VARIABILITY OF DRY MATTER CONTENT OF APPLE FRUIT UNDER THE INFLUENCE OF CULTIVAR AND SOIL MAINTENANCE SYSTEMS

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Abstract

The apple varieties on which we have focused in this study are widespread culture in European Community countries, but less common in orchards in Romania. These varieties are found in the plantation belonging to S.C. Delifood S.R.L. from Urvind village, Bihor county and they are called: Rajka, Rubinola, Topaz, Otava and Goldstar.

The new apple varieties, widely spread in the EU discover the favourable conditions from Urvind in order to create an adequate dry matter content (DM% = 19.6 to 26.4) to ensure their juiciness and appropriate firmness of the pulp much appreciated by the consumers.

For the data we obtained in Urvind, on average over the three experimental years, the quadratic regression has accurately explained the relationship between the content in DM% and sugar (%). There is a linear increase in the sugar content (%) together with an increase of DM % content in the interval of 19.0 to 21.0% DM, followed by a slight stagnation and beyond the 21.5% DM of sugar content (%)it decreases significantly.

Keywords: cultivar, dry content, maintenance systems

INTRODUCTION

The literature is quite rich in experimental results directly linking fruit quality to key elements of culture technology applied in apple orchards. KRUCZYNSKA et al. (2006), GODEC (2004) and KELLERHALS (2004) point out that among the components of culture technology, phytosanitary protection and maintenance mode in the orchard soil had the greatest influence on fruit quality at some of the new varieties of apple (Rajka, Topaz Rubinola) widely cultivated in the EU and not only.

The dry matter content of apples is considered for a long time an essential quality index for this species.

The apples importance as fruit dessert on one hand, and also as a raw material in domestic and industrial processing depends directly on water content of fruit, respectively on dry content of fruit.

Recent research regarding the importance of this feature in assessing the quality of apples (PALMER et al., 2010; LENZ, 2009) reveal that for the new apple varieties introduced to the market in recent years, consumers particularly appreciate juiciness and firmness of apples pulps, features thar depend largely on dry matter content of the fruit.

Variability of dry matter content (DM%) of apples is high and it depends on many factors such as: the genotype considered, the climatic conditions of the year on question, technology of the culture applied, fruit harvesting age, their conditions and duration of storage etc. Depending on these factors, the content of DM% of the apples can vary between 8-37% and, of course, the best quality fruits have DM% with values around the average of the extreme values given above.

Naturally, given the importance of this character in the series of experiments performed at Urvind, Bihor county between 2006-2008 was determined the DM% of fruit content to establish the extent to which genotype (cultivar), system maintenance of soil in the orchard and the interaction between these two factors influence the respective feature.

MATERIAL AND METHODS

Five apple varieties less widespread in Romania's culture but widespread in European Community countries were studied in terms of many particularities of fruit quality. These varieties are: Rajka, Rubinola, Topaz, Otava and Goldstar.

The plantation was set in 1999, with trees grafted on M_9 rootstocks. For the planting distances used of 4 x 1.20 m was achieved a density of 2083 trees/ha. Tree crown was formed and led as a thin spindle with two ridges longer on the row of trees and two shorter ridges perpendicular to the row.

The experience was composed of two factors and it included:

Factor A - soil maintenance systems with graduations:

a_1 - classic Bare fallow with tillage over the entire surface of the orchard;

a_2 - Bare fallow with herbicides on the row of trees;

a_3 - Turf strips between rows and dug on the row trees;

a_4 - total turfs of the orchard soil.

Factor B – soil with graduations: b_1 Rajka; Rubinola b_2; Topaz b_3; b_4 Otava and b_5 Goldstar

It resulted a total number of 20 variants that were located according to the linear block method in three repetitions, each repetition comprising a total of 10 trees.

Such determinations were made on the physical-chemical characteristics of the fruit such as: size of the fruit on samples of 25 fruits, measuring with calipers the large diameter (D), the small diameter (d) and height, and then applying the formula (D+d+h)/3, being expressed in mm.

- The sugar determined with the refractometer, expressed in percents %.

- Acidity determined by titration with 0.1 N NaOH, in the presence of phenolphthalein, expressed as a percentage (%) by multiplying g/kg to 0.067, malic acid equivalent.

Organoleptic assessment of fruit quality by tasting performed by groups of students from the Faculty of Environmental Protection, specializing in Horticulture, University of Oradea, according to STAS analysis Report.

Calculation and interpretation of experimental results was done primarily using variance analysis applied to the series of polifactorial experiments type A x B x years.

To establish the significance between the performances of variants tested was used the multiple comparisons test (Duncan, Tuckey), $DS_{5\%}$ values are calculated using $s^2_{AxBxyears}$ in order to highlight the consistency in time of the results analyzed. The analysed model was presented by ARDELEAN et al., 2002.

To determine the total variance of the analyzed features means in series of experiments A x B x years, we used the following formula (ALLARD 1966):

$$s_P^2 = s_{G(A)}^2 + \frac{s_{G(AxB)}^2}{n} + \frac{s_{G(AxBxani)}^2}{years} + \frac{s_E^2}{nxyears}, \text{ where:}$$

s_P^2 = total phenotypic variance;

s_G^2 = genetic variance (determined by A factor, by interaction A x B and by interaction A x B x years;

s_E^2 = error variance.

Determining the coefficients of simple (r_{xy}), partial ($r_{xy.z}$) and multiple ($R_{x.yz}$) correlation as well as the coefficient of linear b_{xy} and square (c_{x^2y}) regression was done by using the models presented by ARDELEAN (2010). In all the cases, the calculations were performed by using Microsoft Excel program.

RESULTS AND DISCUSSION

The data presented in Table 1 suggests that the three experimental years (2006-2008) were quite similar in terms of temperature, precipitation and sunlight levels during the growing season of the apple so that their influence on the dry matter content of the fruit to be insignificant [$F_{calc} < F_{teor}$ both for the error variance (s^2_E) and for the variance of the interaction between experimental factors and years of experimentation ($s^2_{A\ x\ B\ x\ ani}$)]. It can be concluded, therefore, that the overall variability of the character under discussion is primarily due to the experimental factors and interaction between them and much less due to the environmental conditions during the experimental years and the errors.

Table 1

Analysis of variance for dry mater content (DMC) of fruits in the series of experiments type A × B × Y (Urvind, 2006 -2008)

Source of variation	SS	DF	s2	F Test			
				Versus s2E		Versus s2A x B x Y	
Total	520,67	179					
Replications	3,082	6					
Years	5,842	2	2,921	2,77	<3,07	2,39	<3,40
A × Years	83,272	6	13,8787	13,17**	>2,03	11,36**	>2,36
B × Years	97,202	8	12,1520	11,53**	>2,19	9,95**	>2,51
A (*tillage system)*	29,549	3	9,850	9,35**	>2,68	8,06**	>3,01
B (*cultivar*)	112,610	4	28,1524	26,72***	>2,45	23,05***	>2,78
A x B	39,691	12	3,3076	3,14*	>1,83	2,71*	>2,18
A × *B* × Year	29,318	24	1,2216	1,16	<1,61		
Error	120,108	114	1,0536				

Table 2

Effect of cultivar and tillage system on dry mater content (DMC) of fruits in the series of experiments type A × B × Y (Urvind, 2006 -2008)

Cultivar / *Tillage system*	Rajka	Rubinola	Topaz	Otava	Goldstar	*Mean of tillage system*
Bare fallow	26,4 a	24,4 ab	24,0 bc	23,5 Bc	23,5 bc	24,4 A
Bare fallow+herbicides	22,2 bcd	23,0 bcd	23,5 bc	23,4 bcd	21,9 cde	22,8 AB
Turf strips	21,0 de	21,7 cde	21,1 de	21,4 de	21,8 cde	21,4 AB
Turf	20,5 e	20,4 e	20,1 e	19,8 E	19,6 e	20,1 B
Mean of cultivar	22,5 M	22,4 M	22,2 M	22,0 M	21,7 M	

$LSD_{5\%}$ *for two means of A* = 2,6 – 3,2 %
$LSD_{5\%}$ *for two means of B* = 2,4 – 2,9 %
$LSD_{5\%}$ *for two means A* × *B* = 2,3 – 2,7 %

The summary of experimental results regarding the effect of genotype and tillage system of soil in the orchard, shown in Table 2, allows some interesting discussions on how the respective factors and their interaction affected the fruit content of DM%.

The difference between any two values, followed by at least a common letter, is not significant

The last row of the table mentioned above is grouping the five apple cultivars tested in just one group, all placed between the values of DM% giving the apples a balanced juiciness and firmness, preferred by consumers (22.0 to 22.5%). Because the difference of content in DM% is not ensured statistically among the five cultivation, we must conclude that all varieties (Rajka, Rubinola, Topaz, Otava and Goldstar) have presented, in Urvind conditions, a juiciness much appreciated by consumers. Even Goldstar variety that is considered a “dry apple” is juicy enough and very likely more appropriate for being kept during the winter under controlled atmosphere and/or normal conditions (household).

It is interesting to note that, a similar juiciness was reported by other researchers too (Iancu et al., 1991) who worked with older varieties of Delicious group (Golden Spur) or even the variety Goldstar (CZINCZYK, 2005), in both examples obtaining for the respective cultivars, higher content values of the fruits in DM% (25-29%).

The effect of soil tillage systems in the orchard are not as important as other quality elements, which is quite predictable from the data table variants regarding F values calculated. It is obvious the significant difference between bare fallow and total turfs of the orchard, in terms of fruit dry matter content, the difference being in favour of the bare fallow (24.4% versus 21.1%).

What we need, however, to note is that, despite the significant difference between the two values of DM%, both are in the area which provide the apples an adequate juiciness and positive firmness of the fruit pulp. We might say, based on these results that the soil tillage system does not adversely affect, drastically the apples content of DM%, even for the new apple varieties, a conclusion that is extremely important for organic and sustainable fruit growing conditions in which herbicides and mechanical works of the soil are reduced as much as possible or even totally eliminated.

The interaction cultivar x soil maintenance system in the orchard has, as shown in Table 2, the most obvious influence on variability in fruit dry matter content. Limits of feature variability (from 19.6 to 26.4%), under the influence cultivar x soil maintenance system, are more pronounced than those reported for the effects of each experimental factor considered separately (from 21.7 to 22.5% and that 20.1 to 24.4%). Steadily and quasi-general, the DM% content is higher in fruit harvested from trees grown on bare fallow (with soil tillage or herbicide one at a time) compared to turf grass strips on the middle between rows and total turfs.

The results are, in a way, surprising as we might consider the herbaceous vegetation from the last two variants of soil maintenance which consume a large part of nutrients, out of which the dry matter is synthesized. This is true but also true is the fact that mulch resulting from mowing the herbaceous vegetation provides efficient water storage reserve in the soil which naturally leads to a more pronounced accumulation of water in the fruit thus reducing the content of DM%.

In the experiments performed by us at Urvind, the experimental factors taken into consideration (soil maintenance system and cultivar) allowed the calculation of correlation and regression statistical indexes. The obtained results are shown in Figure 1.

In most tree species, such as the vines, the connection that exists between DM % content and sugar content of fruit, respectively mash (Brown, 1975) has been known for a long time. In fact, based on such a well-known connection were developed rapid methods for determining the sugar content of fruit based on dry matter determinations, using portable or laboratory refractometers.

Using simple formulas, reading is conversed from DM % in sugar % and some refractometers the reading is given directly in sugar %.

In the experiments performed by us in Urvind, between 2006-2008, to determine the sugar content of different experimental versions was done with refractrometers, by DM % readings and their conversion into sugar % with some formulas specific to apple.

Because the tested cultivars were new, we thought it appropriate to see if and when their connection between DM % and sugar content % is real and thus allows us to determine the sugar indirectly by content in DM. The results obtained are shown in figures 1 and 2.

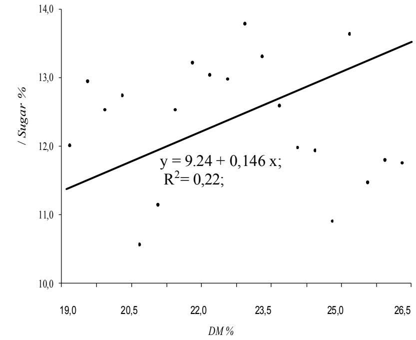

Fig. 1. Linear regression between weight of fruit (dg) and total fruit yield (t/ha) in the series of experiments A x B x Year. Urvind, 2006 – *2008*

From the data presented in Figure 1 we observe that the five varieties tested on the four soil maintenance systems, the three-year data show a positive relationship between the two characters only at the level of correlations. Thus, the value of R^2 = 22 and r_{xy} = 0,44*, confirms that there is a single, positive and significant correlation, at the $P_{5\%}$ level which suggests that, in general, an increase in the content of DM % is accompanied by an increase, more or less proportional of the sugar content %.

Linear regression analysis between the two characters has confirmed, to a large extent, the results obtained through correlation analysis. The regression proved to be linear, positive, with a regression coefficient b_{xy} = 0.146 which is however insignificant for $P_{5\%}$ ($t = 2.08 < 2.10$). This lack of significance should be considered in light of the two values t ($t_{empiric}$ = 2.08 and $t_{teoretic}$ = 2.10) which are quite close, which verifies the positive trend of regression even if it is placed just below the minimum limit of significance.

Because of this result, and also based on the model of the distribution of empirical values of sugar content % according to DM content %, we used the quadratic regression analysis of the two characters to see if it is explained more accurately, and possibly statistically assured, the relationship between the respective characters. The results are shown in Figure 2.

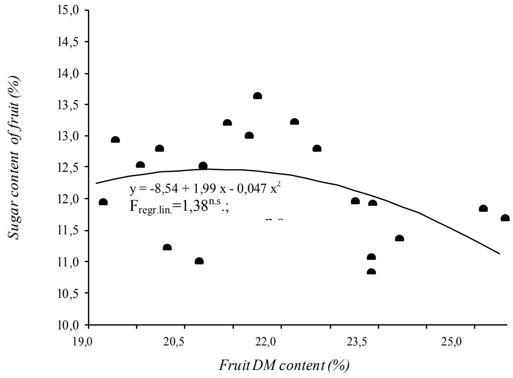

Fig. 2. Square regression between dry matter DM % and sugar content (%) of fruits in the series of experiments A x B x Year. Urvind, 2006 – 2008

Regression curve shown in Figure 2 shows that, at least for the data we obtained from Urvind, on average over three experimental years (2006-2008), the quadratic regression explains quite correctly the relationship between content in DM % and sugar (%). There is a linear increase in the sugar content (%) together with the increase in dry matter content % in the interval of 19.0 to 21.0% DM, followed by a slight stagnation, and from the 21.5% DM value, the sugar content (%) decreases significantly.

The significance of quadratic regression coefficients (b_{xy} and c_{x^2y}) shows, however, that this is not the real pattern of connection between the two characters. Thus, through the variance analysis, the following values were obtained $F_{calculate}$ for total regression, linear regression and quadratic regression: $F_{regr.tot.} = 1.99 < F_{P5\%} = 3.59$; $F_{regr.lin.} = 1.38 < F_{P5\%} = 4.45$; $F_{regr.pătr.} = 0.62 < F_{P5\%} = 4.45$.

It can be concluded, based on these results that, for the five new apple varieties tested in different soil maintenance systems in the orchard, the link between the content in DM % and the sugar content (%) in fruit is positive, direct and significant. The more so as the value t = 2.08 obtained by us for b_{xy} = 0.146 can be considered significant if rounded to one decimal (t = 2.1) which makes it equal to the value $t_{P5\%}$= 2.10, which gives meaning to the respective regression coefficient. In other words, refractometric determination of sugar content (%) of apples remains, for these varieties too, a fast and reliable method of evaluation of an important element of quality in this species.

CONCLUSIONS

The new apple varieties, widespread in the EU find in Urvind favourable conditions for achieving an adequate dry matter content (DM% = 19.6 to 26.4) to ensure their juiciness and firmness of the appropriate pulp and appreciated positively by consumers.

For the data we obtained from Urvind, on average over the three experimental years, the quadratic regression explained correctly the relationship between the DM content % and the sugar content (%). There is a linear increase of the sugar content (%) together with an increase in dry matter content % in the interval of 19.0 to 21.0% DM, followed by a slight stagnation and beyond the value 21.5% DM, the sugar content (%) decreases significantly.

Limiting ourselves to the five apple varieties studied, we recommend the Rajka variety for those who intend to set plantations of apple fruit to obtain a high content of dry matter and implicitly sugar, suitable both for their capitalization as dessert fruits and also as raw matter for domestic and industrial processing.

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