

WALNUT BIODIVERSITY IN THE WESTERN BALKANS

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Abstract

*Most parts of the western Balkans have favourable climate and soil conditions for walnut growing. In this area, the walnut was mostly propagated generatively, which led to the fact that every tree is a special genotype. The walnut population is extremely heterogeneous and it showed a great variability in a nut size and weight, kernel percentage, kernel color, the time of leaf bud burst, male and female flowering, duration of a vegetative period, yield, resistance to *Gnomonia leptostyla* and *Xanthomonas juglandis*, etc.*

At the Faculty of Agriculture in Novi Sad, the study of walnut population started in the 1950s. UPOV descriptors were used for the analysis of the walnut population. This research has resulted in the selection of a number of walnut selections and five walnut varieties (Sampion, Srem, Tisa, Backa, Mire). Some characteristics of these varieties and eleven promising selections – candidates for varieties – are given.

Key words: walnut, western Balkans, biodiversity, genotype, selection, variety

1. INTRODUCTION

Due to highly favourable climate and soil conditions in the area of the western Balkans, a large, extremely heterogeneous walnut population has been formed both spontaneously and by planting seedlings. This was contributed by the fact that until recently the walnut was propagated almost exclusively by seeds in this area. This method of propagation created a population in which every tree represents a distinct genotype. In the area of the western Balkans, there are a number of walnut trees in small plantations, along tree-lined roads, in gardens and forest populations; over 98% of these trees are seedlings. Most of walnut trees are found up to an altitude of 400 m; there are a lot of trees at an altitude from 400 to 600 m and a few trees up to 1,200 m. Trees are also found at the altitude of 1,400 m in Montenegro, because there is a substantial impact of Mediterranean climate.

The first research on the walnut population in the western Balkans was conducted by Fazlagić (1935) in the thirties of the last century in Bosnia and Herzegovina. The most extensive research was done in Serbia: Rudić (1962), Jelenković (1966), Đurđević (1968), on the territory of the former Yugoslavia: Korać, Cerović, Gološin (1973, 1976, 1980, 1982, 1988, 1989, 1990, 1991, 1995, 1997a, 1997b, 1999, 2000, 2001, 2003, 2004, 2008 and 2010), Manušev (1970) in Bosnia and Herzegovina, Hlišč (1972) in Slovenia, Kuzmanovski (1976) in Macedonia, Miletić (1996) in the region of Timočka Krajina, Bugarčić (1985) in the region of Čačak, etc.

The natural walnut population in Romania was studied by Cosmoulescu and Botu (2012). The walnut population in Greece was studied by Rouskas and Zakinthinos (2001). By collaborative work of Germain et al. (1997) in Spain, Portugal, Greece and Italy, walnut genotypes were selected from local populations which have a late time of leaf bud burst, lateral bearing, high fruit quality and tolerance to *Xanthomonas juglandis*. The selected genotypes were later used in various programs of walnut hybridization, which produced several varieties. In Bulgaria Zahov (1948) chose a number of selections from a local population, out of which some were later recognized as varieties including Sejnovo, which is still one of the leading varieties. Zeneli, Kola & Dida (2005) studied the natural walnut population in Albania and they identified a great heterogeneity and selected several genotypes as promising. Norouzi et al. (2013) examined the walnut population in Iran. In Hungary Szentiványi (1990) made a selection of genotypes from a natural population which produced modern leading varieties in that country (Tiszacsecsi 82, Milotai 14, etc.). In Turkey, an extensive selection of the walnut from a very rich natural population was made, which resulted in a number of walnut varieties

and selections. There are a number of authors who worked on walnut selection in Turkey such as Celebioglu, Ferhatolu & Burak (1988), Kuden, Kaska & Türemis (1997), Akca and Sen (1997), Sen et al. (2001), Sutyemez et al. (2001), etc. Karadag and Akca (2011) state that more extensive work on walnut selection in Turkey started in 1970 and that in the first stage, eight selections were recognized as varieties, while more than 200 selections are candidates for varieties. In Moldavia the walnut population was studied by Curkan (1969). Kondratenko et al. (2001) made a selection of the walnut from the natural population in Ukraine; the focus of the selection was on choosing genotypes with high quality of fruits, lateral bearing and tolerance to diseases. Norouzi et al. (2013) note that in Iran there is a wide variety of walnut population which was propagated only by planting material gained from seeds. Rihter and Jadrov (1985) examined a large walnut population in Russia. According to Pieklo and Czynczyk (1990), the selection of walnuts from a natural population started in Poland in 1950; a number of genotypes chosen in the process of selection later became varieties. Diaz et al. (2005) identified and examined a number of walnut populations in the north of Spain. Sharma and Sharma (2001) selected several quality walnut genotypes from a numerous natural walnut population in the Indian state Himachal Pradesh. Khattak et al. (2000) chose several selections from a natural walnut population and four of them were recognized as varieties. In Italy, the resistance of genotypes to *Gnomonia leptostyla* was examined in different natural populations (Pollegioni et al., 2012).

All the studies on walnut populations in various parts of the world have shown their great variability in the size and weight of a nut, kernel percentage, kernel color, time of leaf bud burst, time of male and female flowering, duration of vegetative period, time of leaf fall, yield, etc. Some research on natural populations resulted in creation of walnut varieties or selected genotypes were used as one or both parents for creating new varieties. Selected genotypes were often used as donors of genes for resistance to diseases, lateral bearing, cluster bearing, high quality of a fruit, a late time of leaf bud burst and early time of leaf fall, etc.

The aim of the decades-long work of the Department of Fruit Growing and Viticulture at the Faculty of Agriculture was to examine this rich population and select biotypes with the best characteristics which would be recognized as varieties and mass multiplied in the next stage. Another strand of work was the selection of types with particular qualities which would be used for creation of varieties by hybridization.

In the first phase, the walnut population was studied in the entire area of the western Balkans, whereas after 1990s the study has been reduced to Serbia, which is the richest in natural populations.

2. MATERIALS AND METHODS

The walnut population was studied in the entire area of the western Balkans with special attention to particularly walnut regions of Serbia: the Timok valley, Fruska Gora, the Drina valley, the South Morava valley, the West Morava valley, etc. The method used for collecting walnuts of the highest quality was prize contest as the simplest and fastest one.

In this way, several thousands of trees were examined. Apart from the contest, trees along roads were taken into account, which increased the number of examined trees. After the first selection by evaluation of nut quality, the following features were observed on the selected trees: the time of leaf bud burst, the time of leaf fall, flowering, the predominant location of fruit buds on a one-year-old shoot, and other characteristics. A special attention was given to the tolerance of selected genotypes to *Xantomonas juglandis* and *Gnomonia leptostyla*. After these first examinations, the chosen selections were grafted and planted in collection orchards. The largest collection orchard was planted in Beska (about 50 km north of Belgrade). UPOV descriptors for walnut were used for the description of the studied genotypes (UPOV 2013).

The data obtained for measurable parameters in the research (nut weight and kernel percentage) were processed in the statistical software STATISTICA 12 (StatSoft, 2012) by Analysis of Variance (ANOVA), while other examined parameters are presented descriptively or by scoring method according to UPOV descriptors for walnut.

3. RESULTS AND DISCUSSION

In the western Balkans area there are about 8,000,000 trees. The largest average yields are achieved at the altitude from 150 to 400 m. In the plain regions, yields vary from year to year depending on the occurrence of late spring frosts, which might be avoided by the choice of adequate varieties and selections.

3.1. Walnut population variability

Considering almost exclusive generative propagation of the walnut, it was created an extremely heterogeneous population which is ideal for work on the selection.

The variability in some features examined in the walnut population of the western Balkans is given in the tables 1-14.

The time of leaf bud burst. In order to compare walnut types from different regions, we used renowned varieties and selections. Table 1 shows that the biotypes with an early and early to medium time of leaf bud burst are most prevalent (about 75%), which particularly leads to quite frequent damage from late spring frosts. There are few genotypes with a late or late to very late time of leaf bud burst, while only three genotypes with a very late time of leaf bud burst are recorded. The interval between the earliest and latest genotypes was up to 60 days. Thus the genotype NM 16 (chosen as the selection Super Kasni) starts the vegetative period about 20 days after the variety Franquett. The selection Super Kasni starts the vegetative period in the second half of May, while its time of leaf bud burst in 1987 was on 2 June. Our newest selection Mostonga regularly starts the vegetative period in late May or early June, about 7-8 days after the selection Super Kasni.

Table 1. The prevalence of walnut genotypes in the western Balkans according to the time of leaf bud burst

Note	Time of leaf bud burst	Example Varieties	Prevalence in population (%)
1	Very early	Serr	7.1
2	Very early to early	Ashley, Chici	18.5
3	Early	Chase D9, Sorrente, Vina	27.4
4	Early to medium	Adams 10, Hartley, Pedro	22.7
5	Medium	Chandler, Howard	12.7
6	Medium to late	Grandjean, Marbot, Mayette	6.5
7	Late	Franquette, Parisiene	3.7
8	Late to very late	Ronde de Montignac	1.4
9	Very late	-	

Cosmulescu and Bota (2012) divided the walnut according to the time of leaf bud burst in three groups. The first group, whose time of leaf bud burst is between 20 and 30 April, is most prevalent with 62.7%. The time of leaf bud burst for 35% of examined walnut genotypes is between 1 and 5 May, and for 2.3% it is after 10 May, which roughly agrees with our research, where the division is slightly more precise. According to the studies of Rouskas and Zakynthinos (2001), among chosen selections the time of leaf bud burst of 16 selections is very early to early, it is early for 27 genotypes, early to medium for 23, and medium to late for 4 of them. Such a composition of the natural walnut population in Greece can be explained by the impact of Mediterranean climate where late spring frosts are not prevalent and they have not made natural selection related to the time of leaf bud burst like in Serbia where late spring frosts are frequent. Karadag and Akca (2011) state that the time of leaf bud burst of Turkish varieties is early, which has a negative effect on a yield level, which greatly varies

from year to year due to a frequent occurrence of late spring frosts. Therefore, they have made a selection from the local population of genotypes with a late time of leaf bud burst with the aim of creating new varieties and starting material for hybridization. The time of leaf bud burst of chosen selections is from 19 April to 7 May. According to the research of Aleta and Ninot (1993), the time of leaf bud burst of most selected genotypes is early under Spain's conditions, before 10 April. Atefi (1993) indicates that the selection of genotypes from a local walnut population started in 1984, and about 10% of genotypes belong to the group with a late time of leaf bud burst, which approximately coincides with our studies.

The time of leaf fall. The time of leaf fall of most genotypes is early (about 51%), then medium (about 32%), and a late time of leaf fall is least prevalent (about 17%), and consequently, the damage from winter frosts are not serious (Table 2).

There is a positive correlation between the time of leaf bud burst and the time of leaf fall. When the time of leaf bud burst is late, the time of leaf fall is also late, and vice versa. There are also a number of exceptions. The time of leaf bud burst of our variety Sampion is medium, and its time of leaf fall is early. The time of leaf bud burst of the selection Super Kasni is very late, and its time of leaf fall is medium, like most of the examined walnut genotypes. The duration of a vegetative period of the selection Super Kasni is about 160 days.

Table 2. The prevalence of walnut genotypes in the western Balkans according to the time of leaf fall

Time of leaf fall	Example Varieties	Prevalence in population (%)
Early	Adams 10, Chase D9	51
Medium	Franquette, Grandjean, Hartley	32
Late	Ashley, Choco, Marbot, Serr	17

Arzani et al. (2008) states that the duration of a vegetative period is very important, and gives example of the selections BA150, AA33, AA37, and AA115 which start the vegetative period late, but finish it on time. Therefore, their vegetative period is short.

Table 3. presents the time of male flowering compared to female flowering – dichogamy. The most prevalent genotypes are those with protandrous flowering (87.3%), then ones with homogamous flowering (11.2%), and only 1.5% have protogynous flowering.

The selection Rasna has a particularly long period of male flowering (about 25 days on average). This selection is homogamous and its time of male flowering corresponds to most varieties from our collection.

Table 3. Time of male flowering compared to female flowering of walnut genotypes in the western Balkans

Type of flowering	Example Varieties	Prevalence in population (%)
Protandry	Corne, Franquette, Marbot, Parisienne	87.3
Homogamy	Meylannaise, Ronde de Montignac	11.2
Protogyny	Amigo, Chico	1.5

According to the studies of Cosmulescu and Botu (2012) in Oltenia region, protandrous flowering accounts for 59.7% of genotypes, protogyny for 33.1%, and homogamy for 7.2%. It can be noticed that most genotypes have protadrous flowering, like in our research, whereas the least prevalent genotypes are ones with homogamous flowering, unlike in our studies. Rouskas and Zakynthinos (2001) state that among selected genotypes, 34 have protandrous type of flowering, 21 protagynous, and only 2 have homogamous type of flowering. According to the studies of Sutyemez (2001), the examined genotypes up to the altitude of 740 m are mostly protagynous, while genotypes at higher altitudes (1,160 m) are mostly protandrous. Sutyemez (2001) indicates that only 24 trees out of 171 selected ones are homogamous (about 14%), which is close to our results. Karadag and Akca (2011) state that according to their study, in Amasya Province there are over 50% of walnut genotypes which are protandrous. Arzani et al. (2008) state that 32 examined genotypes are protagynous, 19 are protandrous, and 7 are homogamous. Considering that these studies were conducted under significantly different climate conditions, the discrepancy with our study can be explained by that fact.

Table 4. indicates that the most prevalent genotypes in the walnut population in the western Balkans are ones with strong tree vigor (45.7%), and genotypes with weak vigor are least prevalent (only 4.7%).

Table 4. The prevalence of genotypes in the western Balkans according to tree vigor

Tree vigor	Example Varieties	Prevalence in population (%)
Weak	Chico, Gustine, Vina	4.7
Medium	Franquette, Hartley, Marbot	21.6
Strong	Corne, Parisienne,	45.7
Very strong	Serr	28.2

Aslantas (2006) indicates that the examined trees in Anatolia Province are mostly with medium vigor to strong vigor, while the trunk circumference of 528 examined trees was up to 4.5 m. Akca and Ozongun (2004) state that they examined 20 genotypes selected in Turkey, out of which most of them were trees with strong vigor (8), then with medium vigor (7), while trees with weak vigor were least prevalent (5), which to some extent differs from our study, where strong and very strong tree vigor was most prevalent, while the prevalence of trees with weak vigor was minimal.

Most genotypes in the population of the western Balkans had very small (28.6%) and small nut size (32.2%), as it is shown in Table 5. Nut weight was between 2.9 g (genotype V₁) and 32.1 g (genotype 105/76, which had kernel percentage of only 26.2%).

Table 5. The prevalence of walnut genotypes in the western Balkans according to nut size

Nut weight	Example Varieties	Prevalence in population (%)
Very small	Lozeronne	28.6
Small	Chico, Grandjean	32.2
Medium	Franquette, Marbot, Payne, Serr	19.2
Large	Hartley	12.8
Very large	Bijoux, Sanland	7.2

According to Kuden, Kaska & Türemis (1997), the selected genotypes in Turkey have a nut weight from 9.3 g to 18.1 g, which is in accordance with our studies. According to Aslantas (2006), in Anatolia, Turkey the selected genotypes had a nut weight between 9.07 g and 16.01 g. Walnut selections in Bitlis Province had similar nut weight (10.94 – 17.20 g) according to the studies of Balta et al. (2007). In India, according to Sharma, Sharma & Gautam (2005), nut weight varied from 4.85 g to 16.59 g within the examined population, whereas according to the same authors (Sharma and Sharma 2001), the nut weight in another region of India varied from 6.40 g to 20.55 g. According to Cosmulescu and Botu (2012), in Romania nut weight was 6.8 – 18.4 g.

Table 6 indicates kernel percentage. In the population of the western Balkans, there is a prevalence of genotypes with low kernel percentage. Only one third of studied genotypes had kernel percentage of 40% and above (Table 6), while only 9.3% had high and very high kernel percentage. The highest kernel percentage was 68.3% (62/76).

Karadag and Akca (2011) state that, according to their studies, the kernel percentage of the selected genotypes in Amasya Province is from 42.88 to 67.14%. These studies are in accordance with our findings in respect of the highest kernel percentage, since one of our genotypes had 68.3% of kernel. Sen and Tekintas (1992) state that the kernel percentage of the selected genotypes is from 39.01% to 57.53%. According to the studies of Cosmulescu and Botu (2012), in Oltenia region the kernel percentage in walnut population varied from 23.6 to 71.7%. According to Arzani et al. (2008), the selected genotypes in central Iran have a kernel percentage from 38.4 to 79.6%. Four Pakistani walnut varieties, which are the result of the selection from a natural population, have a kernel percentage from 43 to 47% (Khattak et al., 2000). The chosen selections from the walnut population in Greece, according to Rouskas and Zakynthinos (2001), have a kernel percentage from 47.1 to 55.0%.

Table 6. Kernel percentage of weight relative to total weight of nut of walnut genotypes in the western Balkans

Note	Kernel percentage (%)	Example Varieties	Prevalence in population (%)
1	Very low	Corne	65.8
2	Low	Mayette, Marbot	15.2
3	Medium	Franquette, Hartley	9.7
4	High	Payne, ChaseD9	6.2
5	Very high	Serr	3.1

Table 7. shows that in the walnut population there is a prevalence of genotypes whose kernels are removed from a shell with difficulty or medium difficulty. The least prevalent genotypes are ones whose kernels are very easily removed (6.7%) or genotypes whose kernels are easily removed (12%).

Table 7. Ease of kernel removal of walnut genotypes in the western Balkans

Note	Ease of kernel removal	Example Varieties	Prevalence in population (%)
1	Very easy	Payne, Pedro, Serr	6.7
2	Easy	Franquette, Hartley, Marbot	12.0
3	Medium	Meylannaise	42.3
4	Difficult	Corne	30.1

According to Ghasemi, Arzani & Hassanici (2012), in Markaz, a province in Iran, the genotype distribution according to the ease of kernel removal from the shell is as follows: 2.85% for very easy removal, 64.3% for easy removal, 15.7% for medium, 14.3% for difficult removal and 2.85% for very difficult removal. Arzani et al. (2008) state that among 58 selected genotypes, 26% are characterized by very easy kernel removal, 43% by easy removal, 29% by medium removal, and only 2% by difficult removal. The quoted data are considerably different from our findings, but it should be taken into account that our results are based on a non-selected population.

In the walnut population of the western Balkans, there is a prevalence of genotypes with medium intensity of kernel color (41.3%) (Table 8). Light kernel color is least prevalent in the population with only 3.9%. The genotypes selected as Backa and Novosadski Kasni have especially pretty kernel color.

Table 8. Kernel: intensity of ground color of walnut genotypes in the western Balkans

Kernel color	Example Varieties	Prevalence in population (%)
Very light	Chandler	3.9
Light	Franquette, Hartley, Serr	26.8
Medium	Parisienne, Marbot	41.3
Dark	-	22.6

The selected walnut genotypes in Amasya Province, Turkey, according to Karadag and Akca (2011), had mostly yellow kernel color, while 11 selections had very light kernel color, and only 3 selections had dark color. This can be explained by the fact that one of basic goals of the selection work was selecting genotypes with light kernel color. Sutyemez, Kaska & Eti (2001) states that most chosen selections have generally yellow color and partly light yellow. According to Arzani et al. (2008), 30 out of 58 examined genotypes have light kernel color, 13 have very light, and 15 have medium dark color (amber).

Location of fruit buds on a one-year-old shoot. Only terminal bud was a fruit bud in most examined biotypes. Only two types had more fruits on lateral buds than on terminal ones, while approximately 5% of biotypes had some lateral fruit buds, but they bore fewer fruits than terminal buds (Table 9).

Table 9. The prevalence of genotypes in the western Balkans according to predominant location of fruit buds

Note	Location of fruit buds	Example Varieties	Prevalence in population (%)
1	at tip of one-year old shoot	Corne, Franquette, Marbot	29.4
2	mainly on the top of long shoots bound on branches of 2 years or older	Hartley	68.5
3	all along the one-year old shoot	Chico, Payne, Serr	2.1

According to Karadag and Akca (2011), the selected genotypes have 30-70% of lateral fruit buds. Similar results were obtained by Aslantas (2006). His research indicates that selected genotypes have 40-63% of lateral fruit buds. Akca and Ozogun (2004) state in their studies that 10-70% of lateral fruit buds were observed on selected genotypes in the region of the Black Sea. 35% of seventy Greek walnut selections have lateral bearing (Rouskas and Zakynthinos, 2001).

Table 10 shows that most genotypes in the population are susceptible (52.85%) or weakly resistant (34.6%) to *Xanthomonas juglandis*. Only 3.6% of the examined genotypes are highly resistant to *Xanthomonas juglandis*, while only 0.1% is highly resistant. Aslantas (2006) states that up to 75% of trees in the walnut population of the north-eastern Anatolia, Turkey, have the symptoms of bacterial infection. According to Aleta et al. (2001), 10 out of 24 examined Spanish selections are sensitive to bacterial diseases at the same level as the variety Adams 10. According to these authors, three selections showed weak sensitivity of nuts to bacterial diseases, while one selection had similar leaf resistance as the variety Adams 10.

Table 10. Resistance to *Xanthomonas juglandis* of walnut genotypes in the western Balkans

Note	Resistance	Example Varieties	Prevalence in population (%)
1	Susceptible or very weakly resistant	Ashley, Gustine, Hartley, Serr, Mayette, Payne, Pedro	52.8
2	Weakly resistant	Grandjean, Franquette, Marbot	34.6
3	Moderately resistant	Corne, Parisienne	8.9
4	Resistant	Chase D9, Adams 10	3.6
5	Highly resistant	-	0.1

Table 11. shows that most genotypes in the population in the western Balkans were susceptible or weakly resistant to *Marssonina juglandis*. The studies of Saremi and Amiri (2010) indicate that a great majority of genotypes in the north-eastern Iran had noticeable symptoms of the infection caused by *Marssonina juglandis*, which is consistent with our findings. The only variety without the symptoms was Alamoty.

Table 11. Resistance to *Gnomonia leptostyla* – *Marssonina juglandis* of walnut genotypes in the western Balkans

Note	Resistance	Example Varieties	Prevalence in population (%)
1	Susceptible or very weakly resistant	Corne, Hartley, Mayette	42.8%
2	Weakly resistant		37.9
3	Moderately resistant	Parisienne	10.7
4	Resistant	Franquette	8.2
5	Highly resistant		0.4

According to Pollegioni et al. (2012), all 31 examined genotypes from the population in Italy were sensitive to *Marssonina juglandis* varying from high to very high level; only one genotype had low sensitivity.

During the study of the walnut population, we have found some forms which are rarely seen.

3.2. Characteristics of chosen varieties and selections

At the Faculty of Agriculture in Novi Sad, Serbia, during years-long research work on natural population, about 200 walnut genotypes were selected, described and studied. By further selection, five genotypes were chosen and acknowledged as the first varieties in the former Yugoslavia: Sampion, Srem, Tisa, Backa and Mire. Some characteristics of these varieties and promising selections – candidates for varieties - which have been chosen in further work are given in Table 12, 13, and 14.

The analysis results of nut characteristics of selected walnut varieties and selections indicated in Table 12.

Table 12. The analysis results of nut characteristics of selected walnut varieties and selections

Variety	Nut weight (g)	Kernel percentage (%)	Kernel color (1-20)	Taste (1-10)	External appearance (1-10)	Class
Tisa	15.5 bc	51.8 de	14	7	7	I
Begej	13.3 e	48.8 f	15	8	7	I
Nera	16.6 a	52.3 cde	18	9	9	I-a
NS Kasni	10.5 gh	54.5 b	18	8.5	9	I
Srem	14.9 cd	57.6 a	16	8	9	I
Rasna	14.1de	52.7 bcde	18	8	8	I
Kasni Grozd.	9.6 h	45.3 g	17	9	7.5	II
Kasni Rodni	12.2 f	46.5 g	18	8	8	I
Milko	13.3 e	47.3 fg	18	8.5	8	I
Sampion	14.2 de	57.8 a	17	9	10	I-a
Radjevina	9.9 h	45.6 g	15	9	8	I
Sava	16.2 ab	51.7 e	18	9	8.5	I-a
Backa	11.4 fg	54.3 bc	19	9.5	9.5	I-a
Mire	11.5 fg	56.7 a	16	8	8.5	I
Macva	13.2 e	51.1 e	16	9	8.5	I
Mostonga	10.2 h	39.8 h	19	8.5	7	II
Sejnovi	12.2 f	53.9 bcd	14	8.5	8.5	I
Franquette	11.2 fg	45.2 g	18	9	8.5	I

Values in the same column for each parameter marked with different letters are significantly different at $p < 0.01$.

The greatest weight was recorded for the selections Nera (16.6 g) and Sava (16.2 g), which had statistically equal nut weight as the variety Tisa (15.5 g). In comparison with the nut weight of the control varieties Sejnovi (12.2 g) and Franquette (11.2 g), all examined selections and varieties had significantly greater nut weight, except the selection Kasni Rodni (12.2 g), the varieties Mire (11.5 g) and Backa (11.4 g) and the selection NS Kasni (10.5 g), which produced nuts of equal weight as the control varieties. The selections Mostonga (12.0 g) and Kasni Grozdasti (9.6 g) were observed to have

the smallest nut weight, statistically significantly smaller compared to the nut weight of the control varieties as well as compared to all other examined selections and varieties.

The highest kernel percentage was recorded for the varieties Sampion (57.8%), Srem (57.6%), and Mire (56.7%), statistically significantly higher than the control varieties Sejnovo (53.9%) and Franquette (45.2%). The following varieties and selections had kernel percentage similar to the variety Sejnovo: Backa (54.3%), Rasna (52.7%), NS Kasni (54.5%), Nera (52.3%), and Tisa (51.8%). The varieties and selections with the kernel percentage at the level of the control variety Franquette (45.2%) were Milko (47.3%), Kasni Rodni (46.5%), Radjevina (45.6%), and Kasni Grozdasti (45.3%). The selections Sava, Macva, and Begej had significantly lower kernel percentage than the variety Sejnovo and considerably higher than Franquette with 51.7%, 51.1%, and 48.8% respectively. The kernel percentage of the selection Mostonga (39.8%) was significantly lowest in comparison with both the control varieties and other examined selections and varieties.

Table 13. shows that the time of leaf bud burst of the selected varieties and selections is early to medium (Backa, Tisa, etc.), medium to late (Rasna, Milko, Kasni Rodni, etc.), and very late (Mostonga – 28 May). The selection Mostonga has an early time of leaf fall, which makes it ready for a winter period. In late January 2012, it was recorded a minimal temperature of -30 °C, which caused damage to a number of walnut trees.

Table 13. Growth stages of walnut varieties and selections (average 2000-2007)

Variety	Time of leaf bud burst	Time of male flowering	Time of female flowering
Tisa	16 Apr	02 May	01 May
Begej	17 Apr	20 Apr	28 Apr
Nera	19 Apr	22 Apr	26 Apr
NS Kasni	04 May	12 May	17 May
Srem	17 Apr	25 Apr	03 May
Rasna	27 Apr	04 May	06 May
Kasni Grozd.	02 May	07 May	12 May
Kasni Rodni	04 May	10 May	12 May
Milko	02 May	08 May	09 May
Sampion	21 Apr	01 May	06 May
Radjevina	30 Apr	02 May	10 May
Sava	22 Apr	28 Apr	01 May
Backa	14 Apr	23 Apr	03 May
Mire	17 Apr	26-Apr	02 May
Macva	24 Apr	01 May	04 May
Mostonga	28 May	03 Jun	05 Jun
Sejnovo	20 Apr	27 Apr	03 May
Franquette	04 May	06 May	12 May

However, the selection Mostonga did not suffer any damage and it produced high yield that year. The time of male flowering was in the period from 20 April (Begej) to 3 June (Mostonga), which is a span of a month and a half. The duration of male flowering for particular varieties and selections is from 5 to 10 days. The selection Rasna has a particularly long period of male flowering which can last up to 20 days. The time of female flowering ranges from 26 April (Nera) to 5 June (Mostonga); the span is 40 days.

Table 14. indicates that most selected varieties and selections are with strong or very strong vigor, except the selection Kasni Rodni which is with weak vigor and NS Kasni with very weak vigor. The studied varieties and selections have moderate to high resistance to *Gnomonia leptostyla*, while some are more sensitive to *Xantomonas juglandis*. Sampion and Mostonga have especially high resistance to low temperatures, while Sava and Backa are a little less resistant. Nera and Sava have the greatest lateral bearing (65 – 85%); Rasna, Kasni Rodni, and Macva - a little less (50 – 60%); while the formation of lateral fruit buds occur in other varieties and selections as well (from 5 to 40%).

Table 14. Biological characteristics of walnut varieties and selections

Variety	Vigor	Resistance to <i>Gnomonia leptostyla</i>	Resistance to <i>Xantomonas juglandis</i>	Sensitivity to low temperatures	Lateral bearing (%)
Tisa	Very strong	5	3	4	5 - 10
Begej	Strong	5	3	4	20-30
Nera	Medium	7	7	4	80-85
NS Kasni	Very weak	7	5	5	10 - 15
Srem	Very strong	5	5	3	5 - 10
Rasna	Strong	7	7	3	50 - 60
Kasni Grozd.	Medium	7	7	5	5 - 10
Kasni Rodni	Weak	7	7	3	50 - 60
Milko	Strong	7	7	3	40 - 50
Sampion	Very strong	5	3	1	5 - 10
Radjevina	Strong	5	5	3	20-30
Sava	Strong	7	7	2	65 - 70
Backa	Medium	5	5	2	30 - 35
Mire	Strong	5	5	4	40 - 45
Macva	Strong	5	3	3	50 - 60
Mostonga	Medium	7	7	1	5-10
Sejnovno	Strong	5	5	4	10 - 15
Franquette	Medium	7	3	2	10 - 15

4. CONCLUSION

Despite considerable production of about 31,000 t of walnut fruits per year, the walnut production in Serbia is not even close to capacities provided by climate and soil conditions. The existing walnut population is very heterogeneous due to the fact that until recently the walnut was only propagated generatively. This has excluded the possibility of producing walnut fruits of equal quality. However, it has provided a chance of selecting high quality walnut selections. Thus five walnut varieties and several selections have been created, and they are in the final phase of examination and multiplication. The varieties Sampion and Backa and selections Nera and Sava produce fruits of highest quality.

The greatest weight was recorded for the selections Nera (16.6 g) and Sava (16.2 g) while the highest kernel percentage was recorded for the varieties Sampion (57.8%), Srem (57.6%) and Mire (56.7%). A late time of leaf bud burst is characteristic of the selections NS Kasni, Radjevina, Kasni Rodni and Kasni Grozdasti. The varieties Sampion and Mire are highly resistant to low winter temperatures, as well as the selections Sava and Mostonga. The studied varieties and selections have moderate to high resistance to *Gnomonia leptostyla*, while some are more sensitive to *Xantomonas juglandis*. The greatest lateral bearing (65 – 85%) have Nera and Sava.

Modern plantations have to be planted with healthy planting material produced exclusively by vegetative propagation. In the last thirty years, the walnut has been propagated practically only by grafting. About 10,000 ha of modern plantations have been planted, and therefore in the following period it can be expected an increase in production and quality of the walnut.

Considering that only a small part of the natural walnut population has been examined so far, and that there have been noticeable results, the work on selection should be continued and the work on hybridization should be intensified.

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