THE "SEMI-MINIMAL" PRUNED "HEDGE" SYSTEM FOR GRAPE VINES LONG TERM EXPERIENCE ON CV. SANGIOVESE (Vitis vinifera L.)

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Abstract:

Context and purpose of the study - In previous experiments carried out in Bologna on Sangiovese grapevines raised with the Australian "Minimal Pruning" system, it has been shown that this system left an excessive burden of buds on the vine (650/meter of row) and inhibited the plant from correctly activating its physiologic self-regulating mechanisms, thus causing alternancy and drops in the sugar content. However, "Minimal Pruning" also reduced labor time and resulted in loose grape bunches on the vine, which are less prone to fungal diseases. Considering the importance of these last results, the University of Bologna has experimented with a cultivation method based on the Australian technique, but modified so as to reduce the bud load and regulate production without losing the advantages of low cost and healthier grapes. The new system, trained to a "Hedge" form with "Semi-Minimal" mechanical pruning, has been tested on Sangiovese grapevines since 1990 and has undergone important structural modifications, which might also make it suitable for other grape varieties.

Material and methods - The initial research on the Sangiovese grapevine trained as a Hedge compared it to the classic Spur-Pruned Cordon (SPC). The Hedge productive surface was 1.2 meters tall and was managed with mechanical "Semi-Minimal" pruning (400 buds/m of row, i.e. 40% less than Australian "Minimal Pruning"), while the classic SPC was managed with traditional manual pruning (18-buds/meter of row). Between 2000 and 2008, the main growth, production and quality characteristics of SPC and Hedge were identified and an assessment was made of the likelihood of shoot density in the lower areas of the Hedge (as already mentioned, 1.2 m tall) to verify the acrotony effect.Moreover from 2013 to 2018 a second model of Hedge, 0.8 m tall ("Shorter Hedge") was used on Sangiovese grapevines (235 buds/meter of row, i.e. 65% less than Australian "Minimal Pruning"). For the "Shorter Hedge" the principal 2013-2018 behavioral parameters were identified and the spatial distribution of shoots and bunches along the productive Hedge wall was also verified.

Results - The results of the first investigation (2000-2008) showed that in respect to the SPC (18-buds/m), the 1.2 m tall Hedge (400 buds/m) gave rise to a larger crop of similar quality to that of the SPC, with a greater number of bunches that were smaller, looser and completely free from botrytis. Nevertheless, in the lower part of the 1.2 m tall Hedge, a small drop in the number of shoots produced was observed after few years.In the second investigation, carried out between 2013 and 2018 on the Sangiovese "Shorter Hedge", with a 0.8 m tall productive surface (235 buds/m), the data confirmed that the lesser height of the yield wall and the relate lower bud number improved the self-regulation and equilibrium of the vines, markedly reducing the annual variability of the different grape parameters. Overall, the vines always produced quantitatively and qualitatively to satisfaction, with many small bunches free from rot. During the trial, a decreasing of shoot and cluster density was not observed in the lower parts of the 0.8 m tall Hedge.Today, after almost 20 years of research, the Hedge system has shown itself to be capable of being practically applied to other grape varieties thanks to its reduced management costs, complete adaptability to integrated mechanization and the positive results regarding the yield and grape quality.

Keywords: Grapevine, Training System, Self-regulation, Mechanization, Semi-Minimal pruning.

1. Introduction

The "Hedge" training system with "Semi-Minimal" pruning was proposed by the University of Bologna as early as the '90s as an alternative to "Minimal Pruning", an Australian method whose results on the Sangiovese variety weren't satisfactory.

It should be noted that in it's original form, "Minimal Pruning" is based on an expansive and three dimensional training method made up of a high, horizontal, permanent cordon, that can be machine harvested and managed with just very light mechanical pruning, in which more than 95% of the wood produced annually is maintained.

This system was developed in Australia in the '80s by Prof. Peter Clingeleffer, head researcher of the CSIRO (Commonwealth Scientific and Industrial Research Organization) and showed to be particularly interesting on grape vine varieties such as Chardonnay, Sauvignon and Cabernet Sauvignon, grown in the warm-arid region of Coonawarra, South of Adelaide **(Clingeleffer, 1983).** In these environments "Minimal Pruning", carried out by quickly brushing the vines with a cutting bar and without manual finishing, aside from strongly decreasing pruning management cost, also provided optimal results in terms of quality and yield, as well as grape health, producing small loose bunches, which are much less subject to fungal infection **(Clingeleffer and Possingham, 1987).** However, when "Minimal Pruning" was tested in colder areas with more rainfall, in Australia and in the United States and later in Spain, Germany and France, this "non pruning" technique has shown some limits in terms of quality, mainly on medium-late varieties **(Ollat *et al.*, 1993).** .

Especially in Italy, the "Minimal Pruning", used on Sangiovese grape variety (*Vitis vinifera* L.) in the Po Valley area, near Bologna **(Intrieri *et al.,* 2001)**, leaving almost all the one-year wood on the plant, as required by the system's protocol **(Photo 1),** produced some negative results because the vines were not able to fully activate the self-reduction of sprouting and fertility to balance excessive annual bud charge (650 buds per meter of row). In these conditions, the plants react with strong alternancy, excessive yields, and too low grape sugar content. Nevertheless, the investigation confirmed that the vines, practically subjected to no pruning at all, had produced a very high number of small loose bunches, that were practically unaffected by Botrytis.

Overall, the research conducted in Bologna on "Minimal Pruning" showed how interesting the implementation of a system conceptually derived from the Australian technique might be, even in temperate environments and for medium-late varieties, if modified in such a way as to reduce the bud load within limits that would regulate the productive behavior of the plant without losing the advantages of the short labor time, lowered costs and grape health.

Based on these considerations, a new high and narrow two-dimensional training system similar to a **"Hedge"** was developed, on which it would be possible to not only machine harvest, but also rapidly carry out a more severe winter mechanical pruning (**"Semi-Minimal Pruning"**) as an alternative to the "Minimal Pruning" technique. In the Hedge is easy to remove part of the one-year wood and related buds with a cutting bar machine. In this way, the vines can be able to activate self-regulatory mechanisms to balance the yields, so as to recuperate the quality characteristics of the grapes and maintain the health benefits of the loose bunches.

The following paragraphs will summarize the research carried out on the "Hedge" system at the University of Bologna from 2000 to 2008 and from 2013 to 2018.

2. The first "Hedge" model with "Semi-Minimal Pruning"

2.1. Material and methods

Taking into account the principles explained above, the first "Hedge" model was set up in February 1997, modifying 11-year-old cv. Sangiovese plants, trained to the classic Spur-Pruned Cordon (SPC) in a vineyard located in Bologna area.

Some of the SPC trained vines were maintained in the original form and used as "controls", while others were manually pruned eliminating about half of the shoots and tying those remaining intact to horizontal wires running along the row, so as to form a productive Hedge wall that was about 1.2 meters tall, as shown in **Figure 1**.

Starting in 1998, winter pruning of the grape vines modified into a Hedge was always carried out mechanically without manual finishing (estimated working time about 6-8 man-hours/ha/year). A vehicle with cutter bars was used, operating on top and along the sides of the rows, first on one side and then on the other, at a distance of about 10-15 cm from the posts and from the support wires **(Photo 2).** In this way part of the buds annually produced were eliminated **("Semi-Minimal Pruning"),** maintaining the vines in a permanent vertical 1.2 meter tall skeletal Hedgestructure **(Photo 3)**. In the Spring-Summer period, the Hedge underwent light mechanical hedging (2-3 times according to growth conditions), with work time estimated to be 2-3 man-hours/ha/year for each operation.

The winter pruning of the control vines trained to SPC was always carried out by hand (work time estimated to be about 60-70 man-hours/ha/year), leaving 8-10 spurs with two buds each per meter of row. In Spring-Summer, the SPC also underwent some mechanical summer pruning, with work time similar to that necessary for the Hedge.

All the other cultivation and pest-management operations were carried out in a very similar way for the two systems, for which the main growth, productive and qualitative characteristics were recorded from year 2000 up to year 2008.

In 2002, the aptitude of the Hedge system for mechanical harvesting was also verified using a horizontal shaker machine. The harvester, equipped with a number of slappers able to explore the entire productive 1.2 m wall, had no difficulty in operating: grapes were completely detached and the harvest quality appeared good, thus confirming that the Hedge training system could be fully mechanized. Work time for the Hedge's grape mechanical harvest was similar to those reported in literature for other systems **(Palliotti et al., 2018)**and estimated to be around 2-4 man-hours/ha/year.

2.2. Results

During the 2000-2008 trial period (**Intrieri and Filippetti, 2007**; **Intrieri *et al.,* 2011)**, the investigations showed that compared to the SPC, in which manual pruning left annually an average of 18 buds per cordon meter, in the Hedge with a productive wall of 1.2 meters, the mechanical pruning left 400 buds per meter annually (**Table 1**), i.e. 40% less in comparison to the previously mentioned bud load (650/m) that were left on the vines subjected to the Australian "Minimal Pruning" model.

The 400 buds/m left by "Semi-Minimal Pruning'', even if still a large amount, were compatible with the physiologic capacity of the Sangiovese variety to reduce alternancy and balance the harvest through self-regulation. In the Hedge, sprouting was reduced by 50% and fertility (number of bunches per shoot) was lowered by more than 75% compared to the SPC. Furthermore, bunches were much smaller, looser and practically free from botrytis (**Table 1**). Overall, the number of shoots and bunches was seen to be superior compared to the SPC (**Table 1**) and the Hedge also showed a greater leaf area and a 40% greater yield, but without differences in the final degree of maturity of the grapes (**Table 2**).

The qualitative results of the 1.2 m tall Hedge, although very satisfactory, still raised some **"critical"** considerations since they were obtained on **"adult"** Sangiovese vines, previously trained as SPCs and possibly having a good carbohydrate reserves: the Hedge would therefore have been able to take advantage of a **"buffer"** mechanism to overcome any nutritional imbalances linked to the relatively high yields. Another **"critical"** consideration was linked to the possibility that the new Hedge system would not be able to maintain a good distribution of the shoots and bunches over time along the entire wall, which was, as already said, about 1.2 m tall. In fact, after five year of production some observations **(Filippetti and Intrieri, 2009;Intrieri *et al.,* 2010),** showed a tendency towards **"stripping"** of the Hedge lower areas (25% fewer shoots in the lower two-thirds of the productive wall in respect to the top third), perhaps caused by

excessive shading or more likely due to the effects of **"acrotony"(Photo 4).** Thus, it was possible to hypothesize that a shorter productive area might limit the stripping and maintain a more homogenous distribution of the shoots and bunches over time.

Considering the two criticism**s** discussed above, it was decided to plan another experiment, in which the vine supporting structure was designed to produce a shorter 0.8 m productive Hedge wall **(Figure 2).** A second aim of the experiment was to check the behavior of theSangiovese young vines managed with "Semi-Minimal Pruning''from the beginning of training period, and to verify if the "Shorter Hedge" might limit stripping.

The results of this second investigation are reported below.

3. The second "Shorter Hedge" model with "Semi-Minimal Pruning"

3.1. Material and methods

For the trial, a young row of Sangiovese vines was used, in which the formation of the Hedge started in 2010 and was manually completed at the end of 2012. Starting from 2013, the winter pruning of the 0.8 m tall productive hedge wall was carried out every year with a cutting bar machine without any manual finishing **(Photo 5)**. In the spring-summer of each year, two to three very light top and lateral cutting operations were performed on the Hedge,and the harvest continued to be carried out with a horizontal shaker unit **(Photo 6).** The work times for the mechanized operations of winter pruning, summer pruning and harvest were the same as that recorded during the precedent trials.

3.2. Results

The main behavioral parameters of the system were recorded on sample stock from 2013 to 2018 and the results showed that in the "Shorter Hedge" an average annual bud load of 235 per meter was left with the "Semi-Minimal Pruning'' (i.e. 65% less than Australian "Minimal Pruning"). In this condition, sprouting was reduced to 60% and fertility was lowered to 0.3 bunches per shoot by self-regulation mechanism. Furthermore, the system gave rise to many small bunches that were free from rot **(Table 3)** and produced a yieldthat was both quantitatively and qualitatively satisfactory **(Table 4).**

The graph of the annual trend (from 2013 to 2018) of some of the principal parameters identified in the investigation (production, bunch weight, °Brix and health status of bunches) clearly shows reduced variability and considerable homogeneity over time **(Graphs 1, 2, 3, and 4),** showing that young Sangiovese grape vines were able to positively respond to "Semi-Minimal Pruning'' from their very first years. The rescaling of the height of the Hedge wall certainly contributed to this result.

Regarding the "stripping" in the lower parts of the wall, some observation was done on the distribution of shoots and bunches, using the **"empiric"** method of manual defoliation of sections of the row, which were chosen randomly every year. Observations of the defoliated vines proved to be particularly useful, because a good growth capacity and a good presence of bunches was observed in all the parts of the Hedge (**Photo 7**), confirming the positive influence of the Hedge wall reduction for these aspects as well.

4. Discussion and conclusions

Research during the last twenty years has shown that the Hedge system with "Semi-Minimal Pruning'', with the appropriate adjustments, lends itself to being used on the Sangiovese variety with notable advantages for reducing costs and positive results on the quality and on the health of the grapes. These results now prompt investigations into the possible use of the same system on other grape vine varieties.

In order to evaluate this possibility, it is important to remember that the principal behaviors of Hedge trained grapevines, i.e. reduced shooting and fertility and the production of small loose bunches, do not represent innovative results, but are the consequence of self-regulatory mechanisms that have been noted and recorded many time in grapes as well as in other fruit species. The self-regulation tend to maintain in

balance the growth and the reproductive activity when the bud load exceeds the normal potential for plant development. In fact, the "Minimal Pruning" applied on various grapevine varieties in the hot-arid regions of South Australia is based on the same principles and has been used with success for over 30 years **(Possingam, 1996).**

Self-regulation can manifest itself in all grapevine varieties and in all environments, but the research of many authors has already shown that in temperate zones and areas with more precipitation than hot-arid Australian regions, vines with bud load similar to "Minimal Pruning" are more vigorous and produce more shoots and bunches. Thus, in conditions of greater vigor it is necessary to lower the number of buds left with the mechanical pruning to avoid alternancy, excessive yield and reduced sugar content **(Ollat *et al*., 1993, *l.c.*).** The "Semi-Minimal Pruning'' method tested in the Sangiovese 0.8-meter wall Hedge in Bologna, had a bud load 65% less in comparison to that produced by Australian "Minimal Pruning"methods**.** Thus, it would seem that in our experiment the bud load and the auto-regulatory reaction are balanced. The use of "Semi-Minimal Pruning'', i.e. of "controlled" pruning intensity, should therefore be able to work satisfactory on other cultivars and in different regions of our country as well, if the choice in hedge wall height, which in turn conditions the bud load, corresponds to the growth capacity of the specific variety.

In truth, a fair number of wine grapevines trained with the concept of the Hedge already exist in the various Italian regions, and are currently under "prudent" evaluation by winegrowers, many of whom are attracted by the fact that semi-minimal pruning can reduce costs and improve the production and health of bunches without decreasing quality. In fact, from the trials carried out on Sangiovese grapevines, it has been possible to establish that the work times for mechanized winter pruning, summer pruning and harvest on the Hedge can all together come in no more that 20 man-hours/ha/year and that by spacing the rows from 2.5 to 3 m apart (about 4 or 3.3 km of row/ha), the yield can be around 20-25 t/ha of healthy grapes of optimal quality.

Generally, the questions posed regarding the Hedge today seem to be similar to those posed once regarding the Free Cordon, a training method developed in Bologna on the Sangiovese grape at the beginning of the '80s that was then used with success in various regions and on numerous grapevine varieties **(Intrieri and Filippetti, 1997).**

In comparison with the Free Cordon, whose characteristics (short pruning and lack of shoot support wires) make it particularly suited to varieties with high basal bud fertility and with naturally up-growing shoots, the Hedge should not have these limitations, since pruning is long and short in the same time and the structure, at least in part, sustains the vegetation **(see Photo 5).** Once the needs of the different cultivars have been ascertained and the necessary modifications made to the Hedge wall, the new system could therefore be successful in other regions and on other varieties.

5. Literature cited

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Table 1. Cv. Sangiovese. Bud load, sprouting, fertility and cluster characters on the Spur-Pruned Cordon (Control) and on the 1.2 m tall "Hedge"(average 2000-2008).*

Training system	Buds left on vines (n/m)	Produced shoots (n/m)	Sprouting (%)	Fertility (cluster / shoot)	Produced clusters (n/m)	Cluster weight (g)	Cluster compactness (OIV index 1-9)	Botrytis (% of cluster surface)
Spur-Pruned Cordon (Control)	18 b	17.5 b	98.1 a	1.31 a	22.5 b	270 a	7.2 a	9.2 a
Hedge wall (h = 1.2 m)	400 a	195 a	49 b	0.35 b	67 a	126 b	4.0 b	0.25 b

*Reworked from Intrieri and Filippetti, 2007 and from Intrieri et al., 2011. Column values marked by different letters are statistically different for P=0.05

Table 2. Cv. Sangiovese. Leaf area, yield and main must biochemical compounds at harvest on the Spur-Pruned Cordon (Control) and on the 1.2 m tall "Hedge" (average 2000-2008).*

Training system	Leaf area (m^2/m)	Yield (kg/m)	Leaf area/yield (m^2/kg)	Soluble solids (°Brix)	pH	Titratable acidity (g/L)
Spur-Pruned Cordon (Control)	5.95 b	6.1 b	0.9 b	20.8 a	3.34 a	8.11 a
Hedge wall (h = 1.2 m)	12.7 a	8.7 a	1.5 a	21.0 a	3.35 a	7.68 a

*Reworked from Intrieri and Filippetti, 2007, and from Intrieri et al., 2011. Column values marked by different letters are statistically different for P=0.05

Table 3. Cv. Sangiovese. Bud load, sprouting, fertility and cluster characters on the shorter 0.8 m Hedge wall (average 2013-2018).

Training system	Buds left on vines (n/m)	Produced shoots (n/m)	Sprouting (%)	Fertility (cluster/shoot)	Produced clusters (n/m)	Cluster weight (g)	Botryitis (% of cluster surface)
Shorter Hedge wall (h = 0.8 m)	235	142	60	0.3	41.7	158	0.7

Table 4. Cv. Sangiovese. Yield and main must biochemical compounds at harvest on the shorter 1.2 m tall "Hedge" (average 2013-2018).

| Training system	Yield (kg/m)	Soluble solids (°Brix)	pH	Titratable acidity (g/L)
Shorter Hedge wall (h = 0.8 m)	6.41	21.9	3.42	6.29

Graph 1. Cv. Sangiovese. Yield (kg/m) from 2013 to 2018 on the shorter 0.8 m tall Hedge.
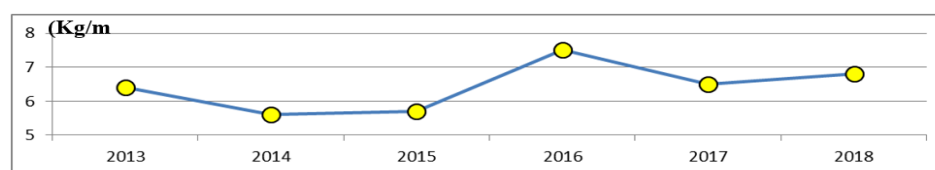
Graph 2. Cv. Sangiovese. Cluster weight (g) from 2013 to 2018 on the shorter 0.8 m tall Hedge.
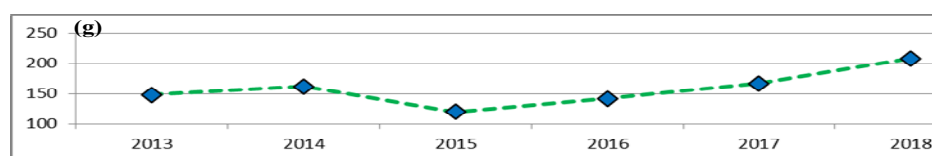
Graph 3. Cv. Sangiovese. Must soluble solids (°Brix) from 2013 to 2018 on the shorter 0.8 tall Hedge.
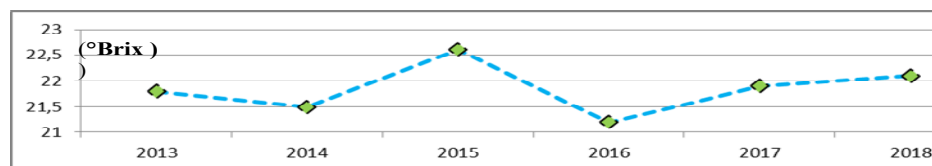
Graph 4. Cv. Sangiovese. Botrytis infection (% of cluster surface) from 2013 to 2018 on the shorter 0.8 tall Hedge.
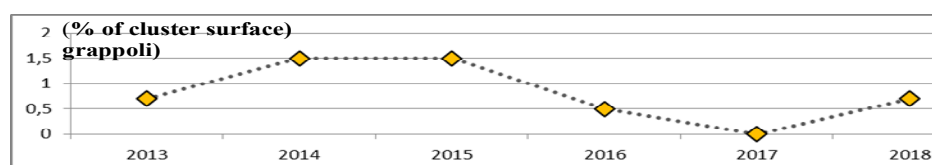
Figure 1. Schematic representation of the Spur Pruned Cordon (A) and its modification to obtain the first "Hedge" model (B), with a productive wall set to be about 1.2 m high.
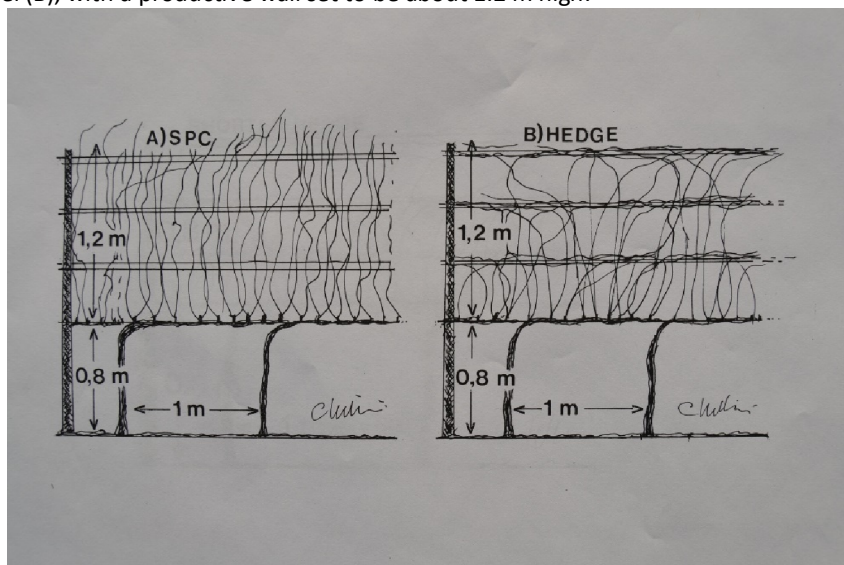

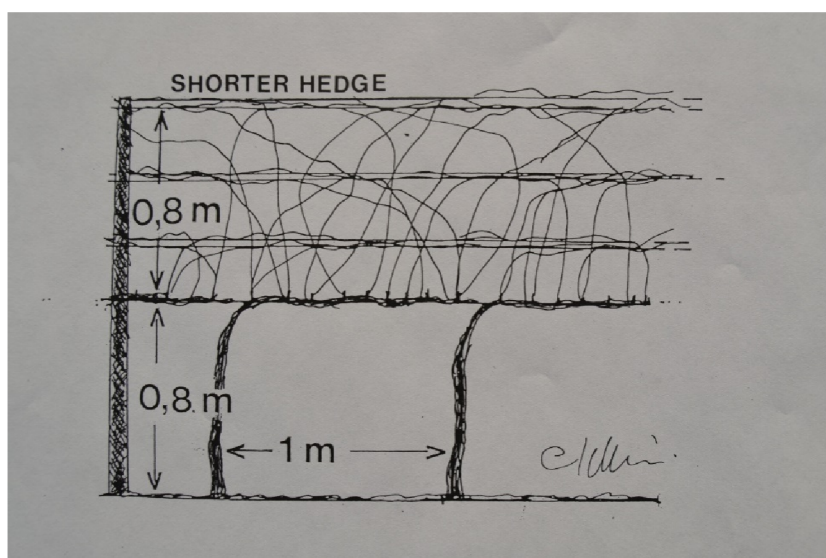**Figure 2.** Schematic representation of the "Shorter Hedge", with a productive wall that is about 0.8 m high.

Photo captions

Photo 1. Sangiovese grape vines raised in Bologna for several years with the Australian "Minimal Pruning" system. The annual bud load was very high (around 650/m of row) and the plants showed strong yield alternancy and reduced sugar content.

Photo 2. "Semi-Minimal" mechanical winter pruning in a tall 1.2 m "Hedge" wall of Sangiovese vines. Working a short distance from the "Hedge" wall, first on one side and then on the other side of the same row, it is possible to eliminate a good part of the year's wood.

Photo 3. The "Semi-Minimal" mechanical pruning makes it possible to maintain the high and narrow structure of the 1.2 m "Hedge" wall over time.

Photo 4. A "Hedge" with a 1.2 m tall productive wall may show a certain tendency towards "stripping" of the lower areas after several years of "Semi-Minimal" pruning, due to shading or more likely due to effects of "acrotony".

Photo 5. Mechanical winter pruning without hand finishing in a row of Sangiovese "Shorter Hedge", with a 0.8 m tall productive wall.

Photo 6. The mechanical harvest of a 0.8 m tall "Shorter Hedge" wall, using a modern horizontal shaker unit equipped with bins for the crop.

Photo 7. A section of a Sangiovese "Shorter Hedge" row with a 0.8 m tall productive wall defoliated at mid-September 2018, before the mechanical harvest. Every year, starting in 2013, the row has been subject to "Semi-Minimal" mechanical winter pruning, but the distribution of the shoots and bunches along the wall has remained homogeneous.

Photo 1

Photo 2

Photo 3

Photo 4

Photo 5

Photo 6

Photo 7