosmetic cream - estimation of stability, safety, antioxidant activity and efficiency, Int. J. Cosmetic Sci., 40:285-294.

[35]Tahir, I.I., Svensson, S.-E., Hansson, D., 2015, Floor management systems in an organic apple orchard affect fruit quality and storage life**,** HortScience, 50(3):434-441.

[36]Tang, W., Wang, W., Chen, D., Cui, N., Yang, H., Hu, X., 2021, Evaluation of the regional-scale optimal K rate based on sustainable apple yield and high-efficiency K use in Loess Plateau and Bohai Bay of China: A meta-Analysis, Agronomy, 11:1368.

[37]Topcu, Y., Uzundumlu, A.S., Calep, S., Hun, S., 2010, Analysis of the factors affecting apple farming: The case of Isparta province, Turkey, Sci. Res. Essay., 5(14):1881-1889.

[38]Tošić, S., Alagić, S., Dimitrijević, M., Pavlović, A., Nijkić, M., 2016, Plant parts of the apple tree (*Malus* spp.) as possible indicators of heavy metal pollution, Ambio, 45**:**501-512.

[39]Tsao, R., 2016, Apples, Encyclopedia of Food and Health, 239-248.

[40]Wang, Y., Li, W., Xu, X., Qiu, C., Wu, T., Wei, Q., Ma, F., Han, Z., 2019, Progress of apple rootstock breeding and its use, Hortic. Plant J., 5(5):183-191.

[41]Wolfram, Research, Inc., Mathematica, Version 12.1, Champaign, IL (2020).

[42]Zanetti, M., Samoggia, A., Young, J., 2020, Fruit sector strategic management: An exploration of agro-food chain actors' perception of market sustainability of apple innovation, Sustainability, 12:6542.

[43]Zargar, M., Tumanyan, A., Ivanenko, E., Dronik, A., Tyutyuma, N., Pakina, E., 2019, Impact of foliar fertilization on apple and pear trees in reconciling productivity and alleviation of environmental concerns under arid conditions, Commun. Integr. Biol., 12(1):1-9.

[44]Zhang, Z., Chang, Q., Zhu, M., Huang, Y., Ho, W.K., Chen, Z., 2001, Characterization of antioxidants present in hawthorn fruits. J. Nutr. Biochem.**,** 12:144-152.

[45]Zhang, Q., Shi, F., Abdullahi, N.M., Shao, L., Huo, X., 2020, An empirical study on spatial–temporal dynamics and influencing factors of apple production in China, PloS ONE, 15(10):e0240140.

[46]Zhang, C., Valente, J., Kooistra, L., Guo, L., Wang, W., 2021, Orchard management with small unmanned aerial vehicles: a survey of sensing and analysis approaches, Precision. Agric., in print, https://doi.org/10.1007/s11119-021-09813-y.

[47]Zhu, Y., Yang, G., Yang, H., Wu, J., Lei, L., Zhao, F., Fan, L., Zhao, C., 2020, Identification of apple orchard planting year based on spatiotemporally fused satellite images and clustering analysis of foliage phenophase, Remote Sens., 12(7):1199.