THE ANNALS OF "VALAHIA" UNIVERSITY OF TARGOVISTE
2016

SPATIAL VARIATION IN BLOOMING AND YIELD IN AN APPLE ORCHARD, IN ROMANIA

Gabriela Teodorescu, Virgil Moise, Aurelia Corina Cosac
Department of Environmental Engineering, Valahia University of Targoviste,
Dambovita, CA 130024, Romania
e-mail: gabriela.teodorescu@valahia.ro

Abstract

The aim of this study was to analyse the spatial variation of blooming, yield and quality parameters, in an apple orchard, by using precision agriculture tools. This study is a preliminary step in order to create management zones, to take the management decisions and made the evaluation of the applied practices. The study was conducted in the Research and Development Station for Pomology Voinesti, Dambovita, on the 0.9 ha orchard. The orchard consists in Florina apple trees and Generos pollinator. The surface was mapped with GPS and the yield of each tree was manually harvested and weighed. Apple quality was evaluated in terms of: firmness, soluble solid content, juice pH. Also, in spring was determined the number of flowers/tree and the exact period of flowering. The interpolated maps were created using Surfer 8 software and the correlations between yield and quality have been established; some quality characteristics are negatively correlated with yield, like firmness.

Keywords: apple, quality characteristics, kriging, spatial variation

1.INTRODUCTION

Apples are a major crop all over the world. It has the third position among the other fruits production with total annual production about 59.000.000 t. In the European Union the annual apple production is about 10.000.000 t and in Romania (379.000 tons). There are also a significant number of farmers in all countries who produce apples as their unique farming activity. On the other hand the percentage of the consumers who eat apples is increasing in our country and worldwide (Apple News. U.S. Apple Association, Vol.36. No.4). The reason is that apples are very healthy for human nutrition and so there is a strong demand by the consumers for more quality apples at affordable prices.

The 5% of fruit production of the European Union comes from Romania. In 2007 the total fruit yield was 3 million tons. The total yield is expected to increase during the next years as there are many developing programs which are funded by the European Union. The apples in Romania are usually used for eating or for drinking as natural juice. It is important to mention that a huge part of the total apple production is exported to other countries and the prices are high (0.64 euro/kg).

The European Union encourages farmers to produce high quality products. Additionally, it is trying to combine consumers' satisfaction with the environmental protection. The application of new and alternative agricultural methods such as the production of certified fruits by integrated crop management is one of the most important issues of the European Union in order to produce safe and more competitive products at the international markets.

A relatively new agricultural management practice is precision agriculture, which is going to be applied and evaluated in apple plantations within this research. The aim of the present research is to assess the spatial variability in blooming, yield, and quality in apple plantations and the effects to the environment.

Precision agriculture is a relatively new management practice for managing field variability. The first applications started at the early 1990's mainly in arable crops, but its application in tree plantations is still very limited mainly because farm mechanization and especially harvesting is still very expensive and the majority of fruits for fresh consumption are harvested manually.

Precision agriculture has developed all over the word, especially in USA (Miller&Whitney 1999, Whitney et al. 2001, Molin et al. 2007) but also in Europe (Aggelopoulou et al. 2010, Tagarakis et al. 2006, Chatzinikos 2007, Stajnko et al. 2004, Lopez-Granados et al. 2004, Tisseyre et al. 2008).

Miller&Whitney (1999), Whitney et al. (2001), Molin et al. (2007) have developed studies on citrus, by establishing yield mapping with an automatic system.

Aggelopoulou et al. (2010) studied the spatial and time variability of apple's quality and yield and created management zones. Tagarakis et al. (2006), Chatzinikos (2007) and Stamatiadis et al. (2007) conducted the studies in the vineyards, establishing the yield variability and the soil properties. Fountas et al. 2010 have developed studies on olive orchards, analysing the soil properties and making yield mapping. Aggelopoulou et al. (2011) have developed an image processing-based algorithm that predicts tree yield by analyzing the picture of the tree at full bloom. The implemented algorithm can be used for yield estimation early in the season in order to apply site-specific management in the orchards over most of the cultivation period.

Stajnko et al. (2004) used the pseudocolor thermal image and colour image from hyperspectral and multispectral camera in order to detect automatically the number of apple fruits and the fruit diameter. Also, Alchanatis (2007) used a hyperspectral machine vision for apple yield images.

Lopez-Granados et al. (2004) have developed the studies on olive, determining the spatial variability of nutrients on olive leaf and site-specific fertilization maps.
In France, Tisseyre et al. (2001) studied yield and harvest quality measurement in precision viticulture.
Taylor et al. (2005) made a comparison of the spatial variability of vineyard yield in European and Australian product systems.
In Romania, Teodorescu (2009) used precision horticulture in several fruit orchards.
Acevedo-Opazo et al. (2007) used NDVI to create the management zones of a vineyard.
Studies on citrus were developed by Whitney (2001), Annamalai et al. (2003), Zaman (2006), Chinchuluun et al. (2007), Okamoto et al. (2007), Xujun et al. (2007), using the tools of precision horticulture.
Kim&Reid, (2004) and Safren (2006) made the apple yield mapping using a multispectral imaging sensor and a hyperspectral machine vision.
For coffee culture Queiroz et al. (2007) studied the spatial and time variability in quality and Balastreire et al. (2002) developed an automatic yield mapping system.
We focused, as a first approach, on an apple orchard planted with Florina trees, having the same applied technology to better analyse the relevance of the spatial variability on yield and quality parameters.

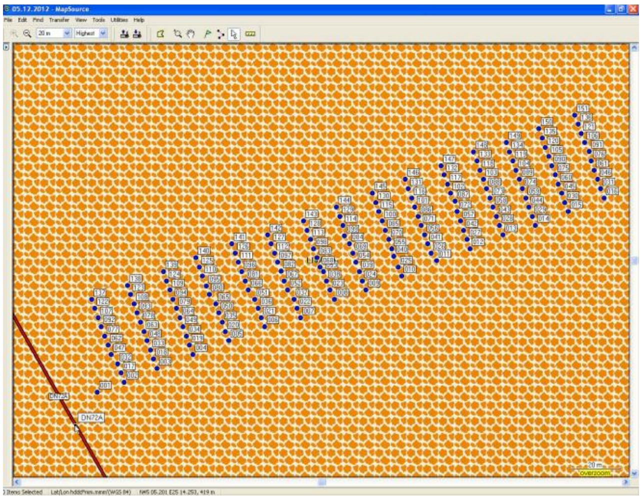
2. MATERIAL AND METHOD

2.1 Study site

The studied area is located in the middle of fruit growing basin Dambovita (25^{0} $14^{'}$ $268^{''}$ E and 45^{0} $05^{'}$ $211^{''}$ N, altitude 423 m), at Research and Development Station for Pomology Voinesti. The area is characterized by a continental climate, attenuated by orographic, hydrographic and biosphere factors. The orchard was planted in 2004, with Florina cultivar, grafted on MM 106 and Generos cultivar as the pollinator. The Florina cultivar is geneticaly resistant to apple scab, very slightly sensitive to powdery mildew and fire blight. Because of the genetic resistence, the number of works in the field and the treatements are reduced to half. A better environmental protection is ensured by reducing the number of treatments and the number of tillage. Thus, the quality of fruits is better and the yield is more healthy.
The mapped surface as 0.9 ha, with 10 rows (Fig.1 **a**). The between-row spacing is 4 m and the intra-row tree spacing is 3 m. Trees were trained as pyramidal-shape. The yield of each 5 tree was weighed to create yield map (Fig.1 **b**).
The soil texture is brown eumezobasic; the maintaining soil system is lying between row and intra-row tree. Due to the genetic resistance to disease of the cultivar, the number of spraying treatments applied to the trees was low (4-6 treatments), applied especially against pests (*Cydia pomonella* and *Quadraspidiotus perniciosus*). For graphical representation of the results, the GeoMap source software was used. For the altitude mapping Surfer software (v.8, Golden Software) was used.

2.2 Sampling

The yield of each tree was manually harvested, in plastic bags and weighed separately to give an average weight in kilograms of fruit per tree (Fig.3). The trees position was, recorded with GPS Garmin Etrex EURO. By using GPS data, from GPS and Surfer 8 software, the yield map was created, indicating the yield of each of the 150 trees mapped. Surfer (v. 8, Golden Software) soft was used to produce interpolated maps.



a)

b)

Fig. 1 Graphical representation of experience a), study area with plastic bags along the rows b)

For each mapped trees, 6 fruits was selected randomly and the quality properties were analysed:

a) The percentage of soluble solids content (SSC) of the juice was measured by refractometer type WZS-I, 900356;
b) Juice pH was measured by a pH-meter 3110 WTW;
c) Flesh firmness (FF) was determined with FT 327 penetrometer (Facchini) with 10 mm diameter plunger.

For all these measurements the averages were calculated. At the same time, the total yield was weighed to determine the correlations between quality parameters and yield.

In May 2012 the flowers per tree were numbered. The data about flowering emphasized the importance of climatic conditions in the manifestation of the phenomon. So, in interpolated maps. IRF-k kriging estimates a value at an unsampled location x_0 by minimizing the estimation variance (which is also the variance of residuals).

The function $K(\mathbf{h}) = \sum_{p=0}^{k} b_p K_p(\mathbf{h})$ is a generalized covariance function, b_p are the unknown coefficients to be determined (equivalent to variogram sills) and the $K_p(h)$ are authorized generic structures (Aggelopoulou and al. 2009). In Isatis these may include a nugget, a linear generalized covariance, a spline generalized covariance or a third-order generalized covariance (Geovariances 2008). The IRF-k approach requires data on a regular grid (approximately the case for our orchard data), and Isatis uses a bilinear interpolator to migrate nearby observation locations to the target grid (Aggelopoulou and al. 2009). Interpolation by kriging was done for Florina flowering and yield data only.

3.RESULTS AND DISCUSSIONS

3.1 Summary statistics and spatial analysis for yield and quality parameters

Summary statistics for the Florina cultivar for the 2012 year of the experiment are done in Table 1, and the spatial coefficients of variability are given in Table 2.

Table 1. Summary statistic for yield and quality parameters for 2012

Cultivar	Variable	Mean	Min	Max	SD_S
	Yield (kg tree)	17.90	8	27	4.80
	SSC (%)	16.2	13.5	18.2	0.95
Florina	Juice pH	3.71	3.54	3.87	0.07
	FF (N)	8.7	7.1	12.1	1.09

$SD_S = \sqrt{var(Z)}$ is the standard deviation for a given year based on measurements at all spatial locations

different values in the northern and southern parts of the orchard.

The yield map (Fig. 3 **a**) shows that the northern part of the orchard was higher yielding than the southern part.

years with earlier springs, the flowering occurs earlier, but its duration may have similar values even when the flowering starts later. The duration of flowering is influenced by temperature fluctuation, recorded during the whole flowering period.

2.3 Data analysis

For data analysis (summary statistics and correlation analysis) it was used S-PLUS 2000_ (MathSoft Inc., Seattle, WA, USA). The coefficient of variation (CV=standard deviation/mean) of a measured variable in a given year provides an estimate of the global spatial variation (each data point is obtained from a different location in the field) (Aggelopoulou and al. 2009).

The Isatis geostatistical software (v.8, Geovariances) was used to determine the spatial relationships of variables. Surfer (v.8, Golden Software) was used to produce

Table 2. Spatial variability of fruit yield and quality

Cultivar	Variable	Coef. of Variation	Coef. of Skewness
Florina	Yield	0.26	-0.28
	Firmness	0.12	0.87
	SSC	0.05	-0.58
	pH juice	0.02	-0.13

For all quality properties, the coeficient of variation is very small (CV: 0.02-0.26).

The coefficient of skewness has both positive and negative values; for negative skewness, most values are concentrated on the right of the mean, with extreme values to the left. For positive skewness, most values are concentrated on left of the mean, with extreme values to the right. The biggest asymmetry is found at firmness, with an asymmetry to the right.

A positive correlation can be made between SSC and pH juice. The higher the sugar content was, the higher the pH juice it was (Fig.2 **a**). For Florina, as flesh firmness decreases, yield increases (Fig. 2 **b**). The soluble solid content and pH juice increases with yield (Fig.2 **c**, 2 **d**).

The map shown in Fig. 3 was produced by ordinary block kriging (4 m x 14 m block). Figure 3 also illustrates typical patterns of variation across the orchard. The Florina 2012 quality properties have distinctly

Trees were also generally larger in the northern part of the orchard. The geographical characteristics of the study area and light duration aspects are some key factors in the variation in yield and quality.

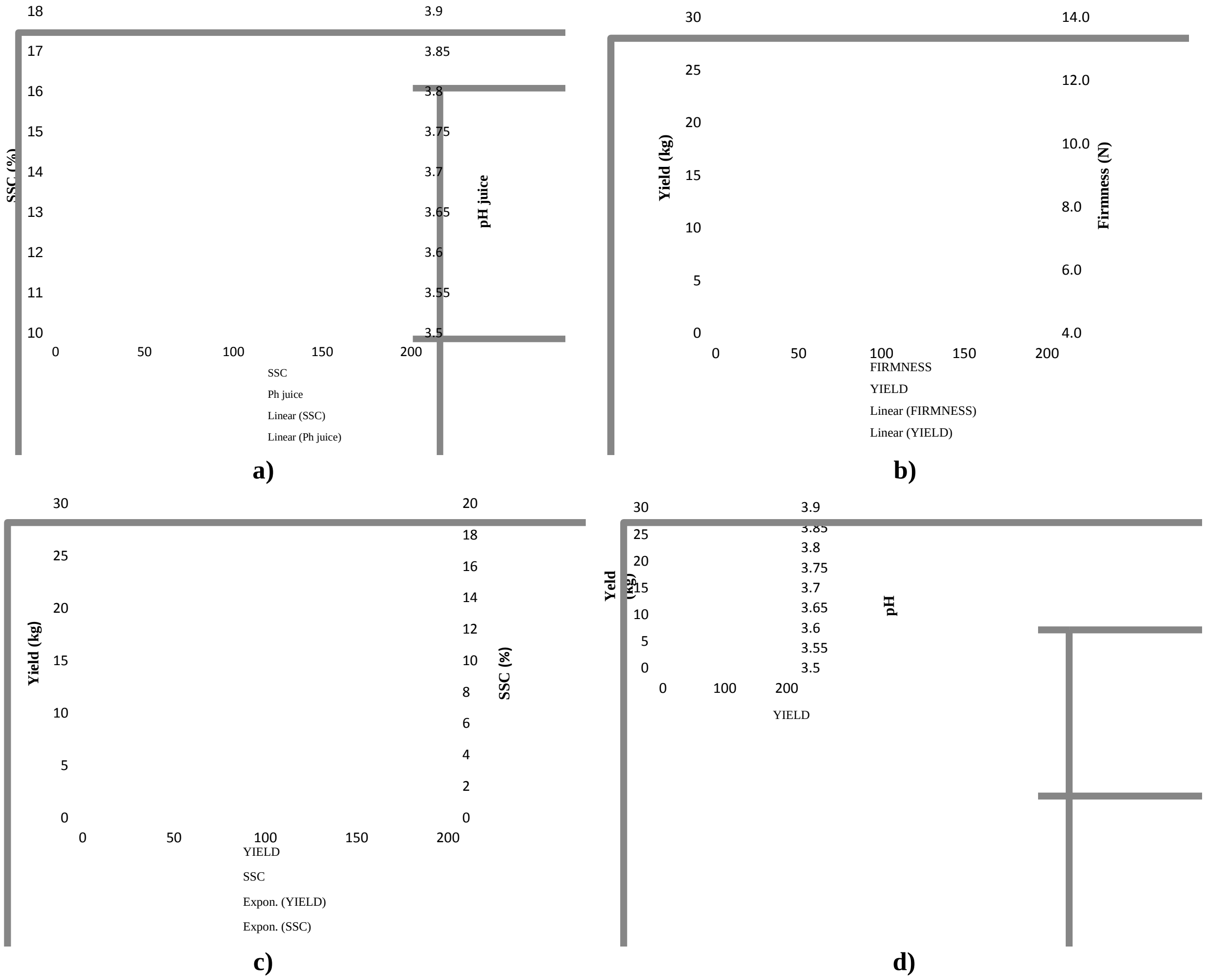


Fig. 2. Correlation between (a) SSC and pH juice, (b) yield and firmness, (c) yield and SSC, (d) yield and juice pH

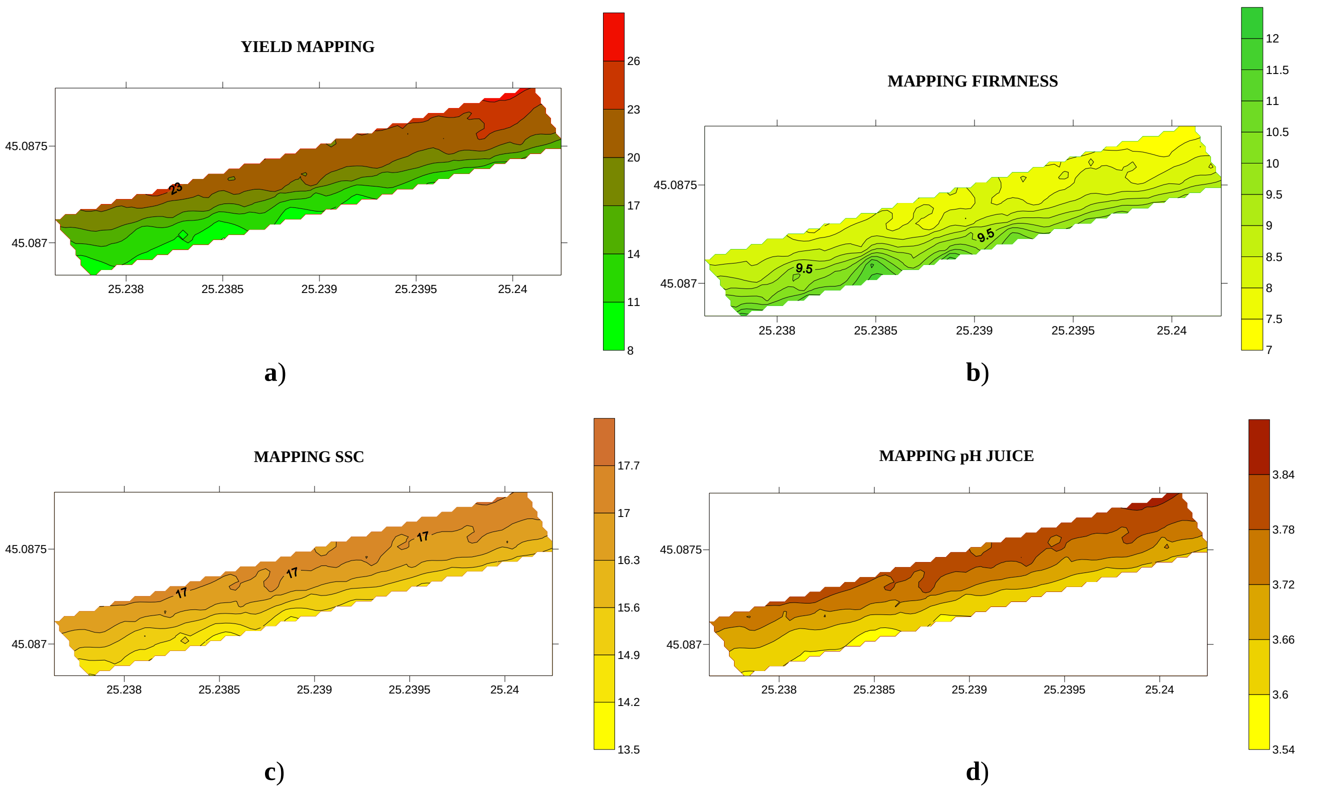


Fig. 3. Maps of a) yield, b) flesh firmness, c) SSC and d) pH juice for the Florina cultivar. Interpolation was done by inverse-squared distance. The scale bar represents interpolated values; the symbols indicate measured data values.

The spatio-temporal patterns of quality and yield variation over the field have implications for management. These data are preliminary because only one season of data were obtained. The data collection continued at least for another 2 years. Sakai et al. (2008), cited by Aggelopoulou and al. (2009), showed that at least four years of data were needed to understand patterns of alternate bearing in a citrus orchard.

3.2 Summary statistics and spatial analysis for blooming

An estimate of the number of flowers early in the season can be useful for both the farmer and the industry to predict yield, reduce production costs by varying fertilizer application and for market planning. By estimating the number of flowers/tree it can be observed the degree of soil nutrition; there is a direct and positive correlation between the number of flowers/tree and the level of production, so the potential yield could be predicted early in the season from flowers distribution maps and could be used for orchard management during the growing season.
Also, the determination of blooming degree presents an economic importance by establishing the necessity of blooming stimulated substances application. Thinning of fruit-tree blossoms is used to regulate the yearly tree bearing and to increase the fruit yield and quality.
For apple crop, climatic conditions influence yield, which is largely determined by good conditions at the beginning and during the flowering. The yield is determined to, by the intensity of flowering which should reach above average.
Beginning of vegetation and flowering are influenced by climatic conditions in the Voinesti, depending on each year of study.
Thus in 2012, daytime temperatures began to rise after 08.05.2012 reaching 18-20° C during the day; in this way it was accelerate mass flowering in the most apple varieties, including differentiated flower buds on the annual branches that were not affected by the low temperatures of the previous period.
Weather conditions in the spring of 2012 caused a mass flowering period 5/12/2012 - 5/15/2012, with completed flowering on 17.05.2012; it is estimated that they provided appropriate conditions for the yield of 2012. Duration of flowering in the climatic conditions of 2012 was 10 days.

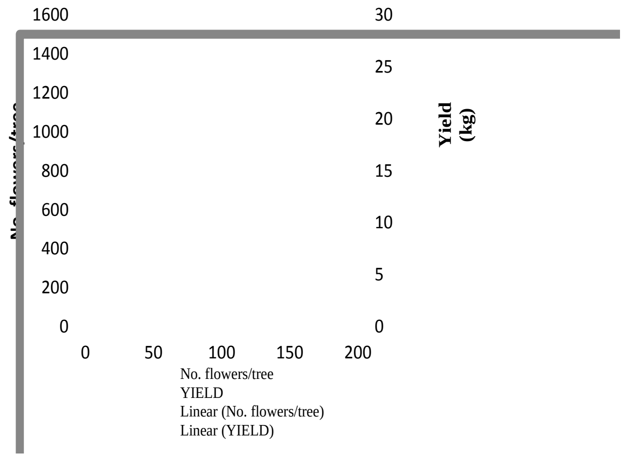


Fig.4. Mapping of number of flowers/tree, 2012
Number of flowers/tree

From the measurements made in the spring of 2012 it was determine the minimum number of 170 flowers/tree, an average number of 625 flowers/tree and a maximum number of 1350 flowers/tree (Fig.4,5).

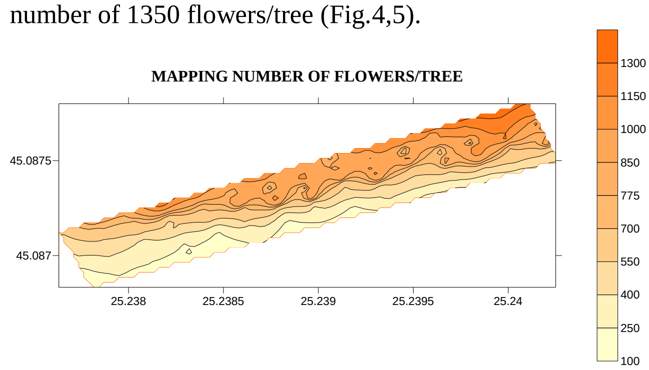


Fig.5. Mapping of number of flowers/tree, 2012

In future work, our aim is not only to describe the yield and quality parameters but also to create the management zones and evaluate the used techniques according to how safe for the environment are they and what is the profit of the farmers.

4. CONCLUSIONS

First, the results of one year experiment are not enough and the study of the orchard will continue.

The conclusions of this study are:

- spatial variability are significant in the study area.
- yield and flowering were correlated with fruit qualities.
- the number of flowers per tree was positively and significantly correlated with yield of the related year indicating that yield might potentially be predicted early in the season from maps of flowering.

Promoting the genetic resistance cultivars in the field is ensured a better protection of the environment and reduced costs with technology.

5. ACKNOWLEDGEMENTS

Thanks to the RDSP Voinesti, Dambovita for the technical support in this study.

6. REFERENCES

[1] Acevedo-Opazo C, Tisseyre B, Guillaume S, Ojeda H (2007) Test of NDVI information for a relevant vineyard zoning related to vine water status. 6th European Conference on Precision Agriculture, Skiathos, Greece, p. 547-554

[2] Aggelopoulou KD, Bochtis D, Fountas S, Swain KC, Gemtos TA, Nanos GD (2011) Yield prediction in apple orchards based on image processing. Precision Agric 12, p. 448–456. doi:10.1007/s11119-010-9187-0

[3] Aggelopoulou KD, Wulfsohn D, Fountas S, Gemtos TA, Nanos GD, Blackmore S (2010) Spatial variation in yield and quality in a small apple orchard. Precision agriculture Vol. 11 Issue 5, p.538-556. doi:10.1007/s11119-009-9146-9

[4] Alchanatis V, Safren O, Levi O, Ostrovsky V (2007) Apple yield imaging using hyperspectral machine vision. 6th European Conference on Precision Agriculture, Skiathos, Greece, p. 555-562

[5] Annamalai P, Lee WS (2003) Citrus yield mapping system using machine vision. ASAE paper number 031002.

[6] Balastreire LA, Schueller JK, Amaral JR, Leal JCG, Baio FHR (2002) Coffee Yield Mapping. ASAE Paper No 021166. St. Joseph, Michigan. ASAE

[7] Blidaru Sinziana**,** Georgescu Andreea (2003) The dynamics of physical parameters in the fruit of *Prunus cerasifera* Ehrh. byotipes- Analele Facultății de Horticultură Timişoara ,Seria a VII-a– Editura AGROPRINT, ISSN 1453 – 1402

[8] Chinchuluun R, Lee WS, Ehsani R (2007) Citrus yield mapping system on a canopy shake and catch harvester. ASAE Annual Meeting 073050

[9] Geovariances (2008) Structure identification in the intrinsic case. In Isatis technical reference, Release 8 (pp. 9 - 51). Avon, France: Geovariances. http://www.geovariances.com.

[10] Kim Y, Reid J (2004) Apple yield mapping using a multispectral imaging sensor. International Scientific Conference on Agricultural Engineering (AgEng), Leuven, Belgium

[11] Lopez-Granados F, Jurado-Exposito M, Alamo S, Garcia-Torres L (2004) Leaf nutrient spatial variability and site-specific fertilization maps within olive (*Olea europaea L.*) orchards. European Journal Agronomy 21: 209-222

[12] Marcotte D, David M (1988) Trend surface analysis as a special case of IRF-k kriging. Mathematical Geology, 20, 821–824.

[13] Miller WM, Whitney JD (1999) Evaluation of weighing systems for citrus yield monitoring. Applied Engineering in Agriculture, 15(6): 609–614

[14] Molin J.P, Mascarin LS, Povh FP, Amaral JR, Oliveira AS (2007) Proceedings of the 6th European Conference on Precision Agriculture, Skiathos, Greece. Poster Abstracts in CD

[15] Morarita Sinziana Venera (2007) The influence of climatic factors of different years on some biotypes of *Prunus cerasifera* Ehrh - Universitatea Lucian Blaga din Sibiu – Conferința Internațională- Agriculture and food industry within the context of European integration, ISSN 1843-0694

[16] Okamoto H, Lee WS, Kane K (2007) Hyperspectral imaging for green citrus detection. Proceedings of the 6th European Conference on Precision Agriculture, Skiathos, Greece. Poster Abstracts in CD

[17] Ortega RA, Esser A, Santibanez O (2003) Spatial variability of wine grape yield and quality in Chilean vineyards: economic and environmental impacts. 4th European Conference on Precision Agriculture, Berlin, Germany, p. 499-506

[18] Queiroz DM, Alves EA, Pinto FAC (2007) Spatial and Temporal Variability of Coffee Quality. ASABE Paper, N. 071141

[19] Safren O (2006) Green apple yield mapping using hyperspectral machine vision. M.Sc Thesis, Ben-Guiron University of Negev, Faculty of Engineering Sciences, Department of Industria Engineering and Management, Israel

[20] Sakai K, Noguchi Y, Asada S (2008) Detecting chaos in a citrus orchard: Reconstruction of nonlinear dynamics from very short ecological time series. Chaos Solitons & Fractals, 38, 1274–1282.

[21] Schumann AW, Zaman QU (2003) Mapping water table depth by electromagnetic induction. Applied Engineering in Agriculture, 19(6): 675-688

[22] Stajnko D, Lakota M, Hoevar M (2004) Estimation of number and diameter of apple fruits in an orchard during the growing season by thermal imaging. Computers and Electronics in Agriculture, 42: 31-42.

[23] Stamatiadis S, Taskos D, Tsadila E, Christofides C, Tsadilas C, Schepers JS (2007) Proximal remote sensing. Technological advances and application in vineyards. 6th European Conference on Precision Agriculture, Skiathos, Greece, Poster abstracts in CD

[24] Tagarakis A, Chatzinikos A, Fountas S, Gemtos TA (2006) Deliniation of management zones in precision viticulture. HAICTA 2006 Conference, Volos, Greece, p.547-554

[25] Taylor J, Tisseyre B, Bramley R, Reid A (2005) A comparison of the spatial variability of vineyard yield in European and Australian product systems. 5th European Conference on Precision Agriculture, Uppsala, Sweden, p. 907-914

[26] Teodorescu G (2009) Improvement of fruit quality using the precision horticulture in Romania. VIII International Symposium Frutic Chile

[27] Tisseyere B, Mazzoni C, Ardoin N, Clipet C (2001) Yield and harvest quality measurement in precision viticulture-application for a selective vintage , 3rd European Conference on Precision Agriculture, Montpellier, France, p. 133-138

[28] Whitney JD, Ling Q, Miller WM, Adair Wheaton T (2001) A DGPS yield monitoring system for Florida citrus. Applied Engineering in Agriculture, 17(2): 115-119

[29] Xujun Y, Sakai K, Manago M, Asada S, Sasao A (2007) Prediction of citrus yield from airborn hyperspectral imagery. Precision Agriculture, 8(3):111-125

[30] Zaman Q, Schuman WA, Hostler HK (2006) Estimation of citrus fruit yield using ultrasonically-sensed tree size. Applied Engineering in Agriculture 22(1): 39-43.