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EVALUATION OF WALNUT CULTIVARS IN THE CONDITIONS OF THE OLTENIA'S HILL AREA REGARDING FUNCTIONING POTENTIAL

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KEY WORDS*: walnut, bearing, yield, cultivars, fruit trees*

ABSTRACT

Modern growing of walnut in Romania is both a requirement and an objective necessity due to the high value of the fruits, the possibilities for commercialization and the historic tradition of cultivation. The main issue in modernizing walnut cultivation is providing a valuable assortment of cultivars, highly competitive on the international markets. In the sub-Carpathian area of Oltenia, which is one of the most favorable for walnut cultivation, the yielding potential was evaluated for 29 cultivars. The geographic origin of the cultivars is diverse (12 Romanian cultivars, 10 from the USA, 5 from France, one from Germany and one from Bulgaria). There are differences between cultivars regarding the fructification type (19 are terminal bearers and 10 are with lateral bearing) and the flowering dichogamy type (10 are protogynous and 19 are protandrous). The average fruit yield for all the cultivars during a period of 11-15 years from planting was 1.66 tons per hectare. The most productive cultivars were: Ferjean (2.4 t/ha), Vina (2.26 t/ha), Hartley (2.24 t/ha), Fernor (1.94 t/ha) and Lara (1.88 t/ha), all belonging to the lateral bearing cultivars group. Out of the cultivars with terminal bearing, the most productive were Valcor (1.86 t/ha), Jupanesti (1.82 t/ha), Velnita (1.74 t/ha) and Franquette (1.70 t/ha). Higher fruit yields for the cultivars with lateral bearing are due both to the genotypes and the favorable climatic conditions in the 2005-2009 period (minimum temperatures up to -20°C and no frosts at flowering time). In the conditions of the sub-Carpathian area of Oltenia walnut production is determined by the genotype (54.1%), the environment (8.9%), the interaction GxE (23.2%) and unknown factors (13.8%).

INTRODUCTION

The walnut has been cultivated in Romania since long time. The inhabitants of Dacia (nowadays Romania) knew about this crop and used the fruits of the walnut as a source of food.

The Latin poet Ovidius, exiled 200 years ago in Tomis (actual Constanta), wrote about the walnut that "it is not pretentious, it grows on the side of the road and does not fear nor the wind, nor the rain, nor the heat or the cold" (Bordeaianu, 1963 cited by Cociu et al., 2008).

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Starting with the XIVth century, the walnut appears in numerous historical documents but also in the names of several settlements (Nucet, Nucul, Valea Nucarilor, etc.) (Cociu et al, 2008).

Walnut cultivation has become during time very important in Romania for the fruit-growing area because of the multiple advantages that walnut products offer (fruits, wood, leafs etc.). With its 2,000 hectares of walnut orchards and over 5 million walnut trees on own roots, Romania has achieved in the last decade a production of 32 to 34 thousand tons of walnuts. This places it amongst the first 7 countries in the world regarding walnut production.

The favorable ecological conditions for walnut cultivation, especially in the Oltenia region, the historic tradition and the nutritional and economic interests create new perspectives for walnut cultivation in the following years (Botu et al., 2010).

The general tendency is to grow the surfaces cultivated with walnut and to modernize the growing techniques in order to get higher yields, better quality and competitivity in the worldwide trade. At present the world production of walnuts of 1,724,172 tons in 2008 (FAO Stat Database, 2010) is not sufficient to cover the demand.

For our country the main issue in the modernization of walnut growing is still the availability of a valuable assortment of cultivars. To this end, the aim is to evaluate in this paper a wide variety of walnut cultivars, with different geographic origin, regarding their yielding potential.

MATERIALS AND METHODS

The research has been conducted between 2004 and 2009 in a trial located at SCDP Valcea which belongs to the University of Craiova. The walnut trees in the trial have 11 and 15 years-old.

The biologic material is composed of 29 walnut cultivars (12 from Romania, 10 from the USA, 5 from France and 1 each from Germany and Bulgaria).

The cultivars are grafted on *Juglans regia* seedlings. Each cultivar is represented by 5-10 trees. Planting distance is 9.0 x 8.0 m (139 trees per hectare).

Trees were trained as mixed pyramid. The soil between trees was sowed with grass. Fertilization has been done annually with NPK (100 kg of N, 20 kg of P and 20 kg of K per hectare). 6 to 7 phytosanitary treatments have been applied per year.

The research methods have been in relationship with the purpose of the work and included complex observations and determinations regarding trees' habit, growth and fruit-yielding phases etc.

Special interest was allocated for:

- establishing fruit yield of the cultivars;
- determining the type of fruit ripening;
- determining the influence of the genotype, environment and the interaction between genotype x environment on the fruit yield (using Two Way ANOVA with repetitions, according to Sohal and Rohlf, 1995).

The data collected has been analyzed biostatistically using:

- mean;
- standard deviation;
- amplitude and the variation coefficients;
- analysis of variance.

During the study period (2005-2009) the average annual temperature was 11.3°C (1.1 °C more than the multi-annual average) and the absolute minimum temperature was -

22.7 °C (2006). The absolute minimum temperatures and the lack of spring frosts have not caused damages to the catkins and female walnut flowers. The annual average of rainfall was 771.5 mm (59.5 mm more than the multi-annual average).

RESULTS

The walnut cultivars of different genetic and geographic origin studied in the North of Oltenia emphasized different behavior regarding growth and fruit ripening (Table 1).

In the 15th leaf a number of 25 cultivars showed high growth vigor, 2 cultivars emphasized very high vigor ('Argesan' and 'Geoagiu 65') and 2 cultivars show medium growth vigor ('Germisara' and 'Orastie').

The dichogamy of the Romanian walnut cultivars is of protogynous type (for 9 cultivars) and protandrous type (3 cultivars).

The foreign cultivars are mostly protandrous-type with the exception of 'Idaho' cultivar which is protogynous.

Flowering of the walnut cultivars takes place between 4th of April and 21st of May in the 5 year study period. During this period no late frosts were recorded. Between the lateral bearing cultivars and the terminal bearing ones there are no more than 4 to 10 days of flowering timing differences.

The walnut cultivars analyzed have two types of fruit bearing:

- terminal (19 cultivars out of which 12 are Romanian). The Romanian cultivar 'Germisara' has intermediary fructification but mostly of terminal type;
- lateral (10 cultivars - 6 are from U.S.A. and 4 are French cultivars).

'Hartley' is considered to have intermediary bearing but most of its yield comes from lateral fructification buds.

Fruit yields of the walnut cultivars in the 11th to the 15th leaf is different (Table 2). At this age, the average yield for all the cultivars is 1.66 tons per hectare.

From the 11th leaf till the 15th one the walnut yields is increasing for all the cultivars and is correlated with the growth of the trees. At this age the walnuts are covering the orchard area from 30.6% to 58.1% (in the case of 'Muscelean') of the total area. The yield increases as well when the foliage grows.

The highest yields have been recorded for the following cultivars: 'Ferjean' (2.4 tons per hectare), 'Vina' (2.26 t/ha), 'Hartley' (2.24 t/ha), 'Fernor' (1.94 t/ha), 'Lara' (1.88 t/ha) and 'Valcor' (1.86 t/ha), significantly comparable with control cultivar which was 'Franquette' (1.7 t/ha). Statistically distinctly significant yield was recorded in the case of 'Fernette' (1.84 t/ha) and significant for: 'Jupanesti', 'Payne' and 'Pedro' (1.82 t/ha).

Significantly negative yields have been recorded for: 'Uzlop 10' (1.18 t/ha), 'Howe' (1.06 t/ha), 'Adams 10' (1.24 t/ha), 'Muscelean'(1.48 t/ha), etc.

The cultivars with lateral bearing have had higher yields than the cultivar used as control ('Franquette').

Out of the cultivars with terminal bearing high yield potential has been recorded for 'Valcor', 'Jupanesti' and 'Velnita'. In the year 2009 it has been noticed that the cultivars with lateral bearing habits have much higher yields than in previous years (2.73 t/ha in 2009; 2.32 t/ha in 2008 and 1.87 t/ha in 2007). The same effect was noticed for the cultivars with terminal bearing but the differences are much lower (1.98 t/ha in 2009; 1.61 t/ha in 2008 and 1.22 t/ha in 2007).

The cultivars with lateral bearing were exposed during the 5 years of fructification to minimum temperatures of up to -22.7 °C and during flowering time they have not been affected by temperatures lower than -1°C.

These cultivars are extremely sensitive to bacterial blight (*Xanthomonas campestris* pv. *juglandis*) and to low temperatures during flowering time. These are the reasons for which they should be grown in the future in the Oltenia region with extreme care.

It was observed also that for the walnut cultivars the variability of the yield is specific (Table 3).

For several cultivars the confidence interval (CI) and the coefficient of variation (CV) are high showing high variability ('Valcor', 'Muscelean', 'Geisenheim 139', 'Howe', 'Ferjean', 'Hartley', etc.). This phenomenon is mostly due to the fact that the cultivars have higher yield each year. Few cultivars have medium variability ('Sarmis', 'Valrex', 'Jupanesti', 'Orastie' and 'Franquette').

The walnut yields in the region of Oltenia hills depends on multiple factors (Table 4). Calculating the estimated variance (s^2) this shows the influence of the genotype (cultivar), environment (years) and the interaction GxE and the error. The F test indicates estimated value of the variance of these factors which are greatly higher than the variance of the error.

For determining the expected variance σ^2 we have used the formulas adopted by Sokal and Rohlf (1995) as follows:

σ^2 error = s^2 error = 0.25

$\sigma^2_{GxE} = n\, s^2\, G \times E + \sigma^2 Є = \frac{S^2_{GxE} - \rho^2}{n} = 0.42$

$\sigma^2 E \text{ (years)} = g s^2 E + \sigma^2 Є + \sigma^2_{GxE} = \frac{S^2_E - \rho^2 - \rho^2_{GxE}}{g} = 0.16$

$\sigma^2 G \text{ (cultivar)} = E s^2 + \sigma^2 Є + \sigma^2 E = \frac{S^2_G - \rho^2 - \rho^2_E}{m} = 0.98$

Where:

- n = pairs of years (2)
- g = genotype or cultivars (29)
- m = years or environment (5)

From summing up the expected variances [$\sigma^2 T = 1.81$ and $\sigma^2 T = V_T$ (phenotype)]

$VT = VG + VE + V_{GxE} + V_Є = \sigma^2 G + \sigma^2 E + \sigma^2_{GxE} + \sigma^2_Є$.

In table 2 we calculated the quantitative and percentage yield at the level of the average yield for all the 29 cultivars in the 5 years of the study.

From these determination results the fact that the genotype of the walnut cultivated in Northern Oltenia is responsible for 54.1% of the total fruit yield while the environment influences by 8.9%, the interaction G x E by 23.2% and the rest of 13.8% is due to other factors or unknown errors.

By generalizing, each cultivar of walnut shows a production which is determined by the genotype, the environment and the interaction GxE.

The quantitative value of the yield determined by the genotype varies between 0.573 tons per hectare ('Howe') and 1.298 t/ha ('Ferjean') and the one determined by the environment varies between 0.094 t/ha ('Howe') and 0.214 t/ha ('Ferjean').

The interaction GxE with a value of 23.2% determines a quantitative value of 0.246 to 0.577 tons per hectare and represents the measure to which a cultivar responds positively to the ecological conditions of an area. In this case however, the high year-to-year yield also plays a role.

In the case of the analysis of these factors other influences were also recorded. These are known as errors and in this case they vary between 0.163 t/ha ('Geisenheim 139' and 'Uzlop 10') and 0.331 t/ha ('Ferjean'). The genotype is the main factor, followed by GxE.

The fruit yield for walnuts is dependent on quality as the cultivars are affected by pests and diseases.

CONCLUSIONS

- Walnut cultivars with different genetic and geographic origin show in the sub-Carpathian area of Oltenia a differentiated behavior in the bearing process.
- The studied cultivars were grouped as follows:
    a) by origin: 12 are Romanian cultivars and 17 are foreign cultivars;
    b) by type of fructification: 19 are terminal bearers and 10 have lateral bearing;
    c) by type of dichogamy: 10 are of protogynous type and 19 are protandrous.
- The average walnut yield for the 29 cultivars at ages between 11 and 15 years after planting was 1.66 tons per hectare.
- The most productive cultivars were: 'Ferjean' (2.4 tons per hectare), 'Vina' (2.26 t/ha), 'Hartley' (2.24 t/ha), 'Fernor' (1.94 t/ha), 'Lara' (1.88 t/ha) and 'Valcor' (1.86 t/ha).
- Fruit yields of cultivars with lateral bearing in climatic conditions lacking lo temperatures which could affect the trees has been superior to the average yield of terminal bearing cultivars (average of 1.97 t/ha compared with 1.49 t/ha).
- The yield has shown high or very high variance (s%= 20-43.4%) for the majority of the cultivars in the 5 years of the study; this was influenced both by the cultivar and also by the increasing yields each year.
- In the conditions of Northern Oltenia the walnut yield is determined by the genotype (54.1%), environment (8.9%), interaction Genotype x Environment (23.2%) and unknown factors (13.8%).

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FAO Stat Database Web Page, 2010 (www.fao.org)

Table 1

Vigor, type of flowering and bearing of several walnut cultivars in Northern Oltenia

No.	Cultivar	Origin	Plant vigor	Type of dichogamy	Type of bearing
1	'Sarmis'	Romania	high	protogynous	terminal
2	'Sibişel 44'	Romania	high	protogynous	terminal
3	'Valcor'	Romania	high	protogynous	terminal
4	'Valmit'	Romania	high	protogynous	terminal
5	'Valrex'	Romania	high	protogynous	terminal
6	'Jupâneşti'	Romania	high	protogynous	terminal
7	'Argeşean'	Romania	very high	protogynous	terminal
8	'Geoagiu 65'	Romania	very high	protogynous	terminal
9	'Germisara'	Romania	medium	protogynous	intermediate
10	'Muscelean'	Romania	high	protandrous	terminal
11	'Orăştie'	Romania	medium	protogynous	terminal
12	'Velnița'	Romania	medium	protogynous	terminal
13	'Adams 10'	USA	high	protandrous	terminal
14	'Chase D9'	USA	high	protandrous	terminal
15	'Geisenheim 139'	Germany	high	protandrous	terminal
16	'Franquette' (control)	France	high	protandrous	terminal
17	'Howe'	USA	high	protandrous	terminal
18	'Idaho'	USA	high	protogynous	terminal
19	'Uzlop 10'	Bulgaria	high	protandrous	terminal
20	'Ferjean'	France	high	protandrous	lateral
21	'Fernette'	France	high	protandrous	lateral
22	'Fernor'	France	high	protandrous	lateral
23	'Hartley'	USA	high	protandrous	intermediate
24	'Lara'	France	high	protandrous	lateral
25	'Payne'	USA	high	protandrous	lateral
26	'Serr'	USA	high	protandrous	lateral
27	'Tehama'	USA	high	protandrous	lateral
28	'Pedro'	USA	high	protandrous	lateral
29	'Vina'	USA	high	protandrous	lateral

Table 2

Walnut yields of cultivars aged between 11 and 15 years-old

No.	Cultivar	Fruit yield (t/ha)					Average yield (t/ha)	Diff. ±	Significance
		2005	2006	2007	2008	2009			
1	’Sarmis’	1.4	1.6	1.6	1.6	2.0	1.64	-0.060	ns
2	’Sibişel 44’	1.2	1.3	1.5	1.5	2.0	1.50	-0.200	ooo
3	’Valcor’	1.4	1.8	2.1	1.7	2.3	1.86	+0.160	***
4	’Valmit’	1.2	1.3	1.7	1.7	2.2	1.62	-0.080	ns
5	’Valrex’	1.3	1.3	1.5	1.6	2.1	1.56	-0.140	oo
6	’Jupâneşti’	1.4	1.6	1.8	2.1	2.2	1.82	+0.120	*
7	’Argeşean’	1.2	1.3	1.5	1.6	2.0	1.52	-0.180	ooo
8	’Geoagiu 65’	0.8	1.2	1.4	1.4	1.9	1.34	-0.360	ooo
9	’Germisara’	1.0	1.4	1.8	1.7	2.1	1.60	-0.100	o
10	’Muscelean’	1.0	1.3	1.4	1.5	2.2	1.48	-0.220	ooo
11	’Orăştie’	1.2	1.6	1.7	2.1	1.7	1.66	-0.040	ns
12	’Velniţa’	1.4	1.6	1.9	1.7	2.1	1.74	+0.040	ns
13	’Adams 10’	0.7	1.0	1.3	1.5	1.7	1.24	-0.460	ooo
14	’Chase D9’	1.0	1.4	1.5	1.6	1.9	1.48	-0.220	ooo
15	’Geisenheim 139’	0.5	1.2	1.0	1.3	1.9	1.18	-0.520	ooo
16	’Franquette’ (control)	1.2	1.6	1.8	1.9	2.0	1.70	-	-
17	’Howe’	0.5	0.8	1.0	1.3	1.7	1.06	-0.640	ooo
18	’Idaho’	0.8	1.1	1.3	1.5	1.9	1.32	-0.380	ooo
19	’Uzlop 10’	0.6	0.9	1.2	1.4	1.8	1.18	-0.520	ooo
20	’Ferjean’	1.4	1.8	2.3	3.4	3.1	2.40	+0.700	***
21	’Fernette’	1.2	1.7	1.8	2.0	2.5	1.84	+0.140	**
22	’Fernor’	1.3	1.6	1.8	2.3	2.7	1.94	+0.240	***
23	’Hartley’	1.4	1.7	2.1	2.7	3.3	2.24	+0.540	***
24	’Lara’	1.3	1.7	2.0	2.8	1.6	1.88	+0.180	***
25	’Payne’	1.2	1.5	1.7	2.0	2.7	1.82	+0.120	*
26	’Serr’	1.3	1.5	1.7	1.7	2.6	1.76	+0.060	ns
27	’Tehama’	1.2	1.4	1.6	1.8	2.7	1.74	+0.040	ns
28	’Pedro’	1.2	1.8	1.7	1.8	2.6	1.82	+0.120	*
29	’Vina’	1.4	1.7	2.0	2.7	3.5	2.26	+0.560	***
	Mean	*1.13*	*1.44*	*1.64*	*1.86*	*2.24*	*1.66*	-	-

LSD 5.0% = 0.098 LSD 1.0 % = 0.132 LSD 0.1 % = 0.155

Table 3

Variance of walnut yield for some cultivars aged 11 to 15 years-old

No.	Cultivar	Average yield (2005-2009) (t/ha)	Standard deviation (s)	Confidence interval (CI) (t/ha)	Coefficient of variation (CV) (s%)
1	’Sarmis’	1.64	0.22	1.42 – 1.86	13.4
2	’Sibişel 44’	1.50	0.30	1.20 – 1.80	20.0
3	’Valcor’	1.86	0.70	1.16 – 2.56	37.6
4	’Valmit’	1.62	0.40	1.22 – 2.02	24.7
5	’Valrex’	1.56	0.32	1.24 – 1.88	20.5
6	’Jupâneşti’	1.82	0.33	1.49 – 2.15	18.1
7	’Argeşean’	1.52	0.31	1.21 – 1.83	20.4
8	’Geoagiu 65’	1.34	0.39	0.95 – 1.73	29.1
9	’Germisara’	1.60	0.41	1.19 – 2.01	25.6
10	’Muscelean’	1.48	0.52	0.96 – 2.00	35.1
11	’Orăştie’	1.66	0.32	1.34 – 1.98	19.3
12	’Velnița’	1.74	0.27	1.47 – 2.01	15.5
13	’Adams 10’	1.24	0.39	0.85 – 1.63	31.4
14	’Chase D9’	1.48	0.33	1.15 – 1.81	22.3
15	’Geisenheim 139’	1.18	0.51	0.67 – 1.69	42.9
16	’Franquette’ (control)	1.70	0.32	1.38 – 2.02	18.2
17	’Howe’	1.06	0.46	0.60 – 1.52	43.4
18	’Idaho’	1.32	0.41	0.91 – 1.73	31.1
19	’Uzlop 10’	1.18	0.46	0.72 – 1.64	39.0
20	’Ferjean’	2.40	0.84	1.56 – 3.24	35.0
21	’Fernette’	1.84	0.47	1.37 – 2.31	25.5
22	’Fernor’	1.94	0.56	1.38 – 2.50	28.8
23	’Hartley’	2.24	0.83	1.41 – 3.07	37.0
24	’Lara’	1.88	0.57	1.31 – 2.45	30.3
25	’Payne’	1.82	0.57	1.25 – 2.39	31.3
26	’Serr’	1.76	0.49	1.27 – 2.25	27.8
27	’Tehama’	1.74	0.58	1.16 – 2.32	33.3
28	’Pedro’	1.82	0.50	1.32 – 2.32	27.5
29	’Vina’	2.26	0.84	1.42 – 3.10	37.2
	Mean	*1.66*	*0.42*	*1.24 – 2.08*	*25.3*

Table 4

Determination of the influence of the genotype and the environment on average yield with the help of variance analysis for the walnut cultivars

Source of variation	SS	Degree of freedom (Df)	Variance			Calculated average annual yield according to expected variance (σ^2)	
			Estimated s^2	F Test	Expected σ^2	Yield (t/ha)	Yield (%)
Genotype (cultivar)	177.42	28	6.33	25.32***	0.98	0.898	54.10
Environment (years)	21.44	4	5.36	21.44***	0.16	0.148	8.9
Genotype x Environment	170.59	112	1.52	6.08***	0.42	0.385	23.2
Error	72.01	144	0.25	-	0.25	0.229	13.8
TOTAL	441.46	288	-	-	1.81	1.660	100

F_G % (28/144) = 1.83
F_E 1% (4/144) = 3.44
F_{GxE}14% (112/144) = 1.51