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Morphometric Characteristics of Fruit Bearing Shoots in Persian Walnut (*Juglans regia* L.) – Potential Selection Criteria for Breeding

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Summary

Morphometric characteristics of fruit bearing branches of 100 walnut trees originating from seeds, were examined. The study was based on tree architecture analysis of fruit bearing wood in four (I–IV) morphological types with different branching and fruiting pattern. Among 14 quantitative characteristics of three-year-old bearer together with the corresponding two-year-old and annual shoots, phenotypic correlations were determined to investigate the relationships among the traits. It is considered for all morphotypes that longer annual shoots are thicker and have more nodes and more vegetative buds. In the morphotypes II, III and IV, the number of fruit bearing two-year-old shoots is correlated with the total number of two-year-old shoots. Longer two-year-old shoots are thicker and have more nodes. In morphotypes I and IV, longer three-year-old bearers usually develop more two-year-old shoots which are shorter and thinner, and have a lower number of nodes. It holds for the morphotype I that more female flowers per inflorescence on annual shoot could be expected when they grow on shorter and thinner two-year-old bearing shoots. Phenotypic correlations that have been determined in the first step of our long term investigation are expected to be useful in walnut breeding for improving two or more traits simultaneously. The work is being continued with a detailed evaluation of yield components (quantity and quality) and testing stability of four morphotypes. In the next two to three years, the most influential morphometric traits of fruit bearing branches could be recommended as a new selection criteria in walnut breeding.

Zusammenfassung

Morphometrische Charakteristiken der fruchttragenden Triebe bei der persischen Walnuss (*Juglans regia* L.) – potenzielle Selektionskriterien für die Züchtung. Bei insgesamt einhundert Walnusssämlingen wurden morphometrische Charakteristiken der fruchttragenden Triebe untersucht. Die Analyse der Baumarchitektur wurde in die Untersuchung miteinbezogen, wobei das fruchttragende Holz in vier morphologische Typen (I–IV) mit unterschiedlichen Verzweigungsmustern und Fruchtbildungen gegliedert wurde. Um die Verbindungen zwischen einzelnen Eigenschaften der dreijährigen Triebe zusammen mit den auf diesen Trieben wachsenden ein- und zweijährigen Trieben auswerten zu können, wurden in die Untersuchung auch phänotypische Korrelationen einbezogen. Es hat sich erwiesen, dass bei allen Morphotypen längere einjährige Triebe dünner waren, und dass sie mehr Nodien und vegetative Knospen entwickelten. In den Morphotypen II, III und IV korrelierte die Früchtezahl auf den zweijährigen Trieben mit der Gesamtzahl der zweijährigen Triebe. Längere zweijährige Triebe waren dünner und entwickelten höhere Nodienzahl. In den Morphotypen I und IV entwickelten längere dreijährige Träger meistens mehrere dünnere und kürzere zweijährige Triebe mit geringerer Nodienzahl. Beim Morphotyp I würden einjährige Triebe mehr weibliche Blüten entwickeln, wenn sie auf kürzeren und dünneren zweijährigen Trägern wüchsen. Phänotypische Korrelationen, die während des ersten Schrittes unserer Langzeituntersuchungen ermittelt wurden, können die Walnusszüchtung positiv beeinflussen. Die Untersuchungen werden mit ausführlichen Auswertungen des Ertrages (quantitativ und qualitativ) fortgesetzt. In den nächsten zwei bis drei Jahren werden die einflussreichen morphometrischen Eigenschaften der fruchttragenden Triebe als neues Selektionskriterium bei der Walnusszüchtung eingesetzt.

Key words. Architectural analysis – common walnut – correlations – morphometric traits

Introduction

In walnut breeding, the fruit bearing type is one of the most important traits. Due to the need of cost efficient production, the most suitable is the lateral fruiting habit, which can assure a high yield (SZENTIVANYI 1990; MCGRANAHAN and LESLIE 1991; GERMAIN 1992). In the areas with frequent late spring frost, such as France, Hungary, Austria, Croatia, Slovenia, the most important selection criterions were late bud breaking and late flowering (GERMAIN 1979, 1992; GERMAIN et al. 1985, SZENTIVANYI 1990; SOLAR et al. 2002). Among desired characteristics are also tolerance to bacterial blight (*Xanthomonas campestris* pv. *juglandis* (Pierce) Dowson) and anthracnosis (*Gnomonia leptostyla* (Fr.) Ces. & de N.), as well as the homogamy and protoginy, apomixis, short dormancy in the areas with mild winters and the resistance to winter frost in the areas with hard winters (GERMAIN 1997a).

According to LAURENS et al. (1998), the breeding programs of woody fruit trees frequently neglect the traits which describe the tree architecture. In most cases these traits are included into the selection processes as secondary parameters. However, they have a great influence on the cultivar characteristics, such as fruitfulness, yield stability, the beginning of fruiting, the time of flowering and ripening of fruits, and the geographic adaptation. The studies of the tree architecture, morphology, physiology of trees, and especially the characteristics of the fruit bearing branches, together with adapted quantitative analysis, statistics and mathematical modeling, can be used as a key in defining new parameters which would suit practical needs better and would shorten the selection processes and reduce the costs.

To improve the knowledge of tree architecture in Persian walnut we conducted the basic architectuaral characterisation (vigour, natural shape of a tree, fruit bearing type, branching) in 840 spontaneously growing walnut trees originating from seeds (SOLAR et al. 2001, 2002). Such characterization is often included in the selection schemes of many breeding programs (FERHATOGLU 1993; KORAC et al. 1993; ALETA and NINOT 1993, 1997; GODEANU and BOTU 1997; ROUSKAS et al. 1997; KUDEN et al. 1997; GERMAIN et al. 1997; LANSARI et al. 2001; ROUSKAS and ZAKYNTHINOS 2001; OZKAN and CELEP 2001; BOTU et al. 2001), but it offers only a vague information on the tree architecture. For this reason, it would be useful to introduce into the selection process new parameters. They should describe the fruit bearing wood, which influences strongly the quality and quantity of the yield.

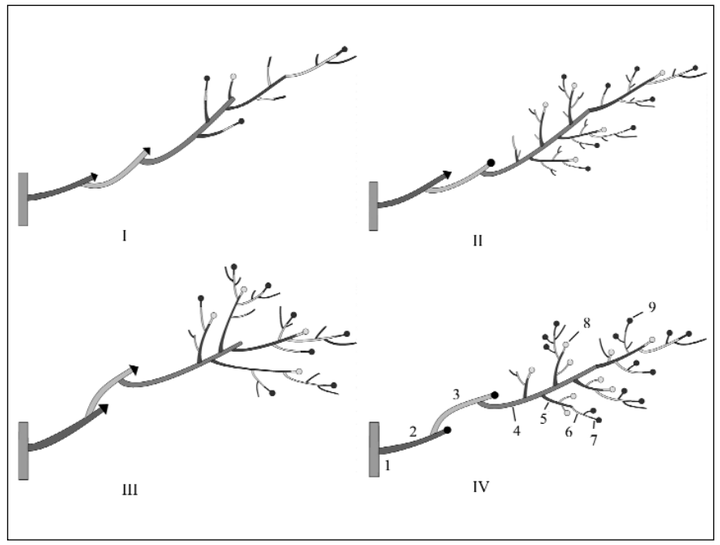


Fig. 1. Architectonic models of morphotypes I, II, III and IV. 1 = trunk (1st order axis), 2 = primary branch (2nd order axis), 3 = secondary branch (3rd order axis), 4 = 3-years-old branch (3YB), 5 = 2-years-old shoot (2YS), 6 = annual shoot (1YS), 7 = current-year shoot, 8 (○) = fruit in the previous year, 9 (●) = fruit in the current year.

Our investigation represents a continuation of the previous work done by GERMAIN (1979) and SZENTIVANYI (1990). More than 20 years ago, they combined terminal fruit bearing French and Hungarian walnuts with lateral fruiting Californian varieties. Their work was largely based on practical experience and aimed at selecting the parents that would produce offspring populations with a high frequency of late sprouting and high yielding genotypes. Our approach is based on exact measurements of the fruit bearing wood parameters. The main objectives of our long term investigation are twofold: (1) to analyse relationships among the most important traits of fruit bearing wood, and (2) to find out which of the fruit bearing wood traits can be easily determined and can be efficiently used as selection criteria at an early stage of development to make the breeding process shorter and more cost effective. In the present paper the results of the first step of the investigation will be presented.

Material and Methods

The analysis was based on a sample of 100 genotypes belonging to the local population grown in the south eastern part of Slovenia, along the Sotla river valley. The population consisted of 840 individuals developed from seeds which were taken from good looking trees with sufficiently large fruits, originating from unknown indigenous genotypes from the nearby villages. Each plant represented an unique genotype, grown together with the others in one environment. The trees were planted in 1988–1992. They were grown without grafting, pruning, mineral fertilization, irrigation, disease, weed and pest control.

The analysed trees belonged to four different morphotypes which were determined on the basis of a three-year observation of the tree habit, density of branching and fruit bearing type (SOLAR et al. 2001, 2003). Morphotype I represents terminal fruit bearing genotypes (i.e. 'Franquette'); morphotype II are inter-

mediate fruiting trees with mezotonic ramification; Morphotype III is characterised by intermediate fruit bearing genotypes with acrotonic ramification, and morphotype IV is distinguished by lateral fruiting (i.e. 'Chandler', 'Lara') (Fig. 1).

These four morphotypes were not the only ones; in the population, there were six others that were less frequent.

Measuring protocol

The study was based on a random sample of 25 trees of each morphotype. The fruit bearing branch was chosen as the basic structural unit consisting of a 3-year-old bearing branch, together with the corresponding 2-year-old shoots and annual shoots. In each genotype five fruit bearing branches symmetrically distributed in the middle of the crown were selected. This means that the analysis included 125 fruiting branches with the corresponding two-year-old and annual shoots.

During the period winter/spring 1998/1999 several measurements were performed.

On three-year-old branches (3YB) the length was measured.

For two-year-old shoots (2YS), on the three-year-old bearer, the total number of 2YS and the number of fruit bearing 2YS were determined. The length, the number of nodes, the branch angle and the basal diameter of 2YS also were measured.

For annual shoots (1YS), on the two-year-old bearer, their number was documented and their length, branch angle and basal diameter were measured. Apart from this, the number of nodes, the number of vegetative buds, the number of mixed buds and the number of female flowers per inflorescence on annual shoots also were counted.

All the parameters except for the number of buds and flowers were measured during winter dormancy. The length of shoots was measured in cm, from the base to the top. The angles of shoots were determined by using a special goniometer, where lower values (in degrees) represented more erect shoots. The diameter of shoots was measured close to their base in mm. The nodes were counted from the base of the shoots towards the tip – from the first to the last (still distinguishable) node.

The fruit bearing shoots were identified by the presence of mixed buds – on the terminal position, or on the lateral position. On the annual shoots, during flowering, the number of vegetative and mixed buds and the number of female flowers in the inflorescence were determined.

The data was analysed using the programme Statistica for Windows (Tulsa, USA 1994). The phenotypic correlation coefficients (Pearson's correlation coefficients) were calculated only for the traits with normal distribution. The calculations were based on mean values of several measurements (in most cases more than 15, depending on the trait and the age of shoots).

Results and Discussion

The highest correlation determined for terminal fruit bearing genotypes (morphotype I) was between total number of 2YS and their angles (r=0.80*), between the number of fruit bearing 2YS and their basal diameter (r=0.71*) and angles (r=0.74*); and between the number of 1YS and their angles (r=0.74*). Long 1YS are expected to be thicker (r=0.49*). Thick 1YS have more nodes (r=0.65*), and more vegetative buds (r=0.48*) (Table 1).

For intermediate fruiting genotypes with mezotonic ramification (morphotype II), the highest correlation coefficients were between the length of 2YS and the number of nodes on them (r=0.92*), between the length of 1YS and the number of nodes (r=0.72*) as well as the number of vegetative buds of 1YS (r=0.72*). The number of fruit bearing 2YS is higher when they have larger angles (r=0.54*). Longer 2YS usually develop more 1YS (r=0.52*). Thicker 1YS have more vegetative buds (r=0.68*). In the case of more 1YS, they grow at larger angles (r=0.49*) (Table 2).

Table 1. Correlation coefficients among 14 studied traits of fruit bearing wood (morphotype I).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
O	0.14	0.27	0.33	–0.26	0.17	–0.25	-0.38	0.03	0.16	–0.03	–0.07	0.26	–0.02	0.00
N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
M	–0.55*	–0.39	–0.31	0.11	–0.40	0.20	0.04	–0.50*	–0.15	–0.54*	0.48*	0.46*	1.00	
L	–0.13	0.05	0.07	0.33	0.30	0.09	0.26	–0.01	0.56*	–0.18	0.65*	1.00		
K	–0.12	–0.24	–0.21	–0.02	0.06	0.23	0.02	–0.29	0.49*	–0.28	1.00			
J	0.39	0.03	–0.08	–0.11	0.30	0.05	0.04	0.74*	0.23	1.00				
I	0.34	0.17	0.19	–0.04	0.53*	0.02	–0.07	0.25	1.00					
H	0.30	0.02	–0.05	0.31	0.23	0.27	0.31	1.00						
G	–0.43*	–0.20	–0.36	0.57*	–0.16	0.41	1.00							
F	–0.54*	–0.62*	–0.71*	0.60*	–0.55*	1.00								
E	0.56*	0.80*	0.74*	–0.10	1.00									
D	–0.44*	–0.18	–0.24	1.00										
C	–0.18	–0.12	1.00											
B	0.65*	1.00												

* ($p < 0.05$)

Legend: A – length of 3YB, B – total number of 2YS, C – number of fruit bearing 2YS, D – length of 2YS, E – angles of 2YS, F – basal diameter of 2YS, G – number of nodes on 2YS, H – number of 1YS, I – length of 1YS, J – angles of 1YS, K – basal diameter of 1YS, L – number of nodes on 1YS, M – number of vegetative buds on 1YS, N – number of mixed buds on 1YS, O – number of female flowers per inflorescence on 1YS. 3YB is a three-year-old bearer, 2YS represent a two-year-old shoot on a three-year-old bearer and 1YS is an annual shoot.

Table 2. Correlation coefficients among 14 studied traits of fruit bearing wood (morphotype II).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
O	–0.18	0.09	–0.02	0.17	–0.05	–0.01	0.14	0.28	0.19	0.15	0.22	0.50*	0.48*	0.49*
N	–0.02	–0.01	0.09	0.04	0.22	0.01	–0.01	0.13	0.02	0.05	0.12	0.19	0.17	1.00
M	0.02	0.12	0.12	–0.12	–0.12	0.14	–0.12	0.22	0.72*	0.14	0.68*	0.70*	1.00	
L	–0.15	0.02	0.12	–0.02	0.10	–0.05	–0.01	0.27	0.72*	0.35	0.41*	1.00		
K	0.11	–0.02	–0.09	–0.26	–0.12	0.32	–0.40*	–0.14	0.58*	0.06	1.00			
J	–0.14	–0.05	0.03	0.20	0.61*	–0.01	0.19	0.49*	0.26	1.00				
I	–0.14	–0.24	–0.04	–0.06	0.06	0.34	–0.06	0.19	1.00					
H	0.01	–0.20	–0.15	0.52*	0.14	0.13	0.59*	1.00						
G	–0.15	–0.15	0.10	0.92*	0.06	0.38	1.00							
F	0.03	–0.23	0.15	0.40*	0.12	1.00								
E	0.21	0.33	0.54*	0.14	1.00									
D	–0.13	–0.12	0.05	1.00										
C	0.26	0.63*	1.00											
B	0.58*	1.00												

* ($p < 0.05$)

Legend: A – length of 3YB, B – total number of 2YS, C – number of fruit bearing 2YS, D – length of 2YS, E – angles of 2YS, F – basal diameter of 2YS, G – number of nodes on 2YS, H – number of 1YS, I – length of 1YS, J – angles of 1YS, K – basal diameter of 1YS, L – number of nodes on 1YS, M – number of vegetative buds on 1YS, N – number of mixed buds on 1YS, O – number of female flowers per inflorescence on 1YS. 3YB is a three-year-old bearer, 2YS represent a two-year-old shoot on a three-year-old bearer and 1YS is an annual shoot.

Table 3. Correlation coefficients among 14 studied traits of fruit bearing wood (morphotype III).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
O	0.25	–0.04	–0.14	–0.03	0.16	0.07	0.04	–0.08	0.12	–0.03	0.20	0.04	0.28	0.81*
N	0.12	0.11	–0.02	–0.03	0.15	–0.01	–0.04	–0.12	0.10	–0.03	0.18	0.07	0.45*	1.00
M	0.47*	0.36	0.41*	–0.29	0.16	–0.16	–0.10	0.10	0.69*	0.05	0.43*	0.83*	1.00	
L	0.48*	0.14	0.38	–0.12	0.09	0.01	0.10	0.20	0.78*	0.13	0.47*	1.00		
K	0.25	–0.14	–0.07	–0.37	0.06	0.28	–0.20	–0.32	0.60*	–0.15	1.00			
J	0.16	0.15	0.40*	0.21	0.39	–0.25	0.11	0.19	–0.03	1.00				
I	0.42*	0.04	0.41*	–0.29	–0.02	–0.02	–0.15	–0.08	1.00					
H	0.19	0.01	0.20	0.10	–0.10	0.03	0.20	1.00						
G	–0.12	–0.54*	–0.07	0.84*	–0.13	0.52*	1.00							
F	–0.01	–0.79*	–0.22	0.49*	–0.51*	1.00								
E	0.20	0.59*	0.37	–0.15	1.00									
D	–0.23	–0.54*	–0.15	1.00										
C	0.32	0.47*	1.00											
B	0.37	1.00												

* ($p < 0.05$)

Legend: A – length of 3YB, B – total number of 2YS, C – number of fruit bearing 2YS, D – length of 2YS, E – angles of 2YS, F – basal diameter of 2YS, G – number of nodes on 2YS, H – number of 1YS, I – length of 1YS, J – angles of 1YS, K – basal diameter of 1YS, L – number of nodes on 1YS, M – number of vegetative buds on 1YS, N – number of mixed buds on 1YS, O – number of female flowers per inflorescence on 1YS. 3YB is a three-year-old bearer, 2YS represent a two-year-old shoot on a three-year-old bearer and 1YS is an annual shoot.

The highest correlation coefficients for intermediate fruiting genotypes with acrotonic ramification (morphotype III) were between the total number of 2YS and their basal diameter (r=–0.79*), between the length and the number of nodes for both, 2YS (r=0.84*) and 1YS (r=0.78*); between the number of nodes and the number of vegetative buds on 1YS (r=0.83*), and between the number of female flowers per inflorescence and the number of mixed buds on 1YS (r=0.81*). 2YS which grow at larger angles are expected to be thinner (r=–0.51*). Longer 1YS were usually thicker (r=0.60*) and have more nodes (r=0.78*) and more vegetative buds (r=0.69*) (Table 3).

On the lateral fruit bearing genotypes (morphotype IV), the highest correlation coefficients were between the length of 2YS and their number of nodes (r=0.89*); between the number of 1YS and their angles (r=0.64*); between the length of 1YS and their basal diameter (r=0.75*) and between the number of mixed buds and the number of female flowers per inflorescence on 1YS (r=0.86*). Longer 3YB bear more total 2YS (r=0.57) and more fruit bearing 2YS (r=0.46*), but less 1YS (r=–0.43*). 1YS grow at larger angles when their number is higher (r=0.64*). In this case, 1YS develop less female flowers per inflorescence (r=–0.53*) (Table 4).

In the morphotypes II, III, and IV the number of fruit bearing two-year-old shoots (2YS) depends on the total number of 2YS (the more total shoots, the more fruit bearing shoots), and the number of nodes on 2YS depends on the length of the shoot (the longer the shoot, the more nodes it has). There is also a correla-

Table 4. Correlation coefficients among 14 studied traits of fruit bearing wood (morphotype IV).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
O	0.23	0.17	0.04	–0.30	0.36	–0.33	–0.24	–0.53*	–0.04	–0.52*	0.11	–0.01	–0.03	0.86*
N	0.30	0.22	0.14	–0.33	0.45*	–0.18	–0.27	–0.46*	0.20	–0.34	0.35	0.16	–0.05	1.00
M	0.01	0.03	–0.16	0.17	0.42*	0.40*	0.37	0.19	0.37	0.37	0.28	0.62*	1.00	
L	0.09	0.23	0.10	0.15	0.42*	0.36	0.36	0.06	0.49*	0.28	0.35	1.00		
K	0.32	0.20	–0.02	–0.46*	0.08	0.22	–0.39	–0.14	0.75*	0.18	1.00			
J	–0.08	–0.21	–0.18	0.14	–0.03	0.47*	0.15	0.64*	0.40*	1.00				
I	0.28	0.19	–0.08	–0.30	0.32	0.11	–0.35	0.07	1.00					
H	–0.43*	–0.17	–0.21	0.46*	0.07	0.32	0.36	1.00						
G	–0.54*	–0.17	–0.13	0.89*	0.18	0.58*	1.00							
F	–0.43*	–0.49*	–0.18	0.56*	–0.14	1.00								
E	–0.01	0.32	0.02	0.13	1.00									
D	–0.65*	–0.30	–0.21	1.00										
C	0.46*	0.59*	1.00											
B	0.57*	1.00												

* ($p<0.05$)

Legend: A – length of 3YB, B – total number of 2YS, C – number of fruit bearing 2YS, D – length of 2YS, E – angles of 2YS, F – basal diameter of 2YS, G – number of nodes on 2YS, H – number of 1YS, I – length of 1YS, J – angles of 1YS, K – basal diameter of 1YS, L – number of nodes on 1YS, M – number of vegetative buds on 1YS, N – number of mixed buds on 1YS, O – number of female flowers per inflorescence on 1YS. 3YB is a three-year-old bearer, 2YS represent a two-year-old shoot on a three-year-old bearer and 1YS is an annual shoot.

tion between the length and thickness of 2YS (longer shoots are thicker).

All morphotypes exhibit significant correlations between the length and the thickness of annual shoots (1YS); between the length and the number of nodes (the longer the shoot, the thicker they are and the more nodes they have); and between the number of nodes and the number of vegetative buds (annual shoots with more nodes have more vegetative buds).

Regarding correlation coefficients of individual morphotypes, the most interesting are those which describe the extreme (terminal and lateral) types or both intermediate types.

In terminal and lateral bearing morphotypes the length of a three-year-old bearer (3YB) was significantly related to the length of 2YS, their thickness and the number of nodes (longer 3YB develop more 2YS, which are shorter and thinner, and have lower number of nodes) and the number of fruit bearing 2YS (longer 3YB develop more fruit bearing 2YS). Taking into consideration the length of the juvenile period the above mentioned correlation coefficients can be very helpful for an early selection.

Some relationships appear to be very specific. In morphotype I, two year-old shoots on long three year-old bearers have larger angles. 2YS are thinner as their number increases. Long annual shoots have larger angles and vice versa. The number of vegetative buds on 1YS is lower if the shoots appear in higher numbers and have larger angles.

In the morphotype II the angles of annual shoots significantly depend on the angles of two years-old shoots. When 2YS have a higher number of nodes, the 1YS are thinner and their number is also higher. The number of female flowers per inflorescence is higher when there are more nodes and vegetative buds on 1YS.

The morphotype III alone had a significant correlation between the number of vegetative and mixed buds on annual shoots (the more vegetative buds, the more mixed buds). In this morphotype the 1YS are longer, if they develop on longer 3YB, which have a higher number of fruit bearing shoots.

The morphotype IV appears to be specific regarding its negative correlation between the number of female flowers per inflorescence and the angles of annual shoots (more horizontal shoots have less female flowers and vice versa).

The improvement of only one trait can take very long time due to the walnut's long juvenile period. Therefore, it is better to improve two or more traits simultaneously. For this, however, it is helpful to have a good information about correlation coefficients among the most important characteristics concerning the walnut tree in general. GERMAIN (1990, 1997b) reported about correlations between the tree crown habit, vigour and the type of fruiting; between the growth vigour and the time of bud breaking. Relationships between the lateral fruit bearing pattern and the annual growth of seedlings; the size of trees, the diameter of trunk and the fruit weight were described by ATEFI (1990, 1993). SOLAR et al. (2001) established correlation coefficients between the time of bud breaking and development of the first male inflorescences; between the growth vigour, crown habit, fruit bearing and the length of the juvenile period.

Fruit bearing wood, on the contrary, has not been investigated in order to include some new informations into the breeding process yet. GERMAIN (1990) defined three fruit bearing types (terminal, intermediate, lateral), but he did not conduct any further analyses. The research of the plant structure has only been used for making decisions in orchard management associated with walnut production technology till now (SABATIER et al. 2001).

The work done by LAURI et al. (2001) contributed significantly to the study on development of morphological criteria to describe the young tree architecture in walnut progenies. In five lateral bearing cultivars they studied the variability of fruit weight in relation with the length of flowering shoots and the number of fruits which developed from one inflorescence. They concluded that at least two factors are involved in nut weight variability: length of preformed subtending axis and number of nuts developing from the inflorescence.

LAURI et al. (1997) also reported the qualitative and quantitative morphological traits that can be used as early selection criteria for apples. Their conclusions were based on morphological measurements (the length and diameter of shoots, the number and length of internodes) and the descriptions (the type of ramification) of fruit-bearing branches of non-pruned trees of seven cultivars. Their results show that axis slenderness is positively correlated with the internode length and that both characteristics seem to be related to a reduced number of growing points through a so-called 'extinction' mechanism. This leads to a high functional autonomy of the remaining laterals, i.e., a high bourse-over-bourse potential what is a valued trait in apple varieties.

In walnut, the lateral fruit bearing pattern (morphotype IV) is one of the most desired traits. So, if we have a population mixture of several morphotypes, it would be advisable to select those with lateral fruiting. This complex characteristic can be determined when the plants are three to four years old and sometimes even earlier. In a case, when the seedlings do not develop lateral female inflorescences on annual shoots until their forth year of age they should be eliminated or used as rootstocks. In this way, we can significantly reduce the population size and the costs. This is very important for the breeding based on recurrent selection (when the breeders deal with 10,000 or more individual plants). The breeding plots can be reduced and the time period needed to complete one cycle becomes shorter. This approach can also be useful in breeding based on classical individual (pedigree) selection. The breeder can evaluate the material (hybrids) at least two seasons earlier, remove the plants with low yield potential and concentrate on multiplying those, that represent new potential varieties.

In our case, the correlation analysis indicates that when we have a large number of individuals belonging to the morphotype IV, we should favour those with fewer annual shoots (in this case there will be more mixed buds on annual shoots and more female flowers per inflorescence). Another useful trait which can be used for early selection is the number of mixed buds on annual shoots (the plants with more mixed buds are expected to have more female flowers in inflorescences).

Conclusions

This paper represents the first phase of a long term investigation associated with practical population breeding. The work is being continued by the detailed evaluation of trees and the productivity (yield components). One of the objectives of further investigation is also the stability of morphotypes over time and environments. During the period of 5 years, when we were observing them, the morphotypes have remained constant. Concerning long life span of walnut trees and long period, needed for some traits to become stable, the observations have to be longer than 5 years. Some of the most influential morphometric characteristics of fruit bearing wood are expected to be recommended as new selection criteria in walnut breeding for the next two to three years. Using these criteria, the classical development of a new variety of Persian walnut, which lasts at least 20 years (GERMAIN 1997a) will be shortened and become cheaper.

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