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FRUIT WEIGHT PREDICTION MODELS IN *Quercus* BASED ON SOME BIOMETRIC PARAMETERS

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Abstract

This study aimed at developing some mathematical models for the estimation of achene weight in oak based on fruit biometric parameters and at evaluating through principal component analysis (PCA) fruit size group affinity with biometric parameters. We studied fruits of two oak species, Quercus petraea and Quercus robur. At achene level, we determined such parameters as achene length (Al), middle achene diameter (MAD), achene basis diameter (Abd), achene tip diameter (Atd), and achene weight (Aw). At cupule level, we determined such parameters as cupule height (Ch), outer cupule diameter (Ocd), inner cupule diameter (Icd), cupule all thickness (Cwt), and cupule weight (Cw). We also calculated fruit size index (FSI). Regression analysis was used to find out equations as achene weight prediction models based on studied biometric parameters. The working process followed a logical pattern suggested a general working model. We obtained a linear equation for the estimation of achene weight based on Atd in Q. robur; all other achene weight prediction equations were of the second-degree polynomial type in both Q. robur and Q. petraea. The level of statistic safety in the estimation of fruit size ranged between R^2 = 0.720 and R^2 = 0.962 in Q. petraea and R^2 = 0.376 to R^2 = 0.928 in Q. robur, respectively. Based on biometric parameters, the fruits of the two species studied were grouped into seven size classes. The PCA analysis explained the variance based on PC1 as 92.573% and on PC2 as 6.2315% in Q. petraea and as 82.041% based on PC1 and as 16.032% based on PC2 in Q. robur. For size classes Qp1-Qp3 in Q. petraea and Qr1 in Q. robur, the least variation of any size parameter leads to achene size, while size classes Qp4 and Qr7, diameter variation significantly determines achene weight increase. In size classes Qp5-Qp7 and Qr2-Qr6, fruit length variation induces a significant fruit weight increase.

Key words: *achene, correlations, models, biometric parameters, PCA analysis, Quercus petraea, Quercus robur.*

INTRODUCTION

Plant fruits have generally been studied to characterise the plant anatomically and morphologically depending on both specific biodiversity and crop biota, to select high-quality seed material or for other practical or economic reasons (Jacobs et al., 2014; Boualem et al., 2015; Silva et al., 2017).
Studies on fruits in different oak species (*Quercus* L.) were conducted for comparative autecology evaluations between different species and under different soil and climate conditions (Diaz-Maroto et al., 2005; Rodriguez-Campos et al., 2010).
To evaluate oak fruit vitality, they conducted studies on fruit density, volume, and weight (Tylek et al., 2015). Depending on fruit quality (their germinating capacity), on penetration strength and on the specific parameters, they also evaluated sapling germination and vitality in different oak species (Ashton and Larson, 1996; Isaeva et al., 2009; Xia et al., 2015).
Most studies on *Quercus*, regarding fruits or fruits and leaves biometry, were conducted to characterise species, hybridisation level, and taxonomic differentiation (Dupouey and Badeau, 1993; Diaz-Maroto et al., 2005; Nikolić et al., 2010; Mijnsbrugge et al., 2011; Tylek et al., 2015; Xia et al., 2016; Denk et al., 2017).
The behaviour of *Quercus* species depending on soil and climate conditions has also been studied leading to the conclusion that some of them tolerate poor, dry soils better (such as *Quercus petraea*), while others need richer,

deeper soils (such as *Quercus robur*) (Lepais and Gerber, 2011).

MATERIALS AND METHODS

The goals of this study were to identify achene weight prediction models based on correlations identified between fruit biometric parameters and to evaluate fruit size group affinity with biometric parameters through principal component analysis (PCA).

The biological material studied was represented by two oak species, *Quercus petraea* (Matt.) Liebl. (sessile oak) and *Quercus robur* L. (pedunculate oak) from the Paniova Woods (ROSCI 0338), Timiș County, Romania, a Natura 2000 site designated for 91M0 Habitat conservation (Mountford et al., 2008). We harvested physiologically mature fruits, at the beginning of October.

The fruit is a nut called an acorn or oak nut borne in a cup-like structure known as a cupule, developed from the concrescence of female flower hypsophyl. In *Quercus petraea*, fruits are, on the average, 15-25 mm long and 10-20 mm in diameter. They have very short peduncles or they are sessile and are located at the tip of the branches. The fruits can be solitary or in groups of 2-5. The cupule has outer scaly formations; scales are generally non-pubescent, with non-concrescent margins, ovate-lanceolate, plane, or little convex.

In *Quercus robur*, the fruit has a long peduncle (30-70 mm), ovoid-elongated, 20-40 mm long. Fruits are brown-yellowish, with olive-green longitudinal stripes when not fully mature. The cupule is small and it has plane triangular scales, regularly imbricated, while basic ones are pubescent, little dished, with concrescent margins, and brown, detached tip. There are 1-5 achenes per peduncle (Clinovschi, 2005; Tutin, 1993; Săvulescu, 1952; Eaton et al., 2016).

During the study period (2017), fructification in sessile oak in the Paniova Woods was relatively abundant, with many acorns on each mature tree, but the fruits had smaller sizes than usually because of the poor climate conditions (low precipitations and hydric stress).

Most fruits are described and characterised bi-dimensionally from the perspective of biometric parameters (length or height and diameter). In oak fruits, we measured several fruit sizes at the level of both achene and cupule

The biometric parameters of the studied fruits focused on achene and cupule: achene length (Al), achene basis diameter (Abd), middle achene diameter (MAD), achene tip diameter (Atd), achene weight (Aw), outer cupule diameter (Ocd), inner cupule diameter (Icd), cupule wall thickness (Cwt), cupule height (Ch), cupule weight (Cw), and fruit size index (FSI), parameters considered representative and use in characterising oak fruits in other studies, as well (Anghel et al., 2017). Size parameters of achenes and cupules (length, diameter, wall thickness) were measured with a high-precision (±0.001 mm) electronic callipers; weight as measured with an ATS 60, Poland, scale with a precision of ±0.001 g. Fruit size index was calculated with the relation (1):

$$FSI = \frac{Adm + \left(\frac{Adb + Adt}{2}\right) + Al}{3} \quad (1)$$

Statistic processing. Experimental data were analyses with regression analysis to obtain models for the estimation of achene weight depending on size biometric parameters. We also used the Principal Component Analysis that explains the existence of the variance in the experimental data set and places the variants in relation to the studied biometric parameters (Biplop) to assess achene grouping and to associate achene weight with size parameters. Statistic safety parameters used were the correlation coefficients R^2, p, RMSEP (Freedman and Pisani, 1978; Loftus and Loftus, 1988; Rujescu, 2015). The analysis followed the steps presented in Figure 1. Statistical analysis of trial data was don with a PAST soft (Hammer et al., 2001) and with the statistic calculus model in EXCEL, while the logical scheme was done in VISIO.

RESULTS AND DISCUSSIONS

Mean data and statistic parameters are shown in Table 1 for *Q. petraea* and in Table 2 for *Q. robur*, respectively. Starting from the relations of interdependence identified between fruit parameters (Anghel et al., 2017) in *Q. petraea* and *Q. robur*, we analysed achenes depending on the studied size biometric parameters.

Depending on the individual values of the studied fruit lots and of specific descriptive statistic elements as intervals in each species, the fruits were grouped into seven value groups shown in Figure 2 for *Q. petraea* and in Figure 3 for *Q. robur*, respectively.

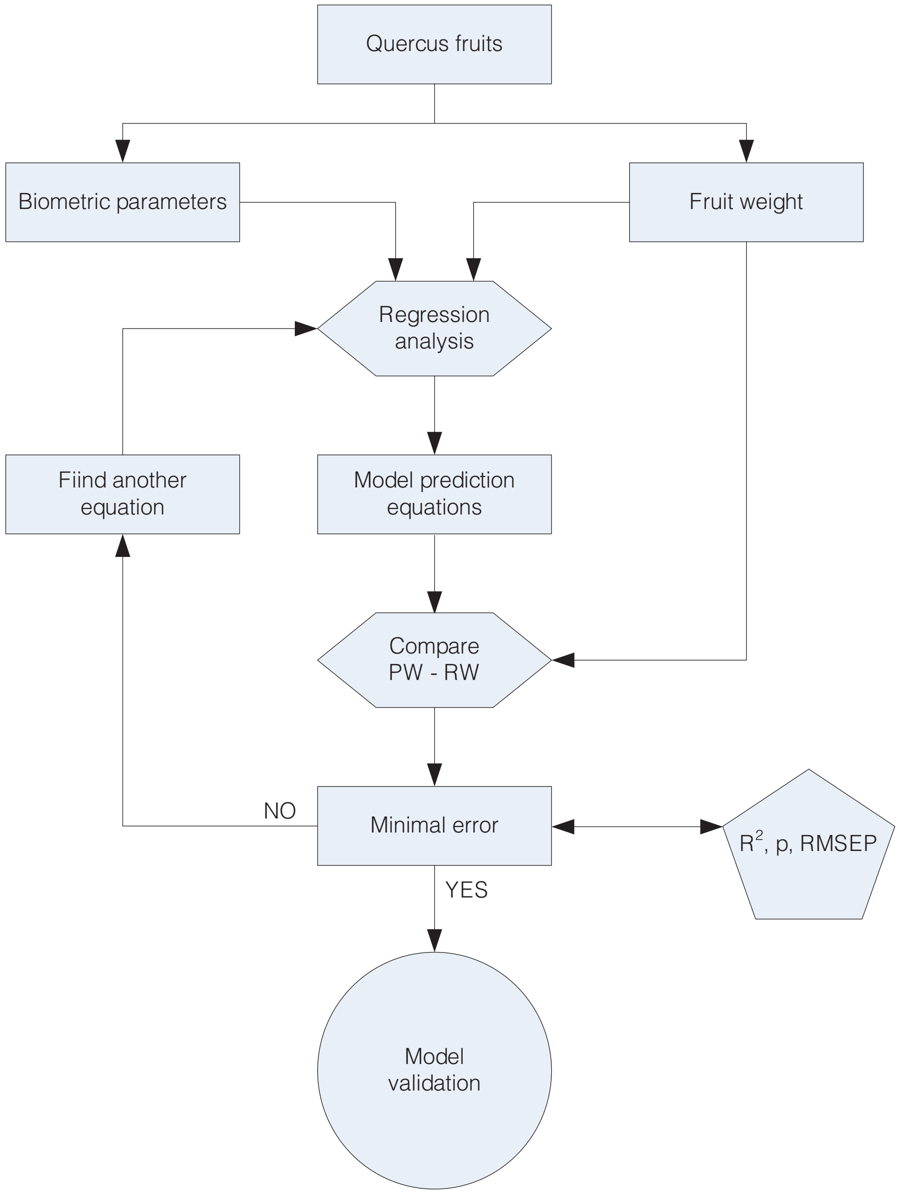

Figure 1. Logical scheme of steps in obtaining achene weight predictive models depending on fruit biometric parameters in *Quercus*

Table 1. Mean data and statistic parameters of the fruits in *Q. petraea*

Descriptive statistics elements	Al	Adb	Adm	Adt	Aw	Ocd	Icd	Cwt	Ch	Cw	FSI
Mean [mm]	18.58	9.19	10.90	7.43	1.33	10.81	9.32	1.35	7.07	0.18	12.60
Standard Error	0.859	0.289	0.331	0.237	0.153	0.231	0.248	0.037	0.182	0.008	0.46
Median	18.35	9.41	11.3	7.61	1.225	10.99	9.41	1.32	7.05	0.179	12.48
Standard Deviation	5.085	1.708	1.956	1.402	0.907	1.369	1.469	0.219	1.075	0.048	2.72
Largest (1)	27.45	11.25	13.68	9.64	2.834	13.12	11.76	2.01	9.06	0.275	16.68
Smallest (1)	9.22	5.18	6.82	4.42	0.173	7.57	6.01	0.91	5.02	0.072	7.78
Confidence Level (95.0%)	1.747	0.587	0.672	0.481	0.311	0.470	0.505	0.075	0.369	0.017	0.94

Table 2. Mean data and statistic parameters of the fruits in *Q. robur*

Descriptive statistics elements	Al	Adb	Adm	Adt	Aw	Ocd	Icd	Cwt	Ch	Cw	FSI
Mean [mm]	28.31	10.46	12.64	7.52	2.62	12.37	10.44	1.58	8.15	0.33	16.65
Standard Error	1.023	0.271	0.342	0.239	0.219	0.289	0.247	0.046	0.124	0.027	0.45
Median	30.18	10.16	12.35	7.41	2.461	11.91	10.12	1.52	8.15	0.258	17.37
Standard Deviation	6.050	1.605	2.024	1.413	1.294	1.711	1.464	0.271	0.736	0.160	2.66
Largest (1)	35.73	14.37	17.53	10.52	5.685	17.70	14.25	2.35	9.51	0.877	19.57
Smallest (1)	9.47	5.98	8.40	4.46	0.092	10.02	8.39	1.23	6.32	0.18	8.17
Confidence Level (95.0%)	2.078	0.551	0.695	0.485	0.445	0.588	0.503	0.093	0.253	0.055	0.91

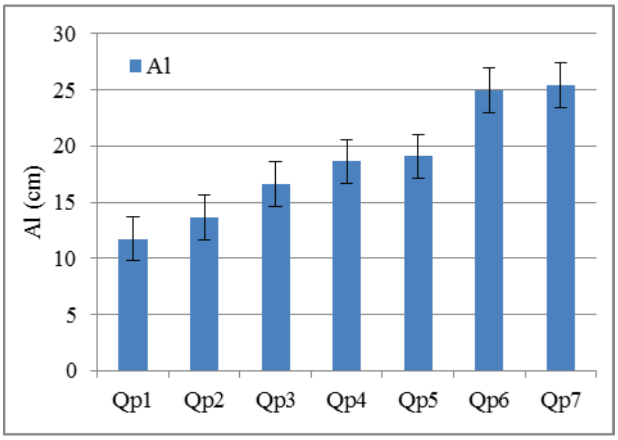

Figure 2. Distribution of size classes in the fruits of *Q. petraea*

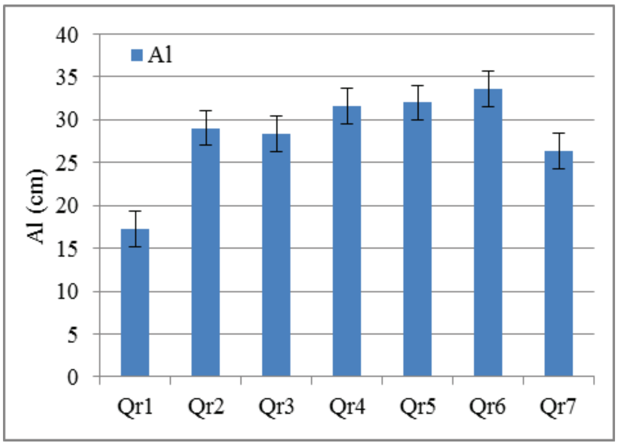

Figure 3. Distribution of size classes in the fruits of *Q. robur*

Regression analysis facilitated the development of an achene weight prediction function depending on their size parameters. In *Q. petraea*, achene weight is described by equation (2) in in statistic safety conditions:

$$y = -2.64115 + Al \cdot 0.11793 + Adb \cdot 0.07616 + Adm \cdot 0.08965 + Adt \cdot 0.01418 \quad (2)$$

where: y = achene weight.

Regression analysis made possible achene weight estimation based on each size parameter described for *Q. petraea* by polynomial equations of the second degree, relation (3) for Al (R^2 = 0.962), relation (4) for Abd (R^2 = 0.743), relation (5) for MAD (R^2 = 0.922), and relation (6) for Atd (R^2 = 0.720).

$$y = -0.0021x^2 + 0.2503x - 2.5336 \quad (3)$$

$$y = 0.0246x^2 + 0.0161x - 0.96 \quad (4)$$

$$y = 0.0326x^2 - 0.2508x + 0.0717 \quad (5)$$

$$y = 0.0169x^2 + 0.2967x - 1.8345 \quad (6)$$

where: y = Aw; x = Al in the relation (3), Abd in the relation (4), MAD in the relation (5), and Atd in the relation (6).

The distribution of predicted values in relation with real values is shown in Figures 4-7.

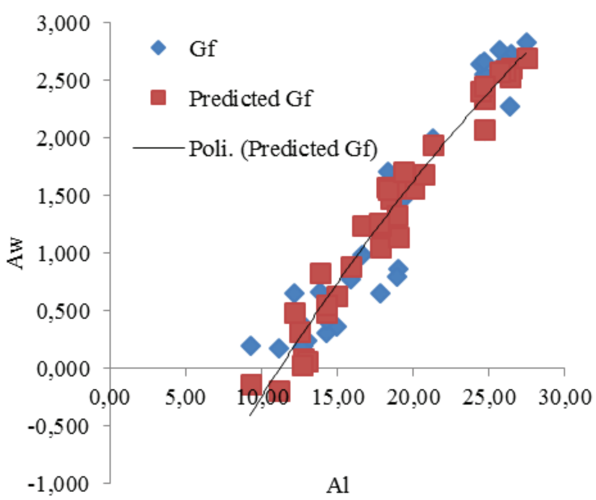

Figure 4. Graphic distribution of fruit weight depending on achene length in *Q. petraea*

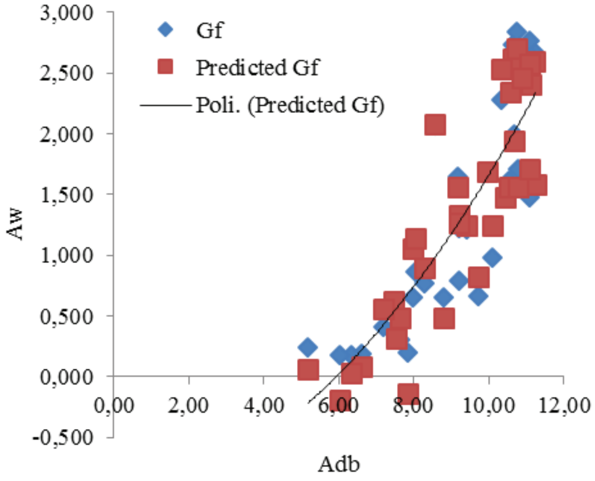

Figure 5. Graphic distribution of fruit weight depending on basal diameter in *Q. petraea*

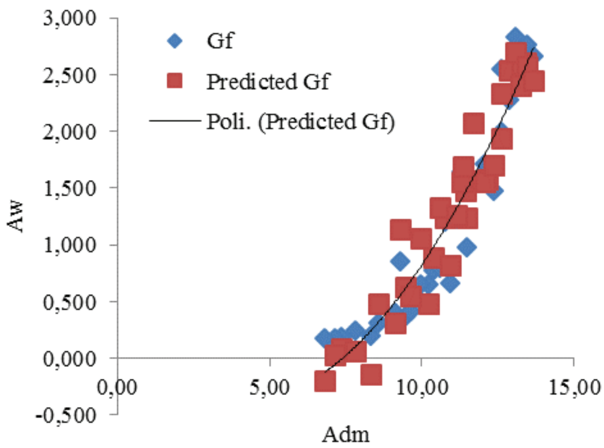

Figure 6. Graphic distribution of fruit weight depending on mean diameter in *Q. petraea*

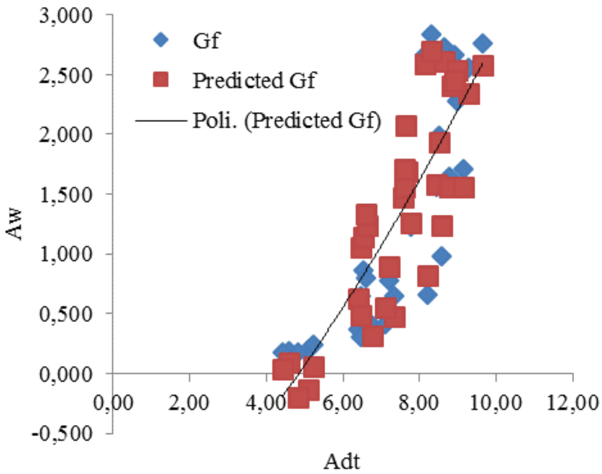

Figure 7. Graphic distribution of fruit weight depending on tip diameter in *Q. petraea*

In *Q. robur*, achene weight is described by polynomial equations of second degree, relation (7) for - Al (R^2 = 0.376), relation (8) for Abd (R^2 = 0.613), relation (9) for MAD (R^2 = 0.928), and by a linear equation, relation (10), for Atd (R^2 = 0.817).

$$y = -0.0053x^2 + 0.3571x - 3.0877 \quad (7)$$

$$y = -0.0198x^2 + 0.9792x - 5.4019 \quad (8)$$

$$y = -0.0197x^2 + 1.0617x - 7.5722 \quad (9)$$

$$y = 0.7383x - 2.9292 \quad (10)$$

where: y = Aw, x = Al for (7), Abd for (8), MAD for (9), and Atd for (10).
The distribution of predicted values in relation with real values is shown in Figures 8-11.

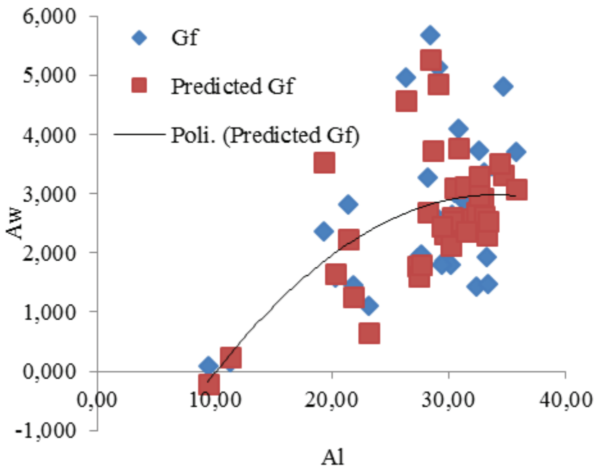

Figure 8. Graphic distribution of fruit weight depending on achene length in *Q. robur*

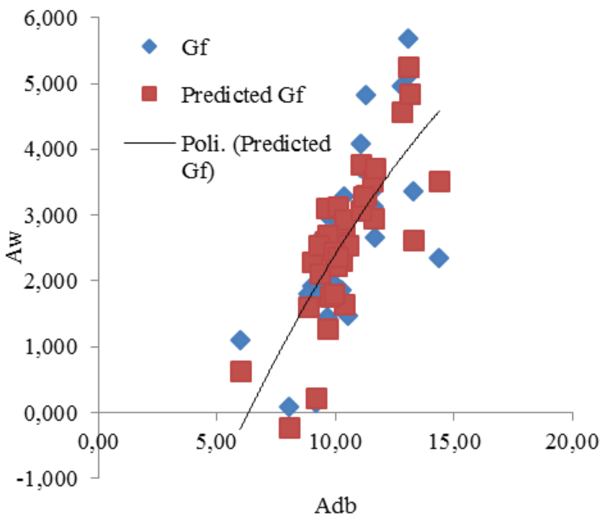

Figure 9. Graphic distribution of fruit weight depending on basal diameter in *Q. robur*

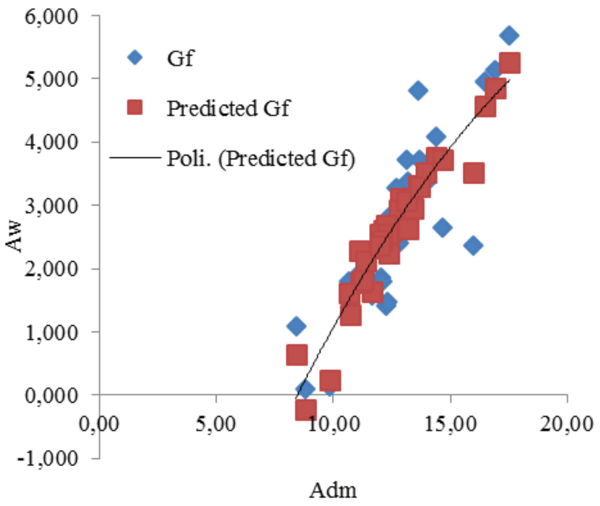

Figure 10. Graphic distribution of fruit weight depending on mean diameter in *Q. robur*

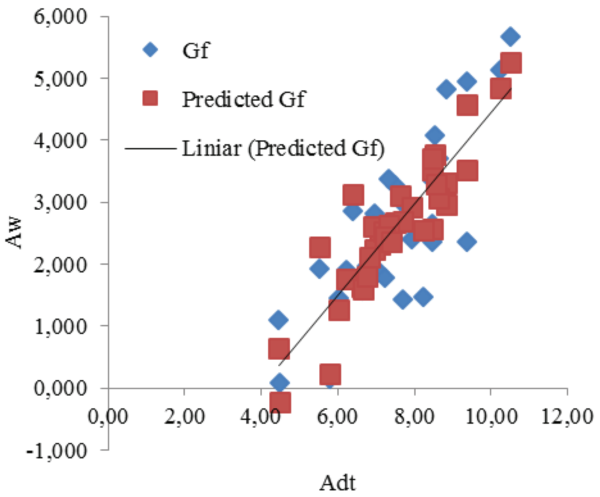

Figure 11. Graphic distribution of fruit weight depending on tip diameter in *Q. robur*

By comparing the results obtained for the two species, a higher correlation level in fruit weight prediction depending on size parameters was observed in the case of sessile oak that for pedunculate oak. Trial data PCA for achene weight depending on size parameters is shown in Figure 12 for *Q. petraea* and in Figure 13 for *Q. robur*, respectively. In *Q. petraea*, the value groups Qp1, Qp2 and Qp3 do not associate with size parameters, which means that, for that size interval, fruit weight increase is influenced by the least variation of any parameter. For the fruits in group Qp4, was observed the determinant influence of the diameter of achene for increasing of their weight, while for the fruits in the groups Qp6 and Qp7, fruit length was determinant for fruit weight increase. In *Q. robur*, there is separate positioning of the value group Qr1, in which size increase of any achene biometric parameter determines a change in fruit weight.

Size groups Qr2-Qr6 were more associated with fruit length, while group Qr7 was more associated with fruit diameter – the group with highest fruit weight mean, despite the fact that depending on achene length it has another position in the series. It is possible that depending on growth conditions and specific leaf area (Sala et al., 2015), the genetic and metabolic specificity of the trees influenced fruits development in a differentiated way (Sala, 2011).

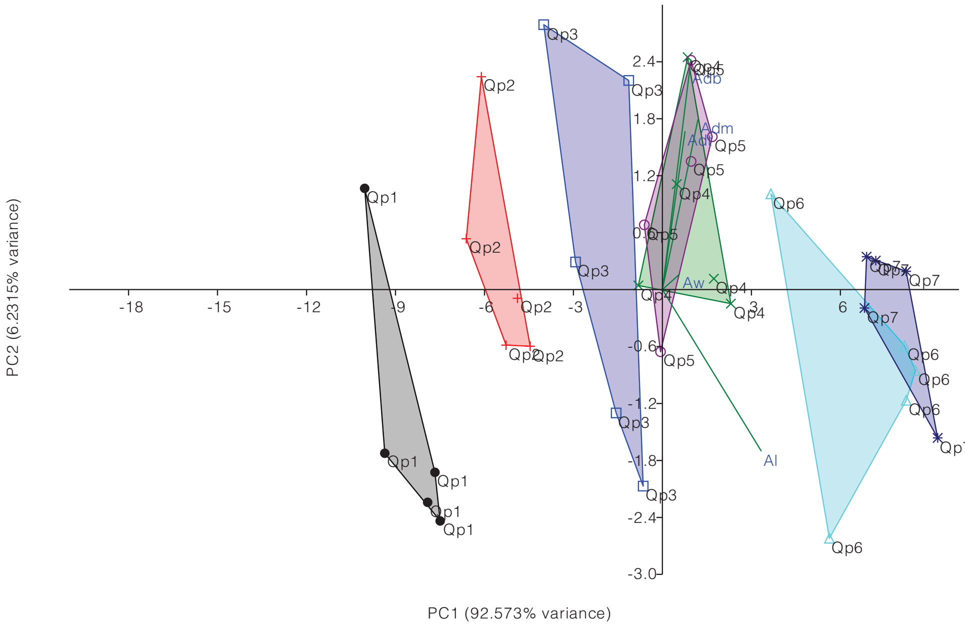

Figure 12. Space distribution of value groups for oak achenes in *Q. petraea* depending on achene biometric parameters

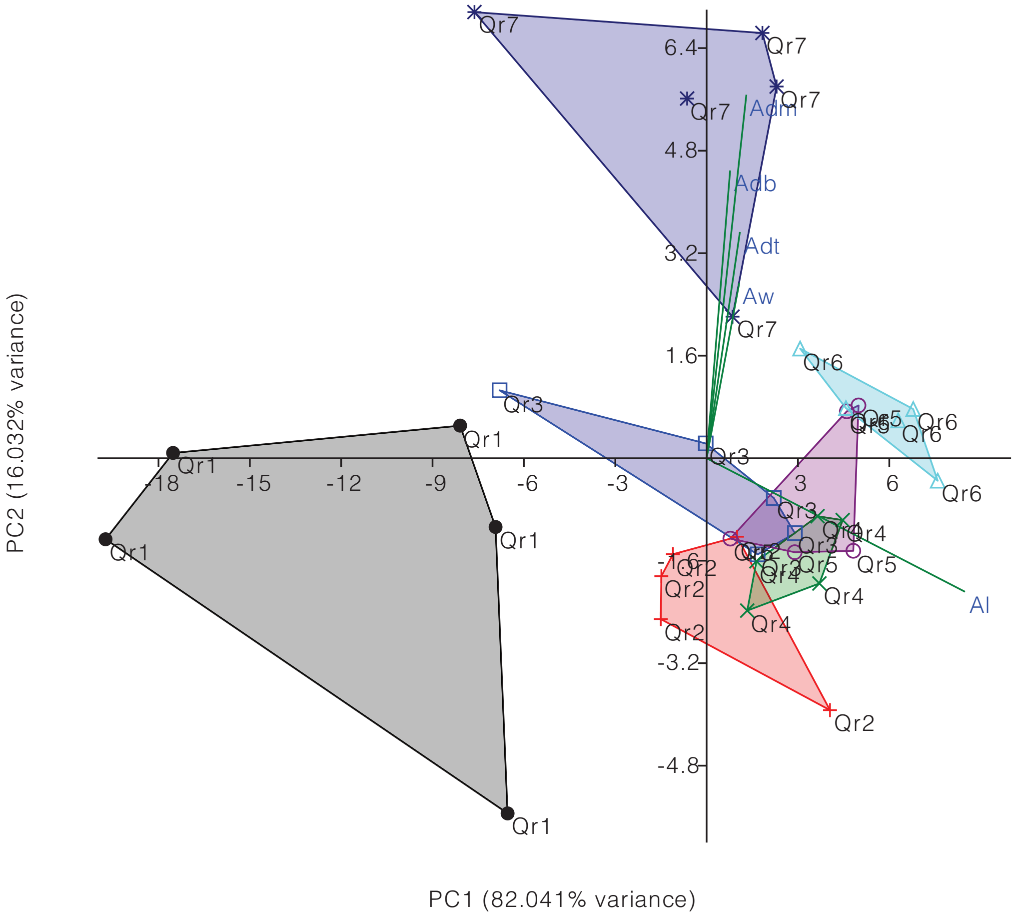

Figure 13. Space distribution of value groups for oak achenes in *Q. robur* depending on achene biometric parameters

CONCLUSIONS

Regression analysis facilitated achene weight prediction models based on fruit biometric parameters in the two oak species - *Quercus petraea* (sessile oak) and *Quercus robur* (pedunculate oak). We obtained linear and polynomial second-degree equations in statistic safety conditions.

PCA pointed out the association of fruit size groups with biometric parameters and explained the very high variance based on PC1 and PC2. It also explains per fruit size groups the biometric parameter contributing the most to achene weight gain.

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