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YIELD MAPPING AND QUALITY ANALYSIS OF FRUIT IN COMMERCIAL APPLE ORCHARDS IN GREECE AND ROMANIA

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Abstract

The aim of the current research is to demonstrate the yield data and the quality features of the fruit of a commercial apple orchard in Greece. The orchard has two cultivars: Cv. Fuji as main cultivar and Cv. Red chief as pollinator. Yield mapping was done during the harvest by weighting the group of apples for every 10m in every tree line. Apple samples were collected before the harvest. The samples were analysed for flesh firmness, fruit mass, soluble solids contents, juice pH and juice acidity. The results showed high spatial yield and fruit quality variability. Moreover the research resulted that there is positive correlation between yield and flesh firmness, pH of juice and juice acidity, while there is negative correlation between yield and soluble solids contents and fruit mass.

Keywords: apple, quality analysis, yield, precision agriculture.

1. INTRODUCTION

Precision agriculture (PA) was initially applied worldwide to arable crops, as they were mechanized and appropriate yield monitor sensors were developed and mounted on crop harvesters such as application of PA on sugar beets (Hofman et al., 1995), on peanuts (Durrence et al., 1999) and on cotton (Vellidis et al., 2003).
In Greece, PA was initiated with yield mapping of cotton fields in 2001. The experiments concluded that even small fields showed high spatial variability in yield (Gemtos et al., 2005).
By the end of the 1990s, researchers and the industry turned the interest to apply PA to high value horticultural crops (Bramley et al., 2005). It was believed that perennial crops, namely vineyards and orchards, could be managed over a long time scale due to low genetic variability between plants due to clonal propagation. The variability measured would be due to site-specific clone-environment-management interaction (Taylor, 2004). Grape yield mapping was applied in Australia and USA in 1999 by sensors mounted on grape harvesters (Arno et al., 2005). However, yield mapping in orchards was difficult and time consuming. In most cases, the fruit was handpicked and placed in bins that were placed next to the tree row before loading onto trailers. Miller and Whitney (1999) and Whitney et al. (2001) focused their work on automated yield mapping in citrus orchards. The fruits were gathered in field bins evenly distributed in the orchard. The workers emptied the harvest bags with oranges from the surrounding trees in the nearby bin. When the bins were loaded on trucks, they were weighed with a system of load cells installed on the truck. The position of the truck was identified with a DGPS (Differential Global Position System) system. The data, fruit weight and position, were analyzed in order to create yield maps.
Apple is the fourth most important tree crop in Greece after olive, citrus and peach (Vasilakakis 2004). Greek apples are of high quality especially when the orchards are at high elevations, where the fruit develop a good taste. Soluble solids content and flesh firmness are the most important maturity indices used for apple harvesting (Blankenship et al. 1997; Marquina et al. 2004).
The aim of this study was to study the within-field variation in yield, and fruit quality features of an apple orchard and to understand the relation between them.

2. MATERIALS AND METHODS

Site description

In Greece, the experiment was carried out on a 1 ha commercial apple orchard (Figure 1) located at Aetolofos area of Central Greece (22^{o} 44′14.28′′ E, 39^{o}39′53.20′′ N). To the north and west of the orchard, there were other apple orchards, to the south there were natural vegetation (shrubs) and to the east there was a wheat field. The orchard was planted with two apple cultivars. The main cultivar was Cv. Fuji and Cv. Red chief used as a pollinator (5 rows of 'Fuji' and 1 row of "Red chief"). Tree rows were spaced 3 m apart and trees in the row were 0.6 m apart. Trees were trained as free palmette and fruit thinning was performed manually one month after full bloom.

Figure 1. The commercial apple orchard studied in Greece
Source: authors

In Romania, the experiment was carried out on a 0.9 ha commercial apple orchard (Figure 2) located at Voinesti area of Dambovita county (25^0 14' 268'' E and 45^0 05' 211'' N, altitude 423 m). The orchard was planted with Florina cultivar and Generos cultivar used as a pollinator. Tree rows were spaced 4 m apart and trees in the row were 3 m apart. Trees were trained as pyramidal shape.

Figure 2. The commercial apple orchard studied in Romania
Source:authors

Data collection

The research was conducted in 2011. In 2011 there were no pest and disease problems but the weather during the fruit set was not optimal because of high air humidity, low temperatures, and high precipitations.

In early November 2011, the apples were hand harvested. They were placed into plastic crates, with a capacity of 20 kg, left along the tree rows before loaded to a platform. The workers were completely filling the crates as they moved along the tree rows. Before harvest, each row was divided into 10 m sections. All crates from each group of 10 m sections were collected together and weighed to give the yield of 10 m per row in order to create a yield map. This length was selected to minimize the error, due to the way the crates were filled. The geographical position of the middle tree of each part was recorded using a GPS device (Garmin Etrex Legend H).

Before harvest, for every 10 meters and every other row, samples of Fuji fruit were collected. At each location 4 fruit were randomly selected from the trees. The samples were examined for the fruit mass, the flesh firmness, the soluble solids content, the pH of juice and the juice acidity. Specifically, each apple was weighted separately to find the fruit mass. Continuously, the skin was removed and by using an Effegi penetrometer with 11 mm diameter plunger the flesh firmness was found by calculating the mean of two measurements taken from opposite sides of each sampled fruit. After that a small amount of juice was used at the refractometer Carl Zeiss Jena to estimate the soluble solids contents. Finally the pH of the juice was found by utilizing a pH meter while juice acidity was calculated by titration of the juice with 0.1N NaOH to an endpoint of pH 8.2.

In Romania, the research was conducted in 2012. In early October 2012 (the first decade), the apples were hand harvested. They were placed into plastic bags, left along the tree rows before loaded to a platform. The geographical position of the middle tree of each part was recorded using a GPS device (Garmin Etrex EURO).

The samples were examined for the fruit mass (using an electronic scale, type Kern, KB model), the starch - iodine test maturity, the flesh firmness (using a FT 327 Facchini penetrometer), the soluble solids content (using a refractometer, type WZS-I, 900356), the pH of juice and the juice acidity (titration with 0.1N NaOH).

Data analysis

At the current research for the comparison of the yield and the fruit quality data, the grid 10m x 12m was selected. The specific size of grid was selected because 10 m was the length among the measurements along the rows (yield, samples) and 12 m for symmetrical purposes and because for every 12 m of apple trees there was one row with pollinator trees. Consequently, all measured data were transformed into 10 m x 12 m grids by calculating the mean value in each grid cell by utilizing the ArcGis 9.3 (ESRI, USA) software. Initially the grid layer was formed into 56 polygons. Continuously, the layers with the quality and yield data (points) were joined to the grid layer using the mean function to calculate the mean values of the points included in each grid cell. Moreover, at the generated maps of yield and quality, four classes were used to represent the data. The classification method used was the quantile by which each class has the same number of features. To compare the final yield maps with the quality maps each polygon took a number from one to four according to the class in which it existed. Finally, the number of matched polygons between yield and quality was calculated.

The software SPSS 16.0 Winwrap Basic (IBM Corporation, New York) was used for statistical analysis of the data. Specifically, Pearson's correlation was done to find the correlation between yield and quality data.

Weather data

The daily relative humidity (RH) and the temperature (T) for both years were acquired from the National Meteorological Service of Greece (EMY) while the daily precipitation data were downloaded from a weather station near to the orchard. The weather data analyzed with the Microsoft Office Excel 2007 Software. The analysis focused on the calculation of the mean values of RH, T and precipitation data for every 5 days from the 1st of April until the middle of May for two years in order to have a better view of the adverse weather condition during the fruit set in 2011 (Table 1).

Table 1. Weather data for the two years

	MEAN RH (%)		MEAN AIR TEMPERATURE (°C)		MEAN RAINFALL (mm)	
DATES	2010	2011	2010	2011	2010	2011
1 - 5 / 4	71.3	78.6	13.3	12.8	0.04	0.88
6 - 10 / 4	61.3	60.8	12.6	15.5	0	0.04
11 - 15 / 4	75.0	62	13.0	13.2	0.28	0.44
16 - 20 / 4	77.6	80	15.6	10.3	1.48	2
21 - 25 / 4	64.3	73.2	16.2	11.8	0	0
26 - 30 / 4	56.3	88.2	15.3	12.9	0.04	1.76
1 - 5 / 5	61.4	87.8	18.7	16.4	0	1.16
6 - 10 / 5	58.2	74.4	18.9	13.6	0	0.64
11 - 15 / 5	55.1	62.4	22.3	16.9	0.46	0.04

3. RESULTS AND DISCUSSIONS

Figure 3 presents the yield variability in 2011. Overall, yield was much lower in 2011 than the previous years. This may have resulted from insufficient pollination and low fruit set. According to the Table 1, relative humidity decreased gradually during the pollination and fruit set period (21st April –15th May 2010) by approximately 10% and air temperature was acceptable for insect mobility, but, in 2011, relative humidity and precipitations remained high throughout the crucial pollination period while air temperature was relatively low. When relative humidity and precipitations are high and air temperature is close or below 15 °C during the pollination period, the pollen-dispersing insects (mainly bees in apple orchards) fly less and only close to their beehives resulting in poor pollen dispersal. Moreover, the high relative humidity in combination with cloudy conditions and low air temperatures during April and early May 2011 must have delayed pollen tube growth resulting in unsuccessful ovary fertilization and reduced fruit set as it is commonly found in apples under similar adverse weather conditions (Childers et al., 1995).

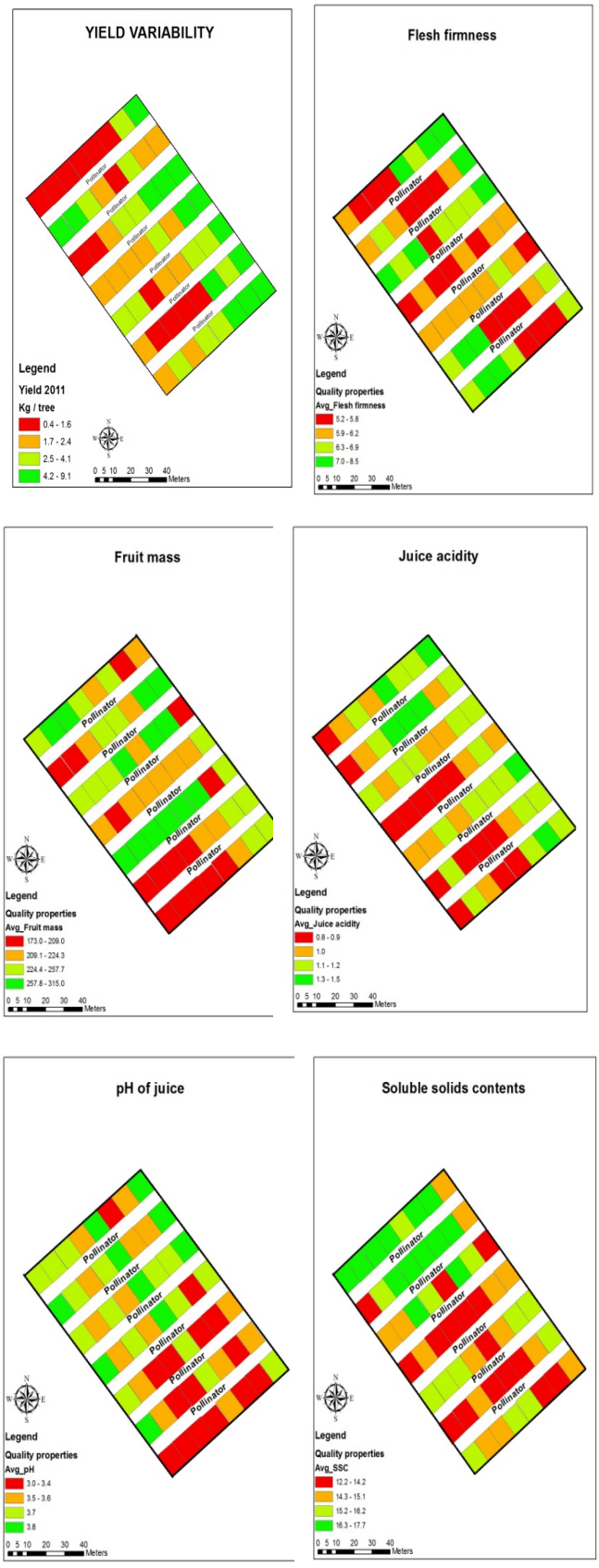

Figure 3. Yield map and fruit quality maps

According to the yield map there were five locations in the orchard where the yield was low and only at the eastern part of the orchard the yield was high. Figure 2 also presents the variability of the fruit quality in 2011. The map representing the flesh firmness of the fruits had 14 polygons at the same class (same colour) as the yield map. Additionally, 10 polygons were at the same class (same colour) at the yield and fruit mass maps while the map with the juice acidity variability had 18 same polygons. Finally, the map which represents the variability of the pH of the juice had 9 polygons at the same class as the yield map while the map with the soluble solids contents had 12.

The correlation of yield data with the fruit quality data showed that there is positive correlation between the yield and the flesh firmness (R^2= 0.15), the pH of juice (R^2= 0.18) and the juice acidity (R^2= 0.2). However it was noticed that there is negative correlation between the yield and the soluble solids contents (R^2= -0.15) and the fruit mass (R^2= -0.4). Additionally, the data analysis showed that as the fruit mass increases the flesh firmness decreases because of fruit maturity. One important result of the analysis is also the negative correlation between the yield and fruit mass. This indicates that the number of the fruits contributes to the increase of the yield and not the size of the apples.

Similar correlations, as obtained from this research, were presented by Aggelopoulou et al., (2009). They resulted that the yield is correlated positively with the pH of juice (R^2= 0.01) and negatively with the flesh firmness (R^2= -0.18), the soluble solids contents (R^2= -0.72) and the fruit mass (R^2= -0.26).

4. CONCLUSIONS

From the results of the current research it could be concluded that:

- The yield is correlated with the quality features of the fruits.
- The negative correlation between yield and the fruit mass and the soluble solids contents indicates that the present of high yields downgrades the fruit quality.
- The increase of the yield depends on the number of the fruit on the trees and not on the fruit size.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] Aggelopoulou, K., Wulfsohn, D., Fountas, S., Gemtos, T., Nanos, G., Blackmore, S. (2010). Spatial variation in yield and quality in a small apple orchard. Precision Agriculture, 11, pp. 538-556.

[2] Arno, J., Bordes, X., Ribes-Dasi, M., Blanco, R., Rosell, R., & Esteve, J. (2005). Obtaining grape yield maps and analysis of within field variability in Raimat (Spain). In: Precision Agriculture '05: Proceedings of the 5th European Conference on Precision Agriculture, edited by J. V. Stafford, (Wageningen Academic Press, Wageningen, The Netherlands), pp. 899-906.

[3] Blankenship, S. M., Parker, M., & Unrath, C. R. (1997). Use of maturity indices for predicting poststorage firmness of Fuji apples. HortScience, 32, 909–910.

[4] Bramley, R. G. V., Proffitt, A. P. B., Hinze, C. J., Pearse, B., & Hamilton, R. P. (2005). Generating benefits from Precision Viticulture through selective harvesting. In: Precision Agriculture '05: Proceedings of the 5th European Conference on Precision Agriculture, edited by J. V. Stafford, (Wageningen Academic Press, Wageningen, The Netherlands), pp. 891-898.

[5] Childers, N. F., Morris, J. R., & Sibbett, G. S. (1995). Modern Fruit Science (Horticultural Publications, Gainesville, Florida), Chapter VI.

[6] Durrence, J., Hamrita, T., Vellidis, G. (1999). A load cell based yield monitor for peanut feasibility study. Precision Agriculture, 1, pp. 301-317.

[7] Gemtos, T. A., Markinos, A., & Nassiou, T. (2005). Cotton lint quality spatial variability and correlation with soil properties and yield.). In: Precision Agriculture '05: Proceedings of the 5th European Conference on Precision Agriculture, edited by J. V. Stafford, (Wageningen Academic Press, Wageningen, The Netherlands), pp. 361-368.

[8] Hofman, A. R., Penigrahi, S., Gregor, B., & Walker, J. (1995). In field monitoring sugar beets. Paper No 95-2114, ASAE, St. Joseph, Michigan, USA.

[9] Marquina, P., Venturini, M. E., Oria, R., & Nequerela, A. I. (2004). Monitoring colour evolution during maturity in Fuji apples. Food Science and Technology International, 10, 315–321.

[10] Miller, W. M., & Whitney, J. D. (1999). Evaluation of weighing systems for citrus yield monitoring. Applied Engineering in Agriculture, 15(6), pp. 609-614.

[11] Taylor, J. A. (2004). Digital terroirs and precision viticulture: Investigations into the application of information technology in Australian vineyards. M.Sc. Thesis, University of Sydney, Australia.

[12]Vasilakakis, M. (2004). General and specialized pomology. Thessaloniki: Gartaganis Publications.

[13] Vellidis, G., Perry, C., Rains, G., Thomas, D., Wells, N., Kvien, C., Hill, R., Dales, D. (2003). Simultaneous assessment of cotton yield monitors. ASAE, paper number: 021163.

[14] Whitney, J. D., Ling Q., Miller W. M., & Wheaton, T. A. (2001). A DGPS yield monitoring system for Florida citrus. Applied Engineering in Agriculture, 17(2), pp. 115-119.