UNIVERSITY OF NOVA GORICA
COLLAGE OF VITICULTURE AND ENOLOGY

WITHIN-CLUSTER VARIABILITY OF 'RUMENI MUŠKAT' GRAPES cv. (*Vitis vinifera* L.) AS AFFECTED BY TRAINING SYSTEMS IN THE BRDA REGION

DIPLOMA THESIS

Tereza JAKIN

Mentor: doc. dr. Paolo Sivilotti

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POVZETEK

V vinogradništvu se srečujemo z številnimi različnimi gojitvenimi oblikami. Vsaka izmed njih različno vpliva na kakovost in dozorevanje grozdja. V tem dvo-letnem poskusu, ki je potekal v vinogradu v Goriških Brdih, so bili izbrani enojni Guyot, dvojni Guyot in cordon esperonato. V sezonah 2011 in 2012 so tekom leta potekale meritve; št. brstov, št. odgnanih poganjkov, količina grozdja, titrabilne kisline, vsebnost sladkorja, pH, masa odrezanega lesa... V letu 2012 so poleg že naštetih bili izmerjeni še velikost jagod in nalaganje sladkorja (sladkor/jagodo, sladkor/trto).

Pri nekaterih meritvah so se pokazale razlike med sezonama; v primeru gojitvene oblike dvojni Guyot se je v letu 2012 količina pridelka povečala, pri ostalih dveh oblikah pa je ta razlika zanemarljiva. Poleg tega je bila v letu 2012 vsebnost sladkorja in titrabilnih kislin v času trgatve višja od prejšnje sezone. Nalaganje sladkorja (sladkor/trto) je bilo v primerjavi z ostalima gojitvenima oblikama največje pri gojitveni obliki dvojni Guyot. Če sklepamo, da se kvaliteta grozdja ocenjuje po vsebnosti sladkorja, kot se to največkrat dogaja v zadružnih kleteh, je v tem primeru najboljša izbira gojitvena oblika dvojni Guyot.

SUMMARY

When we grow a grapevine, several growing systems can be adopted, with different effects on grape maturation and quality at harvest. A two-year trial was carried out in a vineyard of ‘Rumeni Muškat’ in Goriška Brda, comparing three training systems: single Guyot, double Guyot and spurred cordon. In the seasons 2011 and 2012, a set of measurements, including yield and basic quality parameters, was collected. In the last season, grapes were also sampled in order to evaluate sugar loading based on the position of bunches on the cane / cordon. The differences in yield parameters were found between the two seasons, and mainly double Guyot highlighted a significant higher production in 2012. On the other hand, the differences between the other two training system were negligible. No differences in the grape quality parameters among training systems were shown, while the values of sugars and titratable acidity at harvest were trendily higher in the season 2012. The amount of sugar loading (sugar/vine) was as a trend highest in case of double Guyot as compared with the other training systems. Thus, if the grape quality of the grapes is evaluate in terms of sugar loading, as normally happens in cooperative wineries, the double Guyot training system represent, as a trend, the best solution to earn money. .

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1. INTRODUCTION

When we look at pictures of vineyards around the world, the first question that forms in our mind is "why there are so many different ways to grow grapevines?" Actually the answer could be difficult, and maybe not really easy to find, if we are not viticulturists. From the historical point of view, the origin of training systems was related with the areas where the grapevine was domesticated and cultivated. Greeks adopted really short trunks and with not many buds retained during pruning. This strategy was dictated by the lower amount of rain, thus vines needed to be as smaller as possible and with lower yields since available water was limited. Greek style was transported to other countries (Italy, France, Spain) and survived for centuries until nowadays.

On the other hand, when the grapevine reached more northern regions, the availability of water (rainy climates) revealed to be not a limiting factor, and moreover shorter trunks demonstrated their limits since the plants were more susceptible to disease (higher humidity). Thus, the Etruscan viticulture was completely on opposite style as compared with Greek technique, with high trunks, long cordons and cane-pruned shoots; the abundance of water was also profitable for an increase of yield (Estreicher, 2006).

More recently looking at what happened till the sixties, the main goal of winegrowers was to maximize yield, thus larger training systems were adopted. In the last decades the customers required high quality wines, since several secondary metabolites of the grapes (polyphenols mainly) revealed to have healthy properties (Corder *et al.* 2006). The researchers that experienced field comparisons of crop loads ascertained a negative relationship between yield and quality parameters, thus new vineyards were designed with higher plant densities, in order to reduce to plant production obtaining higher quality (Winkler *et al*., 1974).

1.1 Training systems

Within the category of hedgerow training systems with non-divided canopy, a broad distinction can be attempted by separating them into long (Guyot) and short (spurred –

cordon) pruning. There are some well-documented advantages for the latter, such as more uniform shoot growth, higher capacity for reserve storage, and reduced time for winter pruning (Howell *et al*., 1987; Intrieri and Poni, 1995; Tassie and Freeman, 1992). It is strange why this training system was not widespread adopted at least in European countries. Spur pruning has failed to gain broader appeal among growers because of concern about maintenance of cordon health and productivity compared with cane pruning. Cane pruning is considered efficient, with consistent yield potential because the most fruitful nodes are retained. Attempts to convert old cane-pruned vines with large within-row spacing into spure-pruned vineyards in order to reduce management costs (Kasimatis *et al.*, 1985) were sought on Cabernet in Guyot plantings with scarce results.

As a general overview, training systems can be derived from four basic combinations (Reynolds and Vanden Heuvel, 2009):

- head/spur: a short trunk and several two-node bearing units – bush vine;
- head/cane: a short trunk with one or more longer bearing units – Guyot;
- cordon/spur: horizontal extension of the trunk with several two-node spurs – spured cordon)
- cordon/cane: similar to head/spur but with longer bearing units – Sylvoz.

1.1.1 Guyot training

Cane pruning is especially appropriate for cultivars producing small clusters that need the retention of extra buds. Long canes are profitable in order to enhance vine capacity by retaining more apically positioned buds, which are generally more fruitful than basals. Thus cane pruning is particularly important for cultivars that produce sterile o low-fertile base buds. Because the crop develops from only a few canes, particular care must be taken in choosing them. The long length of bearing wood can result in uneven shot development owing to apical dominance (Jackson, 2008).

Guyot training system can be single or double, with the vines trained to a low head 0.9 m above ground. Chosen canes have 8-12 buds (depending on cultivar and intra-row distance) and are tied straight to a wire or bended over it. Renewal spurs are retained in

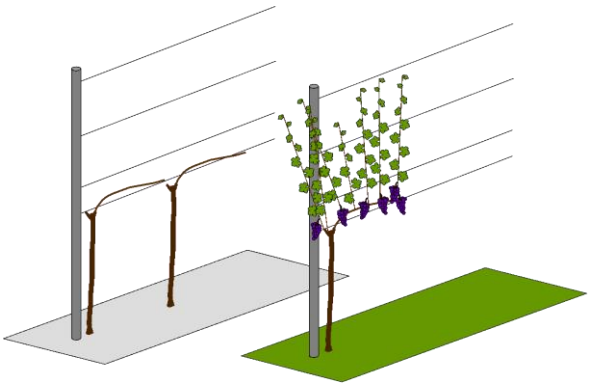
the head of the vine to develop future fruiting canes (Vineyard store, 2012). It is currently the most widely practiced in all the conditions of high plant productivity.

1.1.2 Spurred cordon

Spur pruning tends to show properties that are the opposite of cane pruning. Because of its greater simplicity and uniformity, spur pruning requires less skill. If spurs are located equidistant from the ground, the resulting absence of apical dominance favours uniform bud-break. The tendency of spur pruning to limit productivity can be either beneficial or detrimental, depending on the vigour and vine capacity (Reynolds, 1989). The reduced production might be compensated retaining more buds. Cluster and berry size are generally reduced with spur pruning. Spurs are usually left with two nodes, but occasionally may be reduced to one node for bountiful varieties such as 'Rumeni Muškat' (Jackson, 2008).

The spurred cordon is a training system that is suitable for varieties with fruiting buds at the base of the branches, and so it is not recommended for varieties with low fertility. The system of pruning consists of a horizontal cordon placed at 0,9-1,0 m above the ground, on which several spurs (12-14 buds in total) are retained. One of the features not to be overlooked in this pruning system is the plant density, which means the inter-row and basically the intra-row distance (since longer cordons easily undergo throughout reduction of vitality). Since plant size affects also plant productivity, shorted cordons are more profitable for an increased grape quality (Vineyard store, 2012).

SINGLE GUYOT



DOUBLE GUYOT

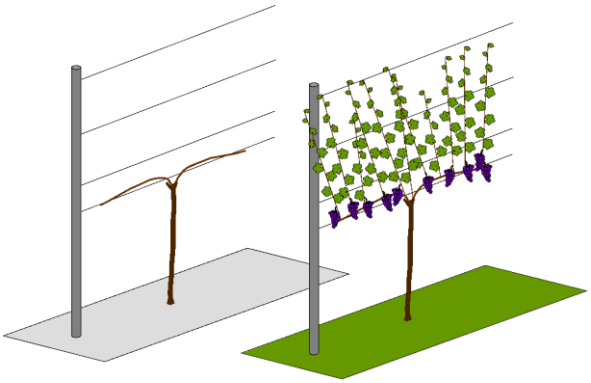


Figure 1: Single and Double Guyot training systems in winter and summer time.

SPURRED CORDON

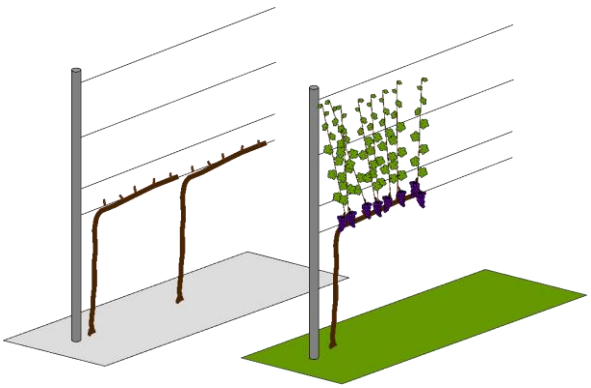


Figure 2: Spurred cordon training system spurred cordon in winter and summer time

1.2 The purpose of pruning

With the word pruning we mean the removal of shoots or canes in winter and /or summer, while training system refers to the trellising used to support, conduct and configure the vine. The major purpose of dormant pruning is to regulate crop size in order to balance the leaf area with crop load thus obtaining a good grape maturation (Dokoozlian and Kliewer, 1995). Generally, more nodes are left on spurs or canes after winter pruning and higher will be the grape production.

Winter pruning is the primary tool adopted to restrict grapevine yield. However, as a perennial crop, the vine stores considerable energy reserves in woody parts. Thus pruning removes nutrients that limit the ability of the vine to initiate rapid growth in the spring. Vines with little mature wood are less able to ripen their crop in poor years than vines with larger cordons or trunks.

1.3 Effects of training systems on yield and quality

Early in the past 20th century, plant physiologists provided the scientific basis for the concept that the active leaf area of a vine is the unit that determines the amount, composition, and wine quality of the crop (Winkler *et al*., 1974).

Grape quality expression was shown related with a particular training system, since it is correlated with light interception (Smart, 1984) and the microclimate inside the canopy and around the clusters (Gladstone and Dokoozlian, 2003). The distribution of the shoots, as imposed with training system, is affected by varietal behaviour resulting in different vigour gradients and assimilate partitioning and with important repercussions on grape and wine quality.

Vitis vinifera vines trained on divided canopy (horizontal or vertical) tend to produce higher yields than those on non-divided canopies, generally because of improved exposed leaf area and light interception, as well as the great number of buds per row that are retained at pruning (Bravdo *et al*., 1985). Generally, increases in yield due to training system tend to result from increases in cluster numbers per vine. Among all of

training systems studies, Alichev *et al.,* (1973) and Howell *et al*., (1991) revealed a direct relationship between fruitfulness and trunk height.

Significant impacts of microclimate resulting from training have been demonstrated on fruit composition and on wine sensory analysis (Peterlunger *et al.,* 2002).

1.4 Berry weight and composition

Berry weight and composition are controlled by complex interactions among genotype, environmental factors and viticulture practice. Both (mean) value and variation range in berry composition play a role in berry and wine quality.

Environmental factors (temperature, sunlight, soil) and viticulture practices (irrigation, pruning, cluster thinning) are known to cause variability within berries, among berries within clusters, among clusters on vine and among vines within vineyard (Gray, 2002; Keller, 2010). This variability can be seen as a benefit or a burden. Genetic variability offers advantages to adapt existing cultivars to a specific growing region, to produce a wide range of different wines from the same cultivar, or to breed new cultivars well adapted to a different specific growing area. On the other hand given variability in response to environmental conditions and viticulture practices may be considered a disadvantage, because it may cause uneven maturity (Selvaraj *et al.*, 1995).

Berry weight within a cluster depends on berry position within the cluster. Berries at the tip (distal end) of a cluster weight significantly less then berries at the centre or shoulder (Pagay and Cheng, 2010; Tarter and Keuter, 2005).

Among grape quality parameters, sugar accumulation and secondary metabolites are the more interested from the enological point of view.

Berry sugar concentration is a relatively stable trait for a given cultivar, being less responsive to environmental conditions and viticulture practices than organic acids (Keller *et al*., 2005). Analysing the compositional change of berries of different sizes, Šuklje *et al.,* (2012) found that despite of similar values in soluble solid concentration in berries, the amounts of methoxypyrazines were much higher in bigger berries than in smaller ones. Thus the accumulation of primary and secondary metabolites is thought to be somehow independent.

1.5 Terroir and grape quality

Season meteorological course has been reported to have a significant effect on wine quality. According to Becker (1985), climatic effect on quality is typical: "in cooler climates white wines are fresher, more acidic and finer in bouquet and aroma; wines produced in warm-regions yield higher alcohol and shorter taste and aroma." Considering one grape variety, the effect of "terroir" always accounts for some typical characteristics in wines. Moreover, in different seasons, wine quality could be significantly different as related with the temperatures during maturation. Therefore for each region, the best variety will be the one that matches the length of the growing season, so that the maturation will occur during the cool part of the season but warm enough to continue soluble solids accumulation and flavour development in the berries. An overview of world viticulture areas would seem to indicate a clear link between climate and grape quality. When in a viticultural area the summer temperatures satisfy the thermal requirement of a specific grape cultivar to ripen, the quality will be not profitably improve because of warmer or longer summers. The evaluation of grapevine variability (both genetic diversity and phenotypic plasticity) is further modified also by the on-going climate changing, which may alter the adaptation of a cultivar to a specific growing season (Bindi *et al.*, 1996; Duchêne *et al.*, 2010). Overall, climate change will modify the whole physiology of grapevine, with strong effects also on wine quality (Jones *et al.*, 2005; Schultz, 2000).

2. AIM OF THESIS

The experiment was carried out with the aim to find out how training systems could affect the yield parameters and the berry components of ‘Rumeni Muškat’ grapes. Thus a two-year trial was carried out in a vineyard positioned on a hilly side within the Brda region. We wanted to investigate the physiological changings induced by cane and spur pruning, in detail comparing double and single Guyot (as cane pruning training systems) with spurred cordon.

Since double and single training systems creates a different shoot development as related with the position along the cane, in the season 2012 grapes were collected in different positions (basal, median and ending nodes along the cane) in order to discover the effect of cluster position on berry size variability and on sugar loading at berry, cluster and plant level.

3. METHODS AND MATERIALS

3.1 Meteorological season course in 2011 and 2012

The meteorological data were obtained from the weather station sited in Bilje that belongs to the environmental agency of Slovenia republic (ARSO). (http://meteo.arso.gov.si/met/sl/app/webmet/#webmet==8Sdwx2bhR2cv0WZ0V2bvEGcw9ydlJWblR3LwVnaz9SYtVmYh9iclFGbt9SaulGdugXbsx3cs9mdl5WahxXYyNGapZXZ8tHZv1WYp5mOnMHbvZXZulWYnwCchJXYtVGdlJnOn0UQQdSf;)

After a really cold season in 2010, the two following 2011 and 2012 were characterised by sunny days, high temperatures and not much rain.

The spring 2011 was relatively warm with an average temperature of 10^{o}C (figure 3). In March the season started with a hurricanic bora that caused some damages in western part of Slovenia. In the middle of the same month, a few days of rain occurred and the temperatures started to rise in the following period. Both April and May were extremely dry and there were already signs of water stress even though two big downpours (even 384 mm/hour) have occurred. However, a catastrophic hail storm in July involved the most part of Goriška Brda region. The damage was extensive; in some parts of the land the yield in the vineyards was completely destroyed. Going on throughout the season, the beginning of August was relatively cold but quickly changed in the second half of the month with enhanced temperatures and a lack of rains that caused again some problems of water stress (even if not much dangerous). At that time the harvest started and lasted on the middle of September for the late ripening varieties. September was a very hot month in comparison with the historical mean, being the temperatures around 4^{o}C above the average.

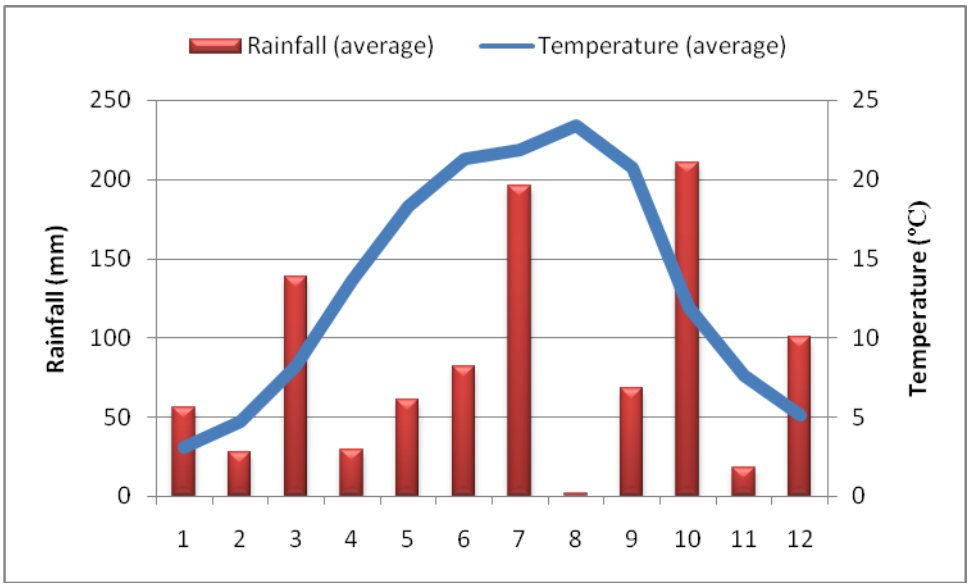


Figure 3: Average month temperature and cumulative month rainfall in 2011 (data collected in the weather station of ARSO located in Bilje).

During the winter 2012 the average temperatures sometimes peaked around 10°C, with the exception of February, to be remember as the coldest year after 1956 (figure 4). A lot of damages were signalled due to the new occurrence of the hurricanic bora. The beginning of the growing season was characterized by a lack of rains, and because of that the plants suffered of water stress already in March. Opposite conditions in April where a few rain events occurred, as typically happens during the spring in the region. The temperatures increased in May, and in June also peaked above 30°C. From this time on, there was a massive drought in July and in August which caused almost a 30% of yield reduction, mainly for some varieties (Bigot *et al.*, 2012). Because of the particular season course of temperatures and water stress, the harvest started in second decade of August.

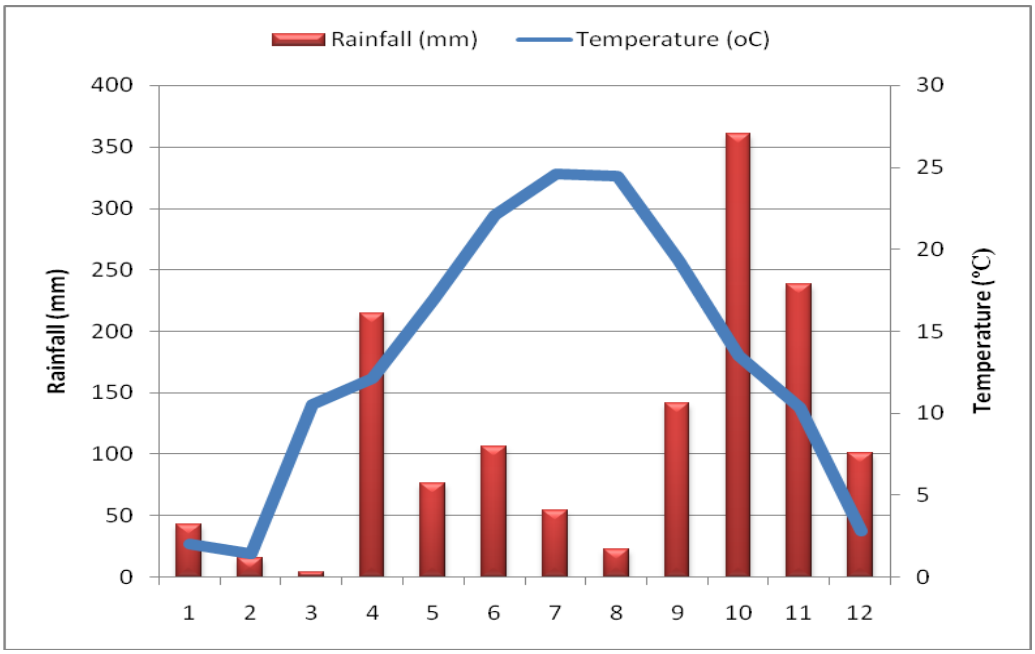


Figure 4: Average month temperature and cumulative month rainfall in 2012 (data collected in the weather station of ARSO located in Bilje).

3.2 Description of Brda location

A vineyard of 'Rumeni Muškat' was planted in the year 1998 (150 vines) in a field located in the hills of Brda region. Because of the excessive slope, the land was settled with terraces exposed towards East. Three rows were planted per each terrace, and in the top of the hill the vineyard was dedicated to the 'Rumeni Muškat' (548 m^2; figure 5). The row orientation is South-East and the plant density of 4000 plants/ha (1 m within rows and 2,5 m between rows). Since the vineyard is located in the hills, the irrigation was not possible at all. The vineyard inter-row was managed with spontaneous cover crops. Soil in this part is light, mainly sand and marl. Light soils are usually well drained and aerated, but because of the large pores they retain relatively little water.

Figure 5: Aerial image of vineyard parcels in the Brda region, with a detail of parcel borders. Blue parcel represents 'Rumeni Muškat' vineyard.

3.3 Experimental design and data collected

The vineyard was divided in three parcels, and within each of them one training system was imposed. Single Guyot, double Guyot and Spurred cordon were selected as the training systems to compare. From each training system 20 vines were randomly selected for data collection.

All training systems shared the same trellis frame, with a main supporting wire holding the cane at 1,1m aboveground surmounted by a pair of wires at 1,7m above ground. The frame was the same with spurred cordon, but the cane (cordon) was tied to main wire.

In winter time all selected vines were pruned.

In case of the single Guyot one cane with 8-12 buds and one spur were retained, while in case of double Guyot, 2 canes with 8-10 buds were left. Canes were tied on one side (single Guyot) or two sides (double Guyot) over the main wire (figure 1). When spurred cordon was pruned, 6-7 spures with 1-2 buds were retained.

At budburst all shoots were counted, and later in the summer also the clusters were computed in the vines selected for this trial. At harvest time clusters from each vine were weighted in order to evaluate yield and average cluster weight.

Before winter pruning, the pruning weight was collected for each vine and Ravaz index calculated by rating total yield per vine and pruning weight (Maccarone and Scienza, 1996). Balanced vines should provide a Ravaz index in between 5 and 10 (<5 under cropped, >10 = over cropped vines).

In both seasons (2011 and 2012) grapes were sampled three times before harvesting. Two hundred berries were chosen randomly from each training system without replicates. Berries were crushed and measured for titratable acidity, pH and soluble solids (Brix). pH was measured with a pH meter and soluble solids with digital refractometer. Titratable acidity was measured with titration with bromothymol blue. Samples of 25 ml were taken and heated to expel carbon dioxide. Thereafter, each sample was cooled to 20^{o}C and 2-3 drops of bromothymol blue indicator were added. Sample was then titrated with 0,25M NaOH, till it changed colour. Relative standard deviation of total soluble solids, titratable acidity and pH was calculated using sets of data with replicates of many experiments carried out in Italy and Slovenia on several grape varieties (Sivilotti, unpublished). The standard deviation for the present experiment was thereafter computed.

In season 2012 three clusters from each training systems were collected from the end, centre and base of the cane / cordon of the vine. Clusters from each position were destemmed. Berries were divided by size in categories; 8mm, 9-10mm, 11-12mm, 13-14mm, 15-16mm and 17mm. Berries from each category were counted and weighted.

The different categories of berries were crushed and measured for soluble solids (Brix). Since the aim of this measurement was to determine the amount of sugar loaded per plant, Brix (1) was first converted to BABO (2); thereafter, sugar loading per berry (mg of sugar/berry, 3), per cluster (g/cluster, 4), and per vine (g/vine, 5) was calculated.

Brix = g/100 ml (1)

*BABO = 0,907*Brix - 1,4222* (2)

*Sugar loading x berry = BABO * berry weight* (3)

*Sugar loading x cluster = sugar loading x berry * (berries x cluster)* (4)

*Sugar loading x vine = sugar loading x cluster * (number of clusters x vine)* (5)

In all the figures, the standard deviation was reported when available. Standard deviation shows how much variation or dispersion exists from the average (mean, or expected value). A low standard deviation indicates that the data points tend to be very close to the mean; high standard deviation indicates that the data points are spread out over a large range of values.

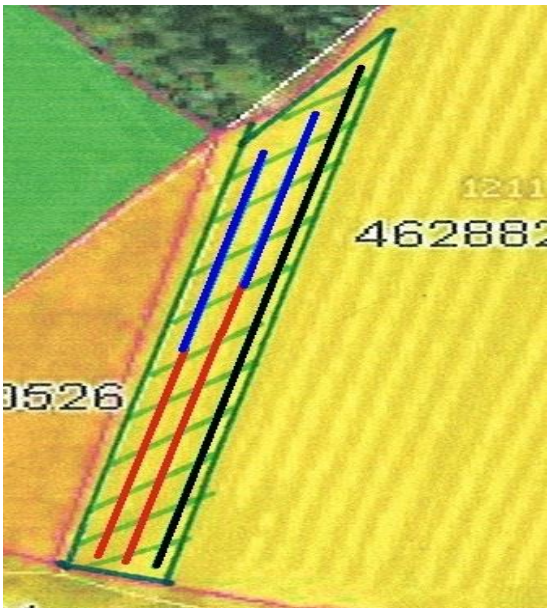


Figure 6: Detail of the experimental design (black line spurred cordon, red line single Guyot, blue line double Guyot)

3.4 'Rumeni Muškat'

Muscat grape varieties constitute an integral part of the world's grape growing and winemaking heritage. There are more than 150 Muscat varieties, whether red or white, whether used in winemaking or as table grapes and whether *Vitis vinifera* or hybrids, all Muscat varieties are characterized by their muscat aroma. Each muscat produces, with subtle variation, wines with the distinct, intense, aromatic, rosy-sweet, and easily-recognized scent of muscat and, unusual for most wine varieties, that actually taste like grapes. The muscat family has two main branches, one based on Muscat Blanc, one on Muscat of Alexandria. Of over twenty identified distinct varieties of the muscat grape, the most desirable for wine due to its powerful aromatic intensity is Muscat Blanc, known as Muscat de Frontignan in France and Moscato di Canelli in Italy. (Lamar, 2001).

Figure 7:'Rumeni Muškat' grapes (http://catalogoviti.politicheagricole.it)

4. RESULTS

The training systems compared in the present experiment highlighted several differences among them, and these will be discussed in detail in the following pages.

4.1 Bud number and bud fertility

The buds retained with pruning are not the same in different training systems and because of the meteorological season course of the previous season, the shoot maturity and thus bud fruitfulness can be significantly affected (Winkler *et al.*, 1974).

The number of buds retained in double Guyot was nearly double than in single Guyot and spurred cordon in both seasons, but mainly in 2011 (figure 8A).

As discussed above, regarding the effect of meteorological season course (see page 9, 10 and 11), it can be useful also to discuss the results of bud fertility. In the season 2011 the average bud fertility was around 0,8 clusters/retained bud, while the value in the following season 2012 was enhanced to 1,3 clusters/retained bud (figure 8B). The lower values showed for the season 2011, were related to the weather conditions in the previous year 2010. In the following season 2012 the bud fertility was found improved because the shoots and the buds could profit of the better meteorological conditions in the season 2011. The viability of bud and flower development is largely affected by the crop load and by the leaf area-to-crop ratio in the previous season when the bud primordia are first formed (Srinivasan and Mullins, 1981). Over-cropped vines will normally bear weaker buds and poor pollinating flowers in the following season; this results in a lower yield. In the year 2010 the rain was abundant and thus also the grape production; moreover, the low temperatures were not profitable for a good maturation of the shoots, probably with negative effects on bud fertility in the following season. While bud fertility was nearly the same in the different training systems in 2011, in the following season 2012 bud fertility was as a trend higher in case of cane training systems (single and double Guyot) mainly in case of double Guyot. Normally the fruitfulness of basal buds is lower that the following ones, thus when canes are well

developed the total fertility of cane training systems is normally higher than in spurred cordon.

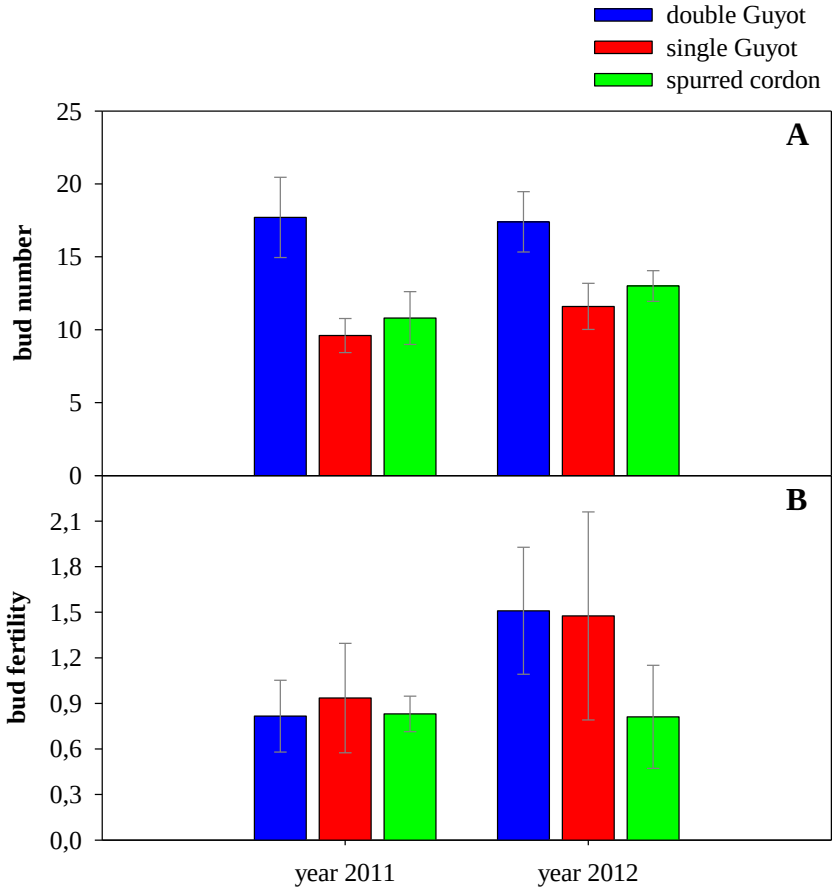


Figure 8: (A) buds retained with winter pruning and (B) effect of training system on total bud fertility. Bars represent SD.

4.2 Number of shoots and shoots bearing clusters

The sprouting of shoots is connected to the particular training system adopted, since some conditions like cane curving are particularly profitable for an increase of bud-burst. In the present experiment, the adoption of double Guyot highlighted a significant higher number of shoots per vine (figure 9A), and this can be easily explain since there are two canes which are curved instead of one (single Guyot). On the other hand, for spurred cordon the vertical position of the retained spurs allow the shoots to grow

especially on the last bud (since grapevine has an acropetal growing behaviour), and this limits the development of basal buds (Winkler *et al*., 1984).

The number of shoots is not related directly with bud fertility, since not all shoots normally yield clusters.

Related to the previous parameter, the shoots bearing clusters revealed some differences among training systems (figure 9B). In the season 2012 the double Guyot training system reported the highest values of shoots bearing clusters, and the spurred cordon the lowest. In the previous season, the values were nearly the same among all training systems compared.

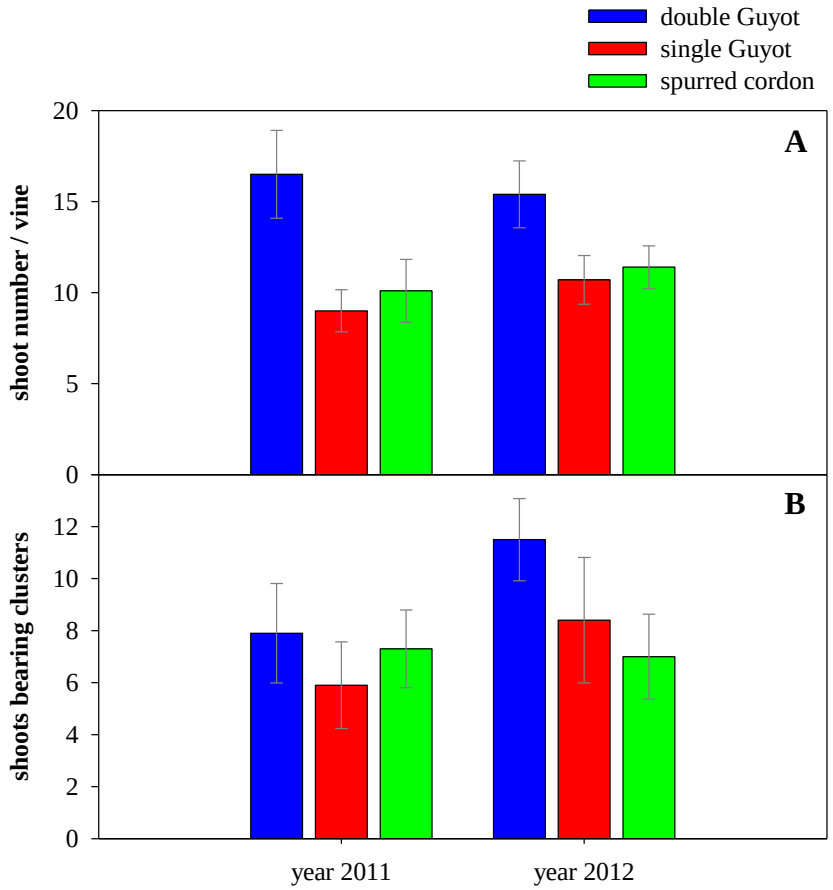


Figure 9: Effect of training system on shoot number (A) and on shoot bearing clusters (B). Bars represent SD.

4.3 Yield parameters

The yield parameters that will be presented in this paragraph are well related with the already discussed data of bud fertility.

In the season 2011 the number of clusters/vine were trendily lower than in 2012 (figure 10A), nearly completely in accordance with bud fertility (figure 8B). In 2011, double Guyot reported more shoots with clusters (figure 9B), but the number of clusters/vine was the same as in the other training systems. Moreover, in 2012 bud fertility was higher in case of both cane training systems (single and double Guyot) but for double Guyot the number of clusters per shoot was trendily much higher (up to 4). In case of spurred cordon it is possible to observe a stability of data between the two seasons, both in terms of bud fertility (figure 8B) and number of clusters/vine (figure 10A). This fact definitely has to be related with the constant fertility of the basal buds in case of spur pruned training systems.

Similar results were also shown in case of the yield per vine (figure 10B). In the season 2011 the single and the double Guyot had nearly the same yield, while was slightly (but not significantly) lower in case of Spurred cordon. The discrepancy between yield and number of clusters in case of single Guyot in 2011 is related to the average cluster weight (figure 10C), that was trendily higher for this training system. This fact was probably due to a compensation effect between number of clusters and cluster weight. The difference in yield between the two years was huge, mainly in case of double Guyot, with an increase of almost 2 kg/vine. As discussed above the number of clusters in the double Guyot training system was much higher in 2012 than in previous season, and this could explain alone the increase in yield as compared with single Guyot (no differences in average cluster weight; figure 10C). In both years the spurred cordon training system reported trendily a lower yield as compared to double Guyot mainly because of a reduced number of clusters (figure 10A). Bernizzoni *et al.,* (2009) and Peterlunger *et al*., (2002) already reported that spur pruned training systems tends to reduce the average cluster weight as compared with cane pruning.

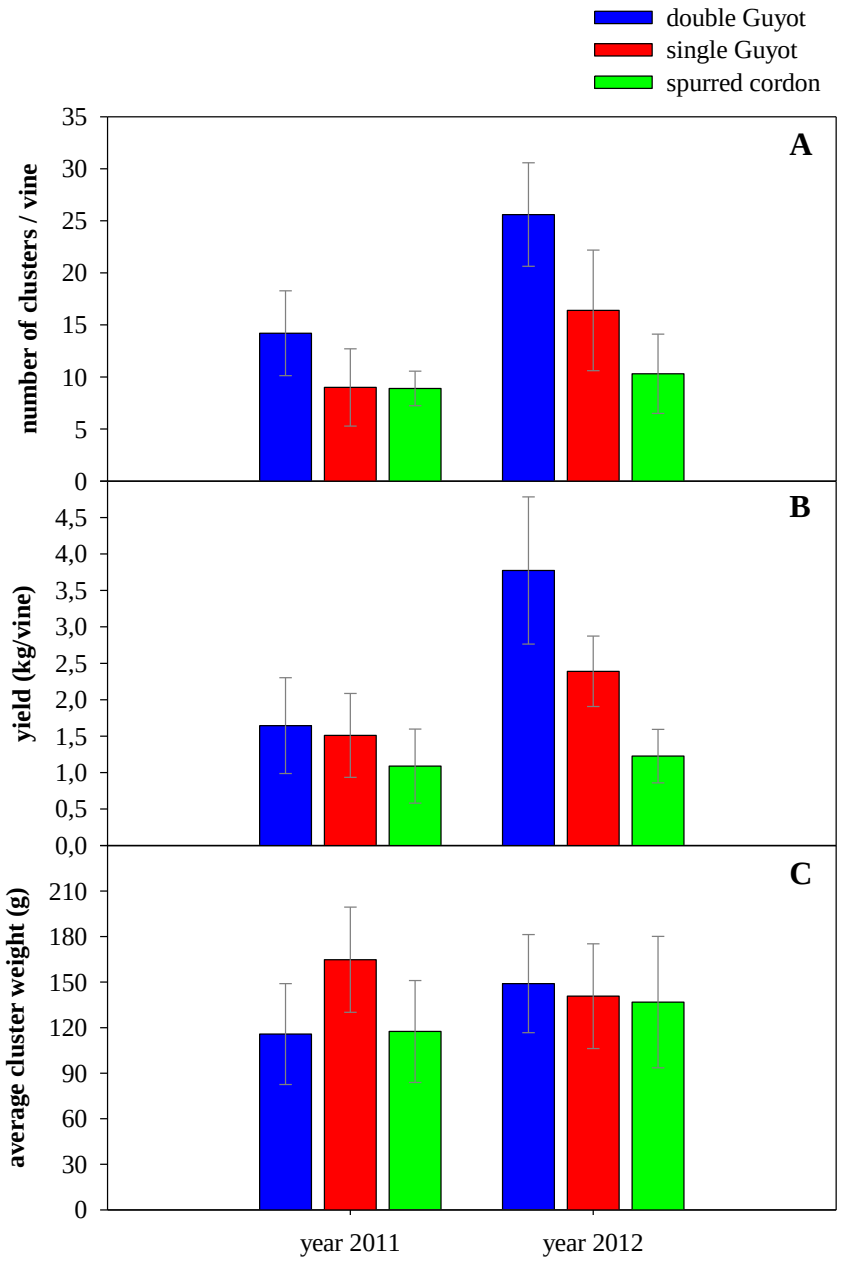


Figure 10: Effect of training system on the number of clustes/vine (A), the yield/vine (B) and the average cluster weight (C). Bars represent SD.

4.4 Pruning weight and Ravaz Index

There were small differences in terms of pruning weight among training system in both seasons (figure 11A), even if slightly but not significant higher values were shown in case of single Guyot, and lower for double Guyot (mainly in 2011) and spurred cordon training systems.

Thus Ravaz Index (figure 11B) - which is the ratio between yield and pruning weight - changed basically because of yield variations (figure 10B). In the year 2011, the values of the index were generally low but not significant differences were ascertained among training systems. By comparing the values of the index, the vines trained with spurred cordon reported a situation of under cropping (2,97), while double Guyot was the only one training system that reported a well-balanced Ravaz index (Maccarone and Scienza, 1996) in the same year (5,44). The values of the index were enhanced in 2012, but mainly for single (trendily) and double Guyot (significantly), while in case of spurred cordon Ravaz Index was again in the range of under cropping (3,72).

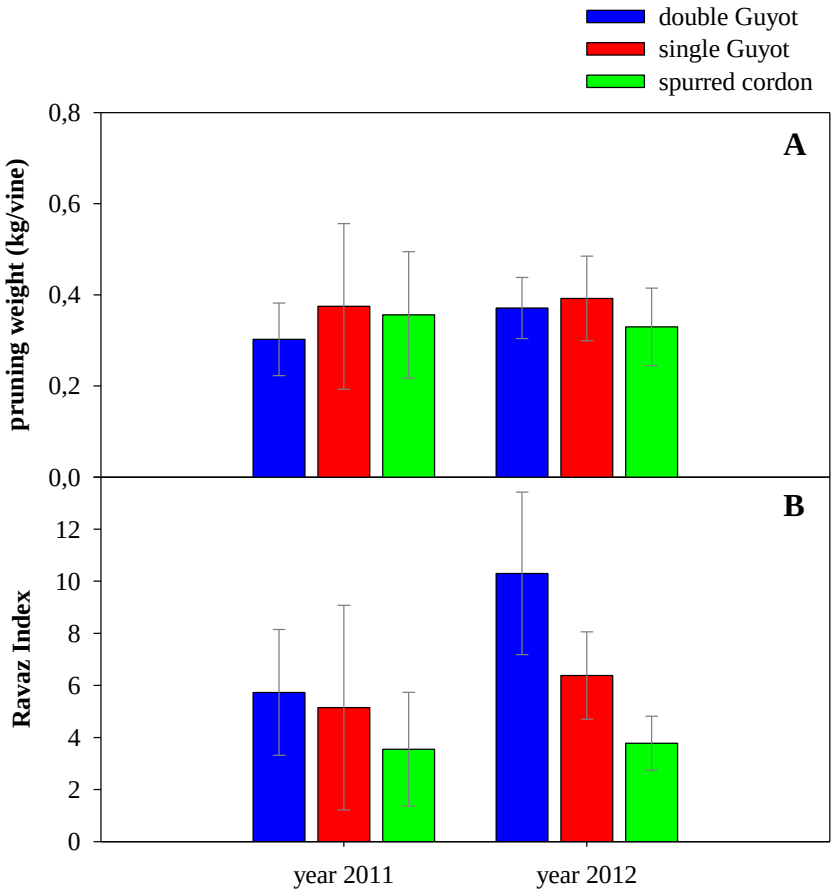


Figure 11: Effect of training system on pruning weight (A) and Ravaz Index (B): Bars represent SD.

4.5 Grape quality during maturation

The evolution of quality parameters during maturation was similar comparing the two seasons, but the differences among training systems were not the same in 2011 and 2012.

During maturation and at harvest in season 2011, no differences among training systems were shown. At harvest time the average of soluble solids (Brix; figure 12A) in all training systems was around 21 Brix with slightly higher values in case of double Guyot. In the following season 2012 (figure 12B), the soluble solids were increased as compared with the previous year. At first sampling the amount of soluble solids was already around 20 Brix while at approximately the same date in 2011 the values were around 15 Brix. At last point of maturation, nearby harvest, the soluble solids reached 21,5 and 23,7 Brix in 2011 and 2012, respectively. The highest values of soluble solids in 2012 has to be related to the higher temperatures and water stress that occurred in the last part of maturation as compared with 2011.

In the year 2011 the training systems did not report wide differences in yield (figure 10A), thus was the same also for soluble solids. On the other hand, double Guyot reported the highest grape production in 2012 (figure 10B), followed by single Guyot and spurred cordon. Even if no statistical speculation can be made, the values of soluble solids were exactly in opposite order, since there is a well-known inverse relationship between yield and soluble solids (Jackson and Lombard, 1993).

As shown for soluble solids in 2011, also titratable acidity (figure 12C) did not highlighted differences among training systems. At harvest time titratable acidity was slightly higher only in case of spurred cordon, while lower values were found in case of single Guyot. In the following season 2012, at two first sampling points a difference between double Guyot and the other two training systems was found (figure 12D). For double Guyot, titratable acidity was trendily higher as compared to the other two training systems. Anyway, at harvest time all three training systems reported nearly similar values of titratable acidity. Since the measurements were not replicated, any statistical speculation on total soluble solids, titratable acidity and also pH (figures 12E and 12F) is not possible.

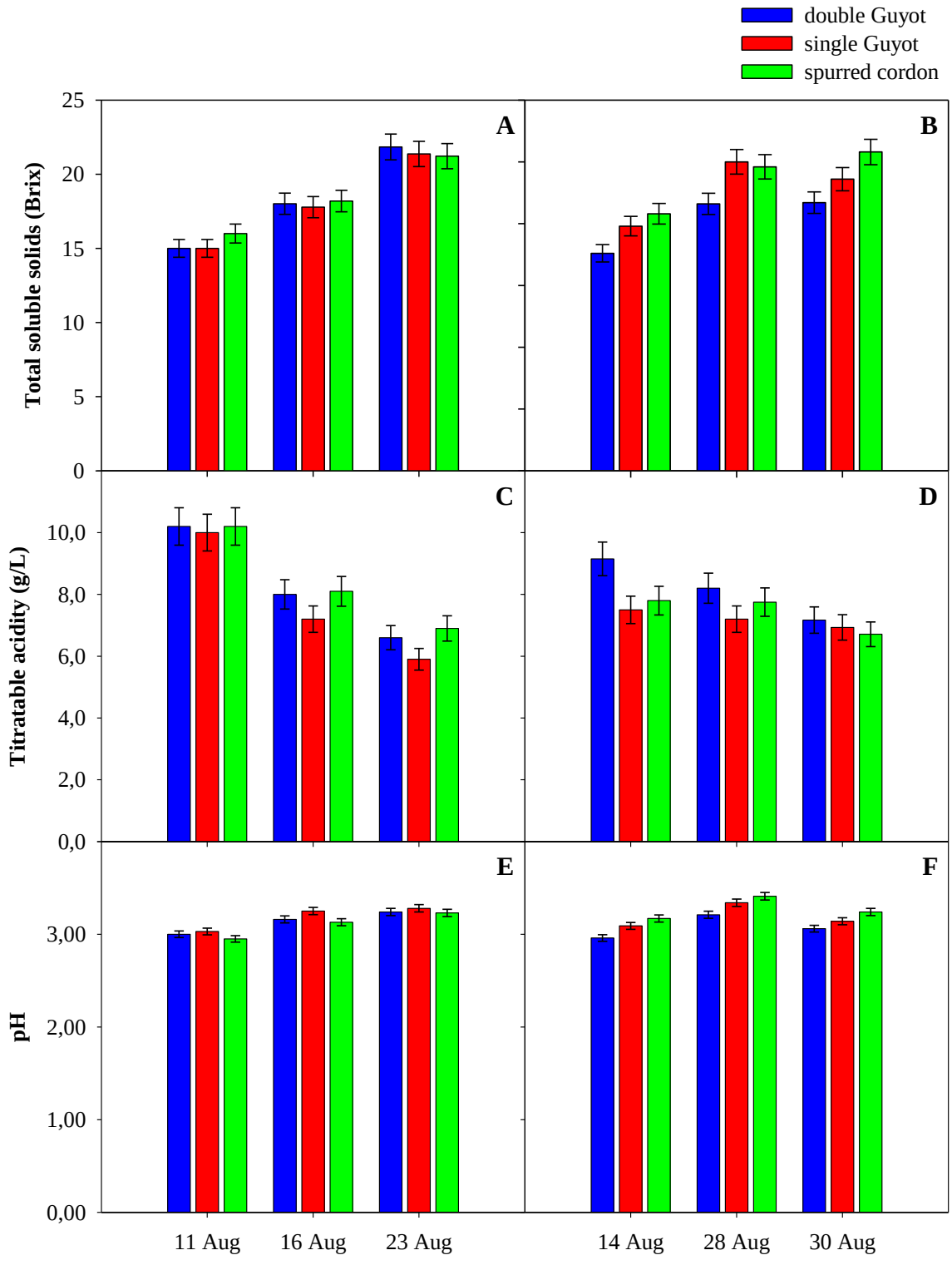


Figure 12: Effect of training system on soluble solids (A, B), titratable acidity (C, D) and pH (E & F) in the seasons 2011 (A, C, E) and 2012 (B, D, F). Bars represent SD.

As opposite as for titratable acidity, pH was enhanced during maturation, with not many difference among training systems at all sampling points. In 2011(figure 12E) slightly higher values of pH were measured in case of single Guyot (3,28) at harvest. In the following season 2012 the values of pH (figure 12F) were trendily the lowest for double Guyot, mean for single Guyot and the highest for spurred cordon at all sampling dates, being the values inversely related with the grape production (figure 10B).

4.6 Cluster characteristics and berry sizing

In the season 2012 beside quality parameters berry size and sugar loading was measured. From each training system, cluster from the end, centre and base of the cane/cordon were collected.

Looking at mean values, berry size was the biggest for spurred cordon and the lowest for Single Guyot, while was intermediate in case of double Guyot (figure 13A). On the other hand, the number of berries x cluster was higher for Single Guyot and the lowest for spurred cordon, but the differences were not significant (figure 13B). Here it is already possible to see that it was a compensation effect, since the clusters with fewer berries yielded on a trend higher berry mass.

Actually, as we can easily calculate, the average cluster weight was the same for all training systems (figure 13C) even if a trend for lower values was shown for single Guyot and spurred cordon (comparable with the values presented in figure 10C). The values of average cluster weight are not exactly the same as in figure 10C, since for berry sizing examination only a sample of clusters was made.

Using the simple calculation (as explained in materials and methods - see page 13-14), the amount of sugar loading was calculated, and basically for all training systems the value of this parameter was around 28.000 mg/cluster (figure 13D). This means that the potential to accumulate sugars in the cluster is not significantly affected by training system.

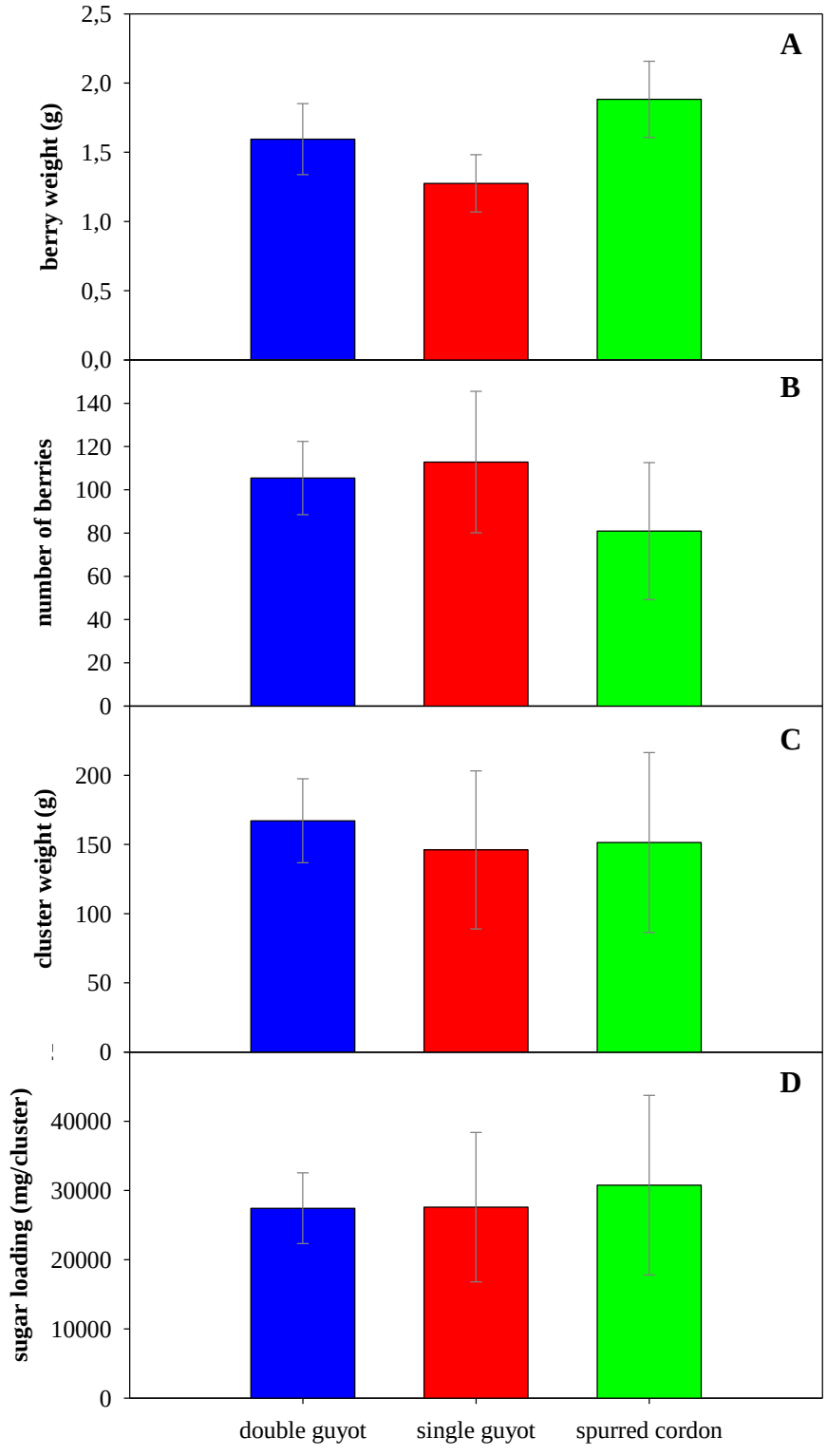


Figure 13: Effect of training systems on (A) berry weight, (B) number of berries, (C) cluster weight and (D) sugar loading x cluster. Bars represent SD.

The sizes of the berries were mainly ranging between 13 and 16mm (figure 14). In Spurred cordon (figure 14A) we found more berries in the category 15-16 mm and bigger berries were observed as a trend in the basal clusters, while similar in the other two positions. In single Guyot (figure 14B), for each position the number of berries had the same weight in the category 13-14mm, but only trendily higher number of smaller berries (9-10 and 11-12 mm) in terminal clusters and higher number of bigger berries (15-16 mm) in central clusters. For double Guyot training system (figure 14C) berry sizing was basically the same as shown for Single Guyot.

Looking at the sugar loading as related with berry size, in all three training systems there is a clear trend towards a higher content of sugars in bigger berries (figure 15).

There is a trend for a reduction of sugar loading in case of the clusters collected in the central position of the cane training systems (single and double Guyot). This fact can be easily explained since normally the shoots growing in the central position of the cane are less vigorous than the basals or the ending shoots.

In case of Spurred cordon on the other hand, the shoots are less and less vigorous from the basal spurs to the ending ones.

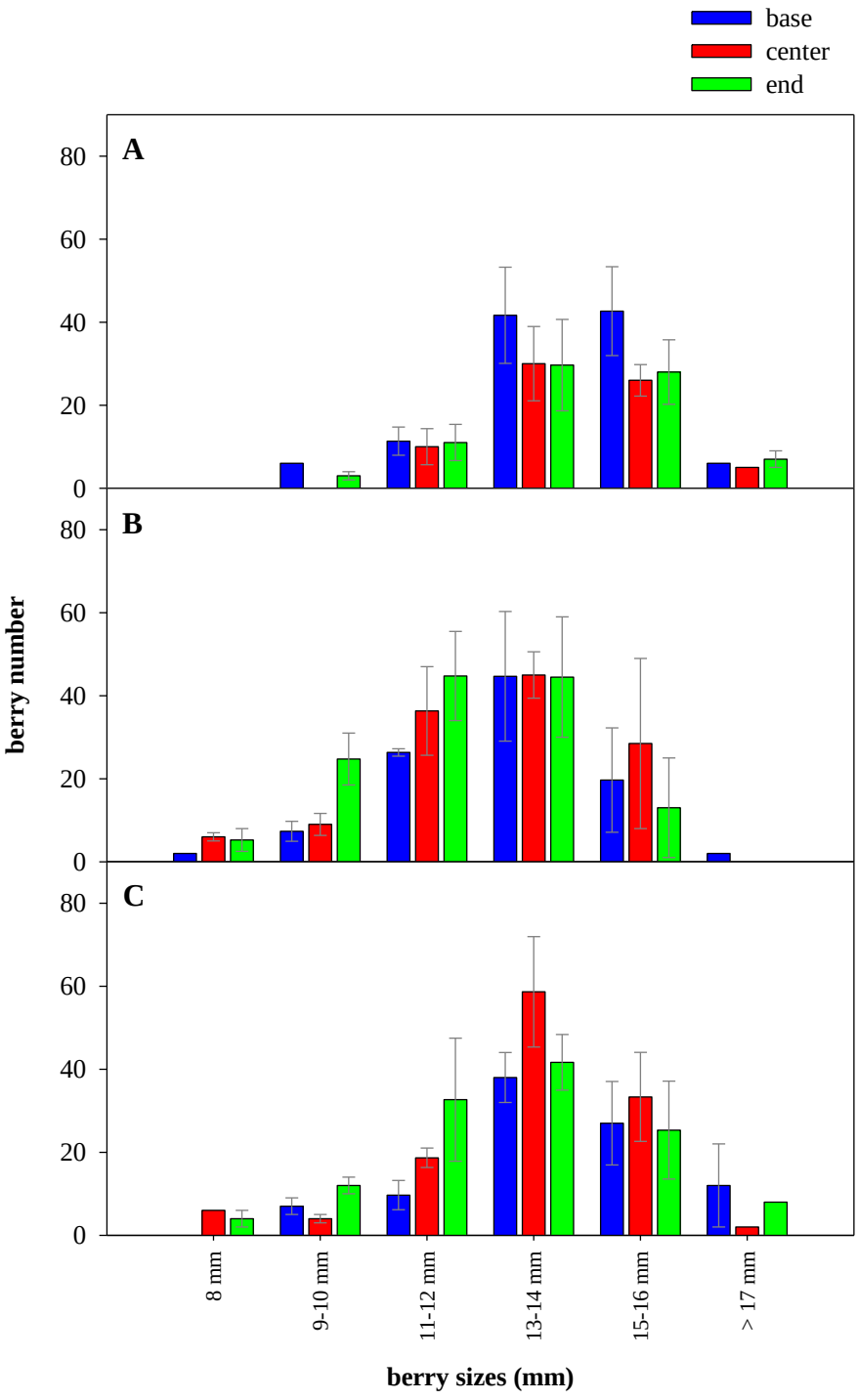


Figure 14: Effect of training systems on berry number in berries of different sizes. (A) Spurred cordon, (B) single Guyot and (C) double Guyot. Bars represent SD. Unique value when bar is not reported.

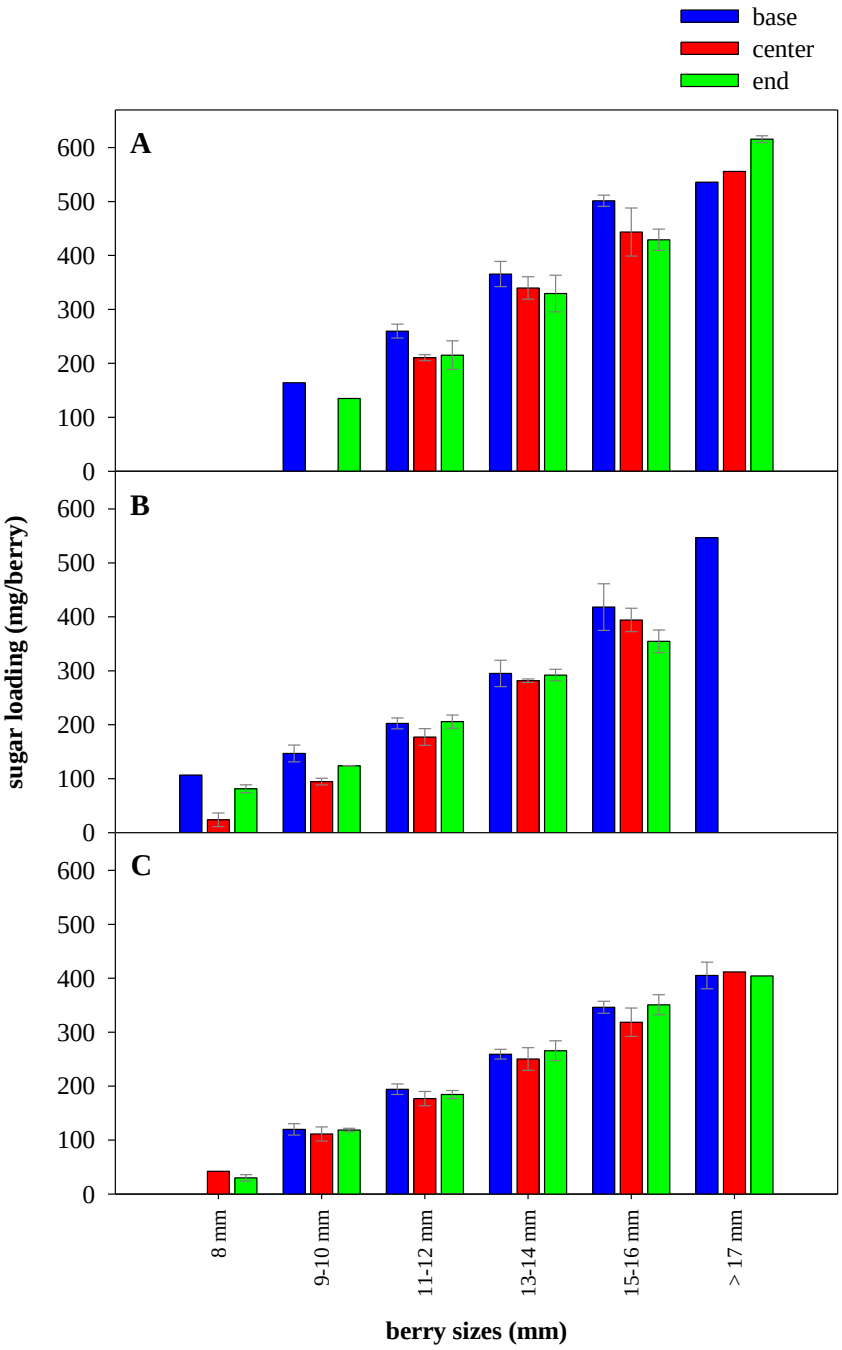


Figure 15. Effect of the training system on sugar loading in berries of different sizes. (A) Spurred cordon, (B) single Guyot and (C) double Guyot. Bars represent SD. Unique value when bar is not reported.

Multiplying the sugar loading x cluster by the number of clusters x vine it is possible to ascertain the amount of sugars loaded for each plant (figure 16). Even if not significant, there is a trend for lower sugar loading in case of single Guyot and spurred cordon while higher values were found in case of double Guyot (almost 400 g/vine). Thus, the crop load reduction connected to training system was not profitable for an increase of sugars, and so double Guyot demonstrated to have the highest potential to load sugars. If the grapes are paid based on sugar loading x plant, as normally happens in cooperative wineries, it is better to adopt the most productive training system.

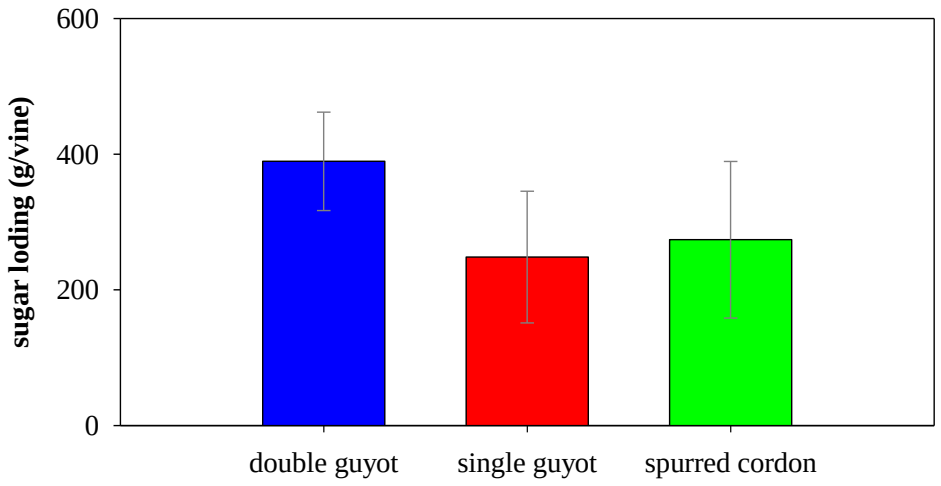


Figure 16: Sugar loading per vine. Bars represent SD.

5. CONCLUSION

In this two-year trial we were seeking to find out how different training systems (double Guyot, single Guyot and spurred cordon) affect grape production and quality parameters on 'Rumeni Muškat' vines.

We observed that grapevine production was very different from season to season, as related with the meteorological course. In the season 2011 the yield was low for all training systems with slight differences among them, while in 2012 the number of clusters (and so the yield) for double Guyot was much higher in 2012 as compared with single Guyot and spurred cordon.

The maturation of the grapes in both seasons did not reported differences as related with training system. At harvest time the average of soluble solids (Brix) in all training systems was 21,5and 23,7 Brix, in the season 2011 and 2012 respectively, and an opposite trend was observed for titratable acidity.

Spurred cordon had lower production (compared to cane pruned training systems) and clusters with trendily less berries but bigger (significantly only as compared with single Guyot). Sugar loading (mg/cluster) was almost the same in cane pruned vines, and slightly higher in case of spurred cordon. Even if not significant, it was possible to observe a trend for highest amount of sugar loaded per vine in case of double Guyot and almost the same in other two training systems.

According to these results, the most appropriate training system for ‘Rumeni Muškat’ in Brda region should be double Guyot, since the production is higher and the grape maturation at similar values than in single Guyot and spurred cordon.

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