Comparison of the mid-wire cordon and the umbrella training system with the grapevine varieties 'Olaszrizling' ('Welschriesling'), 'Szürkebarát' ('Pinot gris') and 'Kéknyelű' varieties in Badacsony (Hungary)

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An experiment was carried out in 2011 and 2012 in the vineyards of the Research Institute for Viticulture and Enology in Badacsony (Hungary) with the varieties 'Szürkebarát', 'Kéknyelű' and 'Olaszrizling' to determine the advantages and disadvantages of umbrella and mid-wire cordon training systems with respect to quality and quantity parameters of the crop. Analyses of fertility rates were carried out on the one hand in the dormant period by anatomisation of the buds, on the other hand by counting the shoots per stock during vegetation. Quality and quantity parameters of the crop were determined at harvest. Results were evaluated by one-way-ANOVA. Based on our results, for 'Szürkebarát' and 'Kéknyelű' the umbrella training system is advisable because of the longer pruning elements and better canopy structure and good light penetration. In the case of 'Olaszrizling' the choice of the training system is determined by the intended quality level. For top quality wine production the mid-wire cordon, for the "everyday" wine the umbrella training system is advisable.
Keywords: pruning, crop quality and quantity, bud fertility, grape

Vergleich der mittelhohen Kordon- und der Sylvoz-Erziehung bei den Rebsorten 'Welschriesling', 'Pinot gris' und 'Kéknyelű' in Badacsony (Ungarn). *In den Jahren 2011 und 2012 wurden Untersuchungen mit den Rebsorten 'Welschriesling', 'Pinot gris' und 'Kéknyelű' im Weinforschungsinstitut von Badacsony (Ungarn) durchgeführt, um die Vor- und Nachteile der mittelhohen Kordon- und der Sylvoz-Erziehung in Bezug auf Qualität und Quantität der geernteten Trauben festzustellen. Analysen der Fruchtbarkeitsrate wurden durchgeführt zum Teil durch Sektion der Knospen im Ruhezustand, zum Teil durch Zählen der Triebe pro Weinstock in der Vegetationsperiode. Qualitative und quantitative Parameter der Trauben wurden bei der Lese bestimmt. Basierend auf unseren Ergebnissen wird die Verwendung des Sylvoz-Systems für die Rebsorten 'Szürkebarát' und 'Kéknyelű' wegen der längeren Schnittelemente, der besseren Laubwandstruktur und der guten Lichtdurchlässigkeit empfohlen. Bei 'Welschriesling' bestimmt das Produktionsziel das Erziehungssystem. Für die Produktion von Topqualitäten empfiehlt sich die Verwendung der mittelhohen Kordonerziehung, für die Herstellung von „Alltagsweinen" eher das Sylvoz-System.*
Schlagwörter: Rebschnitt, Erziehungssystem, Ertrag, Qualität, Knospenfruchtbarkeit

Grape and wine quality are determined by many factors including variety, environmental conditions of the growing area and the impacts of human activities (Zsófi et al., 2010). Vine pruning was well based on experience long before scientific methods came into being. Round the beginning of the Christian era, Virgil and Pliny gave directions for the training and pruning of vines. Without an understanding of the physiological basis, it has been common practice to remove 85 to 98 % of the annual growth of the vine at pruning, and it is still the opinion of many viticulturists that this is beneficial to the vine (Winkler et al., 1974). The grapevine is very responsive to climate. In terms of yield, it is influenced by weather conditions in both the year of the harvest and the year preceding it when the fruiting buds are formed. Warm, dry weather in the previous year, with good wood ripening weather in autumn, will result in buds with strong flowering potential for the coming year (Skelton, 2007). The potential yield of a vine is dependent on the bud fertility and on the number of buds per vine. The bud load per vine is set by management factors such as the training system and pruning (Giulivo et al., 2005). The fruiting ability of a vine is very variable and cropping levels are notoriously difficult to predict. In cooler regions where weather conditions tend to be more changeable and summer rainfall unpredictable, differences in yields between vintages are often as much as 50 %, even though the vines have been left with exactly the same amount of fruiting wood after pruning (Skelton, 2007).

Lying at the northern border of the grape growing area, grapes can be grown successfully only on special training systems in the Carpathian Basin. In this aspect, the use of the most suitable training system for the given variety is an important factor of grape growing (Bényei et al., 1999).

In the grape growing areas of the Balaton-highland as a sign of the climate change in the last years the frequency of the droughty years has notably increased. According to the observations of Diófási (1967 and 1999) in extreme years most of the varieties provide better quality wine with cordon training than with umbrella training due to the higher proportion of the woody parts.

Shoot positioning and canopy division have different effects on canopy architecture and fruit zone microclimate, they also change the canopy density. Shoot positioning resulted in a better light penetration to the fruit zones with higher leaf area, however the number of leaf layers was lower compared to non-shoot positioned canopies.This is a direct effect of vertical shoot positioning, which restricts canopy volume and produces a single column of leaf area (Gladstone and Dokoozlian, 2003).

The optimal canopy configurations must be adapted to regional climatic conditions, which will guarantee a good yield and a good quality of must and wine (Smart, 1973 and 1995). Grapevine canopy depends basically on the density of the leaf layers and on row spacing. Training systems determine the geometry of the canopy and will therefore alter grapevine canopy in influencing the degree of transmission of solar radiation into canopy interior. Other means of altering grapevine canopy are control of the vigour of vines and shoot number control. According to the observations of Barócsi and Kállai (2006) the density of the canopy increases with the increasing bud load on umbrella trained vines. A shading effect of the 30 to 40 shoots in case of the three-cane pruned vines was registered. The photosynthetically active radiation within the canopy of the high bud load treated vines was 15 to 25 % lower than in case of lower bud density. Parallel to this result the temperature within the canopy can be 1.5 °C lower in case of higher bud load, especially in the middle range of the canopy.

A comparative study of climatic variability and vine production in Hungary was carried out by Varga et al. (2007). No significant correlation was found between the temperature during the growing season and the productivity of the vine, but warmer springs had a positive effect on the yield to a certain degree depending on the location in the country. The influence of precipitation on productivity had a lower significance. Six different training systems, two levels (moderate and high) of bud load and two systems of canopy management (optimal and minimal) were evaluated by means of "phytotechnical indexes" in a comparative study carried out in large scale 'Chardonnay' vineyards. Bud fertility and number and weight of clusters were found to be the most important and sensitive parameters which show the most marked differences according to the treatments (Happ and Hegedüs, 1995).

Field experiences showed relations between training system and grape quality in other countries as well. For example own-rooted 'Seyval blanc' vines were evaluated over 5 years with 4 training systems. Cumulative yields over 5 years of the vertically shoot positioned cordon systems were higher than vines with the Sylvoz system. The average weight of cane prunings was higher with the vertically shoot positioned cordon systems than with all other systems. Vines trained to the umbrella system had more canopy gaps, less botrytis bunch rot, and higher juice soluble solids than other systems in some years, but the chemical constituents of the must and wine or sensory evaluations showed little influence of the training system (Ferree

et al., 2002).
A four-year study conducted with three red and three white commercially important French-American hybrid grape varieties to determine their responses to training systems, pruning severities, and spur lengths was carried out by Morris et al (1984). They concluded that the training system had no effect on pH or acidity, but the Geneva Double Curtain (GDC) training system produced lower contents of soluble solids.
The influence of training systems and varieties was investigated by Ollat et al. (1998) by means of the indirect method of leaf area index determination in vineyards. Although the effects of both year and variety were tested, no significant differences were found in the LAI-2000 determinations and by direct Leaf Area Index (LAI) measurements. Authors assume that the geometry of plantation and the training system are more important than variety or year.
Four grapevine training systems were compared for their effects on physiological performance, yield, vegetative growth, and must composition with the variety 'Tempranillo' in Mediterranean weather conditions. Grape yield results showed that the vertical shoot-positioned system was the most productive, adjusted for its greater pruning level. Although acceptable grape quality was obtained with all four systems, single curtain and high bush had greater total soluble solids at the expense of lower grape yield (Baeza et al., 2005).
The influence of the training system on grape and wine quality was analysed by Fazekas et al. (2012). They observed in their experiences with the 'Turan' grapevine variety, that further yield regulations (such as bunch or leaf removal) of low bud loaded vines not always result in better juice quality. In the Research Institute for Viticulture and Oenology at Kecskemét four varieties ('Chasselas blanc', 'Kerner', 'Kövidinka', 'White Riesling') were tested on sandy soils in three training systems (high-stem, moderate high and low training) in four seasons (2001 to 2004) with the aim to find varieties and training systems adapted to the ecological conditions of the Great Hungarian Plain. Winter tolerance, bud fertility, quantity and quality of clusters were studied. Trial results indicate that the genotype of the variety is the most important factor for winter tolerance, bud fertility and quantity and quality of yield; season and training systems mostly influence quantitative characters (bud fertility, cluster size). Quality is only slightly affected by them. The mean yield (11.3 t/ha) of the four varieties in the four seasons indicates that the tested varieties are adapted to high-trunk training in the wine region of the Plain, except the variety 'Chasselas blanc' Fr. 38-95, which produced little sugar in the must (Hajdu and Gábor, 2005). Aim of our study was to determine the effect of the training system on the quantitative and qualitative performance of grapevines to find out which training system is the most suitable for the Badacsony wine region Hungary for the examined varieties.

Material and methods

Location and grapevine varieties

All of the experiments were carried out in the experimental vineyards of the National Agricultural Research and Innovation Center, Institute for Viticulture and Oenology, Badacsony, Hungary. The vineyards had been established in 1994 to 1996 with the vine spacing of 2 x 1 m (Table 1). The rootstock is Berlandieri x Riparia Teleki 5C.

Variants

Cordon and umbrella training systems were applied (Fig. 1). All of the measurements were done in four repetitions by variant. One repetition consists of five stocks. 7 buds/m2 loading was applied with both training systems in the following manner: in the case of umbrella 1 piece of a 12-budded cane and 1 piece of a 2-budded spur were left by turns; in the case of cordon, 1 unilateral arm has 2 pieces of 3-budded spurs and 4 pieces of 2-budded spurs.

Measurements, statistical analysis

Bud analysis

Bud analyses were carried out in the dormant period. Five 12-budded canes were sampled randomly from the 5 stocks per treatment variant per variety per year. The number of bunches per bud was determined by anatomisation of the buds under stereo-microscope.

Analysis of fertility rates

For the determination of the fertility of the former buds, the number of shoots with and without bunches and the number of bunches per shoot were recorded by stock. For the characterisation of the productivity

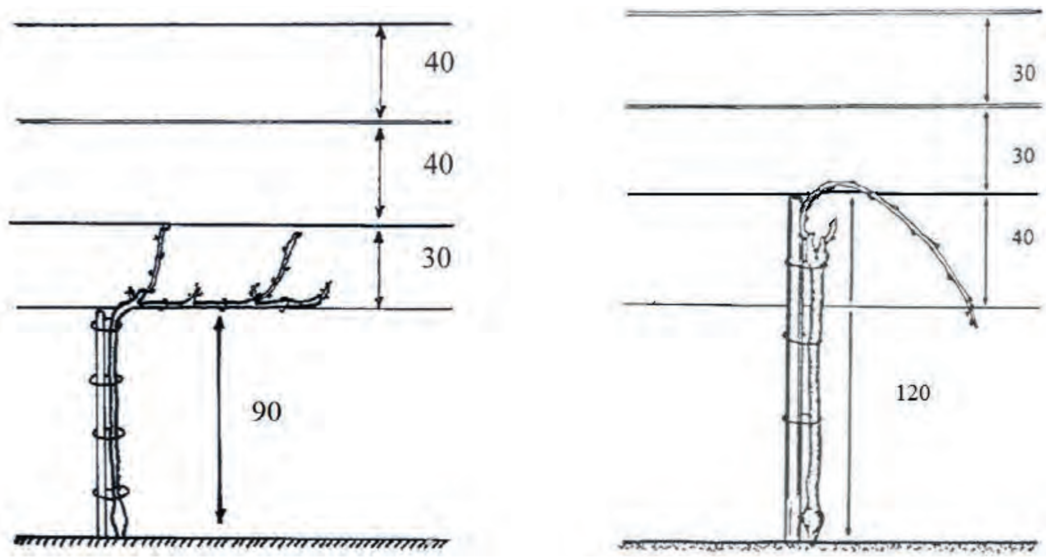

Fig. 1: Structure of cordon and umbrella training systems (Diófási, 1999)

of the stocks different coefficients were used. The absolute fertility coefficient (AFC) is the quotient of all of the bunches and the number of shoots bearing bunches, the relative fertility coefficient (RFC) is the quotient of all of the bunches and the number of shoots, as the bud fertility coefficient (BFC) is the quotient of the bunches on shoots and the number of buds (Bényei et al., 1999).

Harvest parameters, statistical analysis

In 2011 harvest was on 06.09. with 'Szürkebarát', on 26.09. with 'Kéknyelű' and on 04.10. with 'Olaszrizling'. In 2012 harvest was a week or two earlier ('Szürkebarát': 30.08.; 'Kéknyelű': 11.09.; 'Olaszrizling' :19.09.) The following parameters were determined: yield (kg/m2), acid content of the grape juice (g/l) as titratable acidity, and soluble sugar content (°Brix).
For all of the experiments one-way ANOVA was used calculated by Microsoft Excel, the level of significance was determined at p = 0.05.

Results

Meteorological data

The temperature and rainfall data of 2011 and 2012 are presented in Figures 2 and 3, respectively.

Results of bud analyses

Results of bud analyses in 2011 are presented in Table 2. Bud fertility is measured on 12-budded canes and averaged. Based on the results, it can be established, that the ratio of the injury of the main buds was lower than what the natural bud break indicated in 2011.
Relatively high differences in the bud fertility rates between variants were observed only in the case of the umbrella trained 'Kéknyelű' vines - here the fertility of the buds was higher (1.80 and 1.89 in the bunches/no. of buds and bunches/fertile buds, respectively) than with mid-wire cordon trained 'Kéknyelű' vines.
Based on the bud analyses results in 2012, it can be established, that the ratio of injured buds was higher in the case of mid-wire training (Tab. 3.).The ratio of bud injury was higher in 2012 than in 2011, which can be traced back to the lower temperature in February (Fig. 2.). The fertility of the buds in 2012 was higher in the case of umbrella-trained vines with every variety, the highest difference was observed with 'Kéknyelű'.

Analyses of fertility rates

The bunch numbers per shoot were recorded during the vegetation period, and the different coefficients were calculated as described in the material and methods section. Results are presented in Table 4.
All of the fertility coefficients were higher in both of the years and in every variety with umbrella-trained

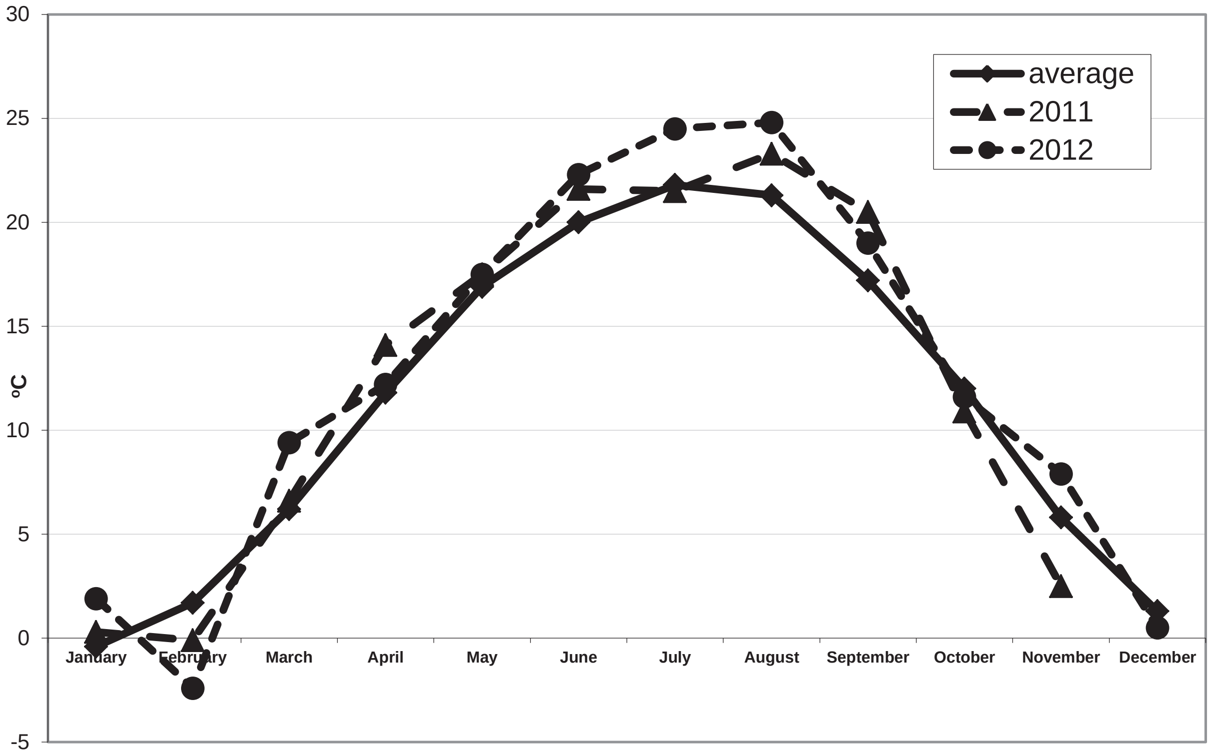

Fig. 2: Monthly average temperature data of 2011 and 2012 with respect to the 30 years average (1971 to 2000) in Badacsony, Hungary

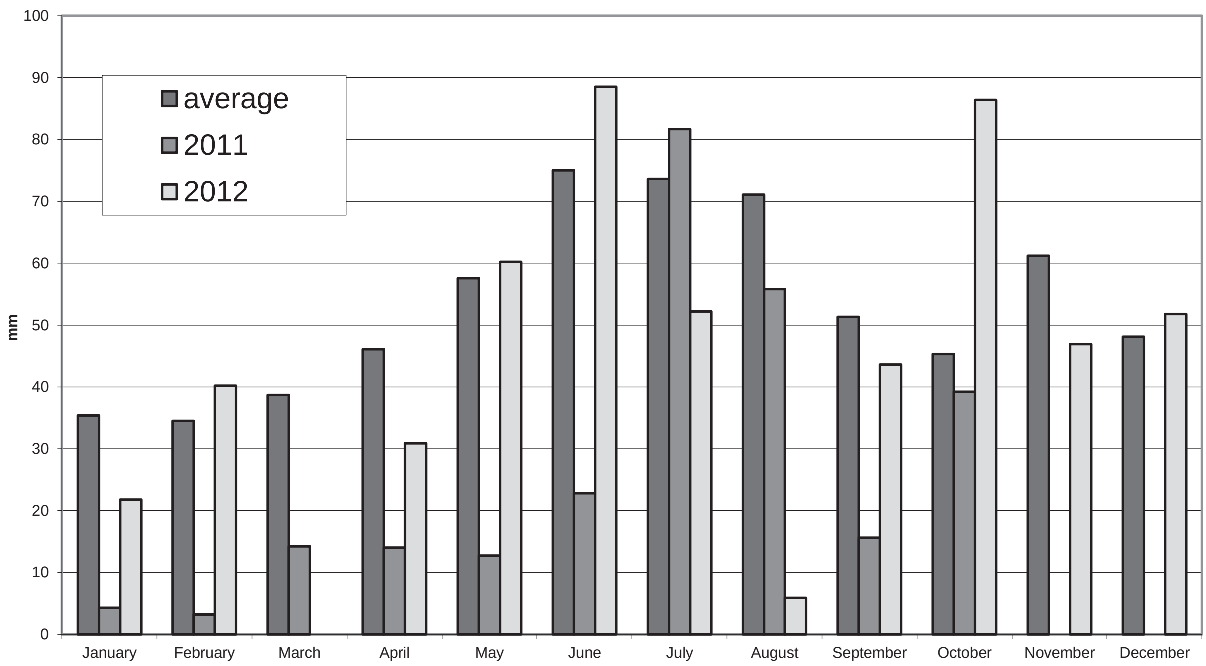

Fig. 3: Monthly rainfall data of 2011 and 2012 with respect to the 30 years average (1971 to 2000) in Badacsony, Hungary

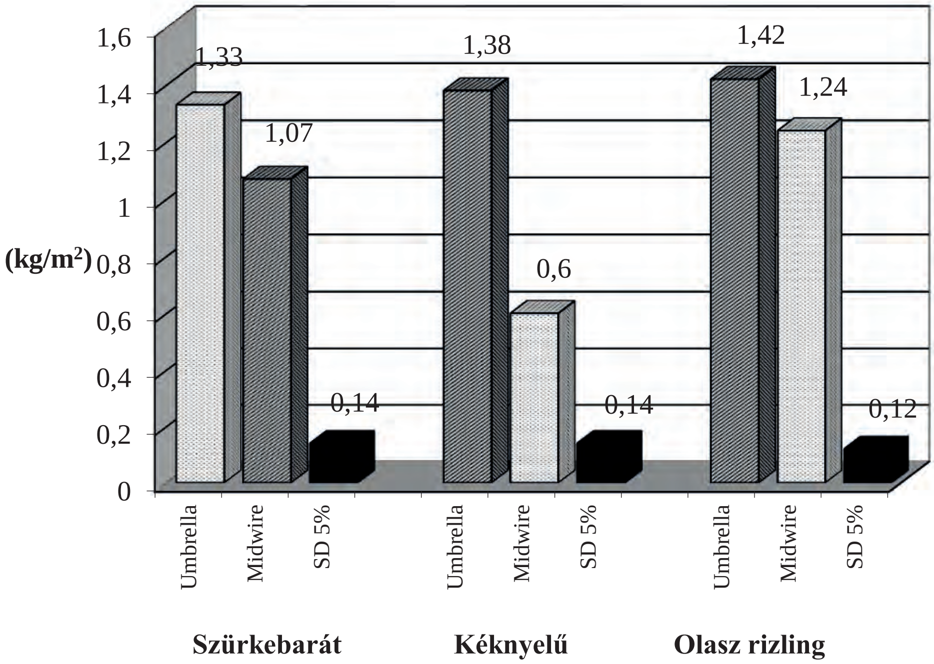

Fig. 4: Yield of grapes related to training systems in 2011 in Badacsony, Hungary

vines. The highest values by variety were observed in 'Olaszrizling' followed by 'Kéknyelű' and 'Szürkebarát'. The fertility rates were higher in 2011 than in 2012.

Harvest results

Yield

The yield of the umbrella-trained vines was significantly higher in both years. The highest difference between treatments variants was perceived in the case of 'Kéknyelű', which yielded 130 % and 37.3 % more in 2011 and in 2012, respectively. The differences in 'Szürkebarát' were 24.2 % and 19.4 %, in 'Olaszrizling' 14.5 % and 18.9% in 2011 and in 2012, respectively (Fig. 4 to 5).
The average yield was higher in 2011 (1.17 kg/m2) than in 2012 (1.14 kg/m^2). The sequence of varieties with respect to yield in both of the years was: 'Szürkebarát', 'Kéknyelű', 'Olaszrizling' (the last yielded the highest).

Sugar content of the must

Significant differences between training systems in sugar content were only observed in the case of 'Kéknyelű' and 'Olaszrizling' in 2011 (Fig. 6.). In the case of 'Szürkebarát' both the yield sugar content and the juice sugar content at harvest was higher in the case of umbrella trained vines, but this difference was not significant. The differences in sugar content in the juice at harvest were lower than in the yield. The umbrella-trained 'Kéknyelű' vines had a by 6 % lower sugar content than the mid-wire cordon trained vines. This difference was 10 % in the case of 'Olaszrizling'. Similar observations were made in 2012 in sugar content (Fig. 7). In this year, no significant differences (p = 0.05) were observed, but in the case of 'Kéknyelű', the difference between the training systems was high.

Acid content of the must, pH values

No significant differences were observed in acidity or pH values, so the detailed results are not presented.

Discussion

Bud fertility analyses

Correlations could be found between yield and fertility of vines in every case. The higher yield can be traced back to the possible higher bunch number per stock. The umbrella training system - regardless of varieties - has positive effects on the fertility of buds. This can be traced back to the better canopy configuration and increasing solar interception by the canopy surface and sunlight penetration into the canopy interior (Gladstone and Dokoozlian, 2003; Smart, 1973 and 1995), which will result in the buds being well charged with flowering potential for the coming year (Skelton, 2007).

Harvest results

'Szürkebarát'

Based on the results it can be established, that both in the aspects of quantity and quality parameters in case of 'Szürkebarát' the umbrella training system is favourable. This can be traced back to the feature generally characteristic for the convar. occidentalis varieties, where the basal buds are less fertile (Sivčev et al., 2004), and this variety needs longer pruning elements. Based on these results the umbrella training system or other systems with long pruning elements (Guyot etc.) are advisable.

'Kéknyelű'

As a convar. pontica variety 'Kéknyelű' has fertile basal buds, but this variety has flower fertility problems, which can be traced back to the functional female flowers and sterile pollen (Györffyné Jahnke and Májer, 2003). Berry set is highly influenced by the structure of the canopy of 'Kéknyelű' (Diófási and Májer, 2001). In this case - providing better canopy structure and as a result of it better sunlight penetration and fertilization - the umbrella is more favourable.

'Olaszrizling'

In the case of 'Olaszrizling', the yields were significantly higher with umbrella trained vines, but it generally coupled with lower sugar contents. This variety is suitable for high quality wine production as well as for "everyday" wines. In this aspect the choice of the training system is determined by the aim of growing. For top quality wine production the mid-wire training, for the "everyday" wine the umbrella training system is advisable.

Fig. 5: Yield of grapes related to training systems in 2012 in Badacsony, Hungary

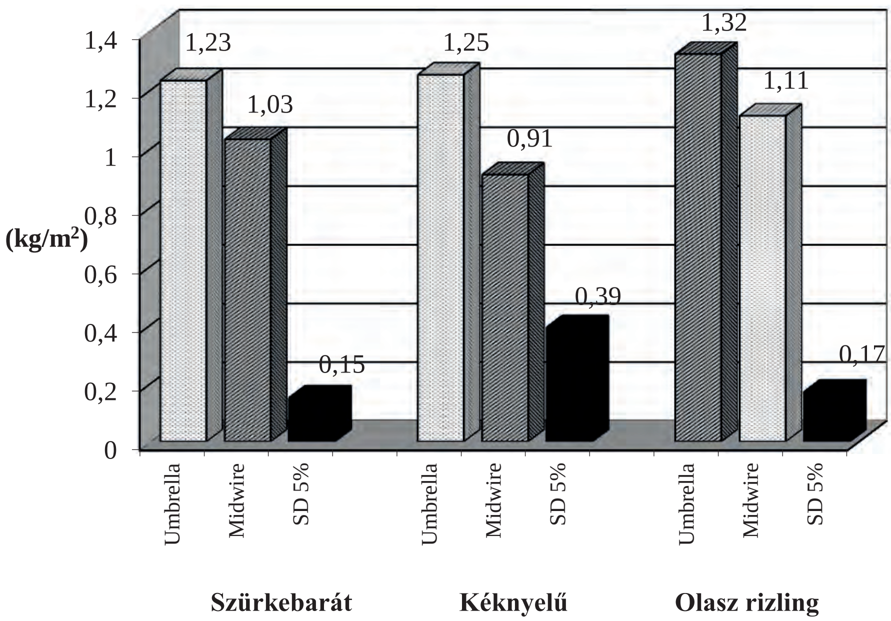

Table 1: Data of the examined vineyards at the National Agricultural Research and Innovation Center, Institute for Viticulture and Oenology, Badacsony, Hungary

Vineyard No.	Cultivar	Date of planting	District	Elevation
1	Olaszrizling	1994 - 95	1.433 ha	130 m
2	Szürkebarát	1994 - 95	0.693 ha	140 m
3	Kéknyelű	1996	1.033 ha	160 m

Table 2: Results of bud analyses (Badacsony, 2011)

Cultivar *training system*	Scale	No. of buds	Fertile buds	Injured buds	Bunches/ no. of buds	Bunches/ fertile buds
Szürkebarát *umbrella*	pieces	60	57	3	1.57	1.65
Szürkebarát *mid-wire cordon*	pieces	60	58	2	1.58	1.64
Kéknyelű *umbrella*	pieces	60	57	3	1.80	1.89
Kéknyelű *mid-wire cordon*	pieces	60	55	5	1.68	1.84
Olaszrizling *umbrella*	pieces	60	57	3	1.50	1.58
Olaszrizling *mid-wire cordon*	pieces	60	60	0	1.58	1.58

Table 3: Results of bud analyses (Badacsony, 2012)

Cultivar *training system*	Scale	No. of buds	Fertile buds	Injured buds	Bunches/ no. of buds	Bunches/ fertile buds
Szürkebarát *umbrella*	pieces	60	55	5	1,62	1,76
Szürkebarát *mid-wire cordon*	pieces	60	48	12	1,33	1,67
Kéknyelű *umbrella*	pieces	60	57	3	1,85	1,95
Kéknyelű *mid-wire cordon*	pieces	60	52	8	1,25	1,44
Olaszrizling *umbrella*	pieces	60	53	7	1,45	1,64
Olaszrizling *mid-wire cordon*	pieces	60	50	10	1,37	1,64

Table 4: Results of the analyses of fertility rates (Average of 20 stocks; Badacsony, 2011 and 2012); AFC = Absolute Fertility Coefficient, RFC = Relative Fertility Coefficient, BFC = Bud Fertility Coefficient

Cultivar *training system*	Year	AFC	RFC	BFC
Szürkebarát *umbrella*	2011	1.52	1.33	1.63
Szürkebarát *mid-wire cordon*	2011	1.46	1.30	1.41
Kéknyelű *umbrella*	2011	1.65	1.38	1.68
Kéknyelű *mid-wire cordon*	2011	1.44	1.27	1.41
Olaszrizling *umbrella*	2011	1.83	1.69	1.96
Olaszrizling *mid-wire cordon*	2011	1.67	1.53	1.64
Szürkebarát *umbrella*	2012	1.53	1.34	1.58
Szürkebarát *mid-wire cordon*	2012	1.35	1.26	1.30
Kéknyelű *umbrella*	2012	1.53	1.32	1.61
Kéknyelű *mid-wire cordon*	2012	1.35	1.25	1.41
Olaszrizling *umbrella*	2012	1.75	1.49	1.88
Olaszrizling *mid-wire cordon*	2012	1.64	1.41	1.73

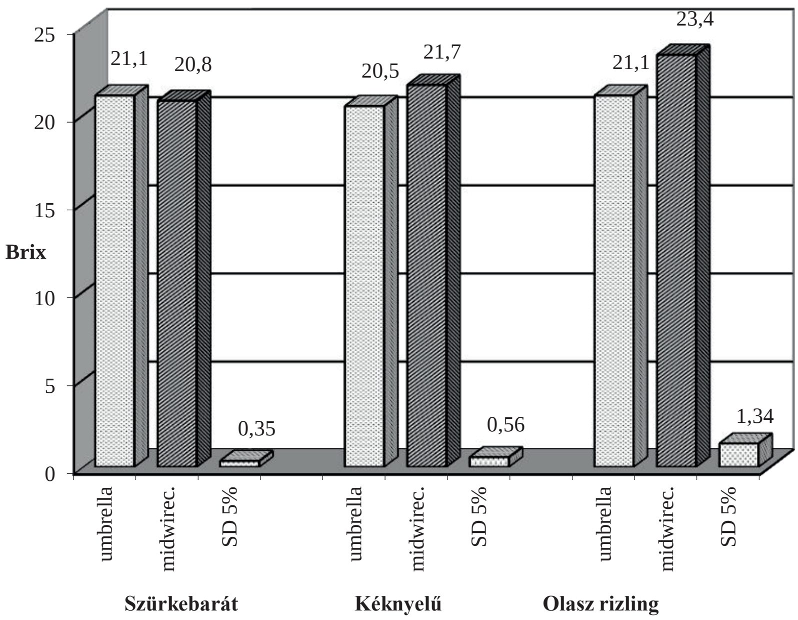

Fig. 6: Sugar content of the juice related to training systems in 2011 in Badacsony, Hungary

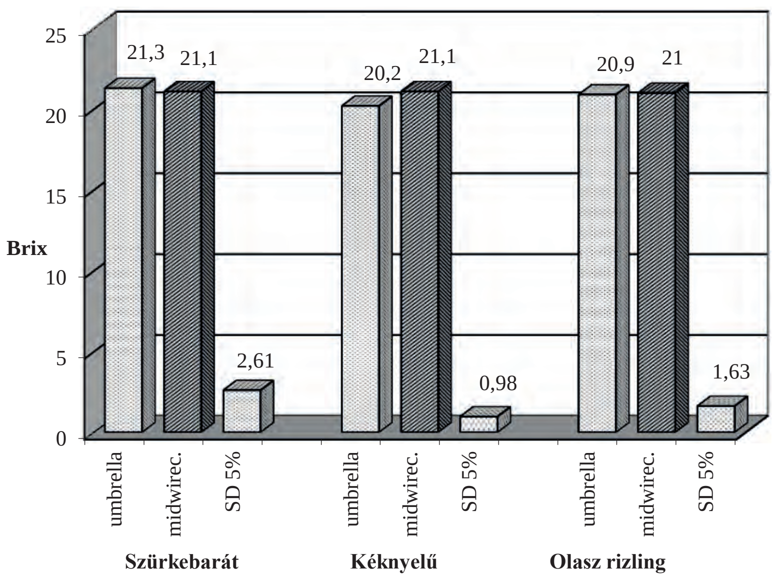

Fig. 7: Sugar content of the juice related to training systems in 2012 in Badacsony, Hungary

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