THE ROLE OF MECHANIZATION IN ZONE/TERROIR EXPRESSION

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1. Introduction

Vineyard mechanization will be addressed in this review paper primarily as related to pruning and harvesting since these operations typically require a great deal of the total yearly labour demand (Intrieri and Poni, 1998). However, to be able to define how mechanization interacts with "terroir", a rigorous definition of the latter term is needed.

James Goode (www.wineanorak.com) states that "terroir" must be reserved solely to describe the physical environment in which the grapevine grows – that is the soil type, microclimate and slope of a defined area. However, we would rather prefer the following broader definition; "Terroir: *the ecology of a wine. The total, inter-related environment wherein a grapevine is cultivated for the purpose of making wine. Key factors include, but are not limited to, cultivar type, soil, climate, vineyard location, planting density, training system, pruning philosophy & the cultural and social milieu wherein the whole enterprise takes place*". In fact, we think that also choices like vine spacing or training system define a "terroir"; if we imagine a high-density vineyard trained to goblet in the south of France to be pulled out and replanted at wider spacing with a strikingly different trellis, could we say that the wine coming from that vineyard is still the expression of the same "terroir"? We doubt it.

Once "terroir" has been generally defined, it has to be verified if the definition holds for both Old and New World. To simplify, it can be stated that Old World terroirists aim to make wines that express the "typicity" of the vineyard site by putting a major emphasis on soil effects; in the New World the "terroir" effect has been somewhat disregarded and it is still viewed, under a more pragmatic way, as a route to improved quality.

Here, another important question rises: are both Old and New World facing viticultural changes that will soon affect the relationship between "terroir" and mechanization? The answer is in the affirmative although these changes have different rationales. The increasing cost of hand labour, often associated with the difficulties of finding skilled workers (mostly for winter pruning), will indeed produce in the Old World an increased interest in mechanized grape production systems. It is a trend that will be hastened if this process is paralleled by lower wine prices on the market.

The New World is already highly mechanized (Australia is the appropriate example here). This high degree of mechanization is facilitated, among many factors, by vineyard size. It is known that some New World vineyards are hundreds of hectares in size, while some in the more traditional parts of Europe are fractions of a hectare. However, this also means that when very large vineyards are machine-harvested in Australia, different "terroirs" are likely blended and their individual winemaking potential is diluted or dispersed.

Given that wine quality is enhanced by fermenting homogeneous lots of fruits and that variation in batches of delivered grapes is mainly due to soil (Smart, 1996), several large companies in Australia are tackling soil mapping to spot zones of similar "Readily Available Water" or are considering precision viticulture (Morris, 2001). Using global positioning systems (GPS) in association with geographical information systems (GIS) makes it possible to divide vineyards into management grids, each of which is quantified and treated separately. Technology is already available (Robertson, 2000) to build sensors that record specific information from each vine in order to formulate maps for vigour, °Brix, phenols and so forth. Of course, this has an impact on mechanization since machineries are being modified to incorporate computerized monitoring devices and sensors. A pertinent example is GIS driven mechanical harvesters, which can adjust speed or slapper frequency according to the maturity gradient along a vine row. Quite paradoxically, it appears that the New World is moving quickly towards these techniques to fill the gap with the Old World in terms of "terroir" expression.

Mechanization clearly interacts with many of the key factors listed within the broader definition of "terroir" (namely vineyard location, planting density and training system). Yet the meaning of “terroir” nowadays is still being associated with the general concept of “recognizable” grape quality. Therefore, the interaction between vineyard mechanization and “terroir” can probably be analyzed from two basic viewpoints:

A) How does the concept of full vineyard mechanization fit with maintenance of high quality requirements? This is a crucial issue. Indeed, still widespread in the Old World viticultural countries, such as Italy, it the “rule of thumb” whereby a fully mechanized vineyard cannot give top quality and that only the patient hand labour can actually achieve the “gold standards”;

B) Is mechanization a useful tool to reach maximum vineyard efficiency? A reasonable definition of vineyard efficiency is reaching the highest yield at the “desired” or “salable” quality at the lowest production costs.

The B statement broadens the area of interaction between mechanization and “terroir”. Here a suitable example is provided in Figure 1, showing the fractional distribution (year 2003) of exported Italian wine as a function of price per litre (Pedron, 2004). The narrow pyramid shows that only 2.9% of the total value is sold at prices higher than €6/l, whereas more than 65 % of the value goes to prices lower than €3/l. Therefore, restricting the term “terroir” to the top price would basically eliminate the need to investigate the interaction between “terroir” and “mechanization” since those bottles are quite likely coming from prestigious sites where labour cost is not, at least not yet, a priority. Clearly, even the lowest price rate can be representative of a “terroir” if the definition given at the beginning of this introduction holds.

2. Mechanical harvesting and “terroir”.

The natural link between mechanical grape harvesting and the “terroir” expression is the effect on grape and wine quality. It would appear that important viticultural nations have a quite different perception of what this means. While Italy, France and Australia, despite differences in tradition, range of varieties and cultural conditions, are recognized worldwide as producers of quality wines, mechanical harvesting in Australia is approaching 100% of total vine acreage (Pocock and Waters, 1998), in France it is now above 75% (Boubals, 1996) and in Italy it barely hits 8% (Intrieri e Filippetti, 2000). A simplified answer to this high variation is that mechanical harvesting in Italy is hindered by smaller farm size and larger variability in cultivars, training systems and sloping conditions (Bonato et al., 1995, Intrieri and Poni, 1995). However, a role is also played by the suspicion that, at least in Italy, many wine makers still regard the mechanically harvest of grapes, which at times is held to spoil the value of “terroir”. Under such circumstances, it is crucial to look at each condition that objectively makes mechanically harvested grapes a potential source for high quality wines.

A successful mechanical harvesting is based on optimal choices in regard to the following issues:

1) Driver skills, machine setting and speed
2) Trellis design and material (type of posts, wires and accessories)
3) Degree of integration between trellis structure and harvester
4) Stage of maturity, incidence of rot, pre-harvest weather course
5) Cultivar suitability assessed as ease of berry detachment and berry skin thickness
6) Principle of harvesting

The quality of the mechanically harvested grapes depends on a fine tuning of the above factors; however, it appears that items 3 and 6 are the most critical. Indeed, if we take item 3, in too many cases the harvester is taken and “used” in an existing vineyard simply because the maximum post height fits the tunnel size. Then, not much attention is paid to the position of fruiting area as compared to shaking organs and intermediate posts which, in turn typically leads to increased grape losses. The reverse process is instead to be recommended: vineyards should be designed and planted as to be potentially mechanizable for harvesting, so that the actual use of machines would simply become an economic decision.

The principle of harvesting (vertical vs. horizontal shaking) is the second key factor about which there seems to be some contradiction. It is known that horizontal shaking, i.e. using over-row machines equipped with slappers to “beat” the vine row asymmetrically and, hence, detach the berries, is by far the most widely used throughout the world. The popularity of this harvesting principle is mainly bound up with the fact that even "existing" vineyards (e.g. hedgerow type with vertical shoot positioning and maximum post height not exceeding 2.2 – 2.3 m above ground) can be more or less successfully mechanized. However, the literature (Carbonneau, 1997; Intrieri and Poni, 1995; Morris, 1997, 2000) is in agreement that, especially on cultivars having low susceptibility to mechanical harvesting such as Pinot gris, Trebbiano, Moscato, Prosecco, vertical shaking can consistently reduce juice loss because its more gentle action on the canopy wall allows part of the grapes to be detached by inertia with nil or minimum contact with the rotating spiked wheel (Tables 1 and 2). Yet, this principle is suitable only for those training systems allowing an up-down oscillation of the wire supporting the cordon, according to the guidelines provided by Shaulis et al. (1960) on the adaptation of the Geneva Double Courtain (GDC) trellis to mechanical harvesting.

If the "terroir" is identified also in term of typical training systems (as is the case with the spur-pruned cordon in the Brunello district), a good example of integration between "terroir" and mechanical harvesting for the sake of quality would be to modify the trellis to make it suitable for a vertical-shaker harvesting. This can be done quite easily by training to an arched vine trunk and using fairly straightforward devices allowing vertical oscillation of the main wire (Intrieri and Filippetti, 2000; Intrieri and Poni, 2004). As a matter of fact, research here has gone further and new training systems like the one named COMBI (Figure 2) have been designed (Intrieri and Poni, 2004) to merge as many as possible positive features, physiological and structural, in a single trellis such as suitability to vertical mechanical harvesting, canopy division to accommodate even high vigour conditions, high investment on a per-acreage basis (rows are planted at 3 m in between for 6,666 m of productive cordon/ha), and VSP canopies with upright shoots to allow better light exposure of the most functional apical leaves from veraison onward.

Another aspect of mechanical harvesting directly linked to quality and often neglected is the composition of the harvested grapes. While there is no doubt that, especially for white musts more susceptible to oxidation (Pocock and Waters, 1998), a mass made of mostly intact berries is preferable to a juicy product, the latest achievement related to the application of vertical harvesting has highlighted that, within Vitis vinifera L., there is quite a high variability among cultivars in terms of composition of machine-harvested grapes (Table 3). For example, COMBI-trained Bonarda and Shiraz grapevines have shown a lower fraction of mass harvested as single berries and, conversely, an increase in the portion of part of the clusters (Intrieri and Poni, 2004).

If a concern over mechanical harvest applied to V. vinifera is juice loss at the pedicel's detachment zone, then having a fairly high percentage of cluster parts (rather than single berries) is indeed a positive feature which ought to be pursued. There is some evidence that, besides a varietal effect, the amount of grapes detached as cluster parts depends upon the principle of harvesting (horizontal shaking diminishes this fraction), ripening stage and pre-harvest weather course. In some years, maturation of the cluster peduncle is partial and this creates an abscission zone which makes it possible to detach the whole cluster with machine vibrations.

3. Winter mechanical pruning and "terroir"

The perception of the role of mechanical winter pruning in the context of "terroir" is again quite different depending upon the viticultural tradition of the given country. In Australia, for example, the technique of *minimal* pruning has been successfully applied in several districts (Clingeleffer, 1993). In countries of the Old World, namely Italy, it still holds a sort of equation whereby the higher node number left on the vine by a non-selective mechanical pruning as compared to hand pruning would in turn lead to higher yield and/or more pronounced biennal bearing and, hence, decreased or uneven quality. Indeed, the typical view of a cordon mechanically pruned for several years showing accumulation of old wood does not seem to fit with the concept of "terroir", which traditionally emphasizes the need for "clean" vines managed with a fairly low node number.

Nowadays, this interpretation of the relationship between "terroir" and the mechanization of winter pruning seems to be too rigid and reductive. Indeed, changes in canopy physiology caused by an increase in node number following mechanical cuts (with or without manual follow-up) are by far more complex.

Increasing node number per vine usually leads to an increase in vine "capacity" (i. e. total effective leaf area per vine), which can counteract the expected yield increment and, hence, act as a buffer for maintaining similar quality; likewise, the higher node number reduces the vigour of the individual shoots (often excessive under a low-node number pruning regime) therefore determining more favourable conditions for sugar accumulation after veraison. Then, too, the question should be probably restated as: can mechanical winter pruning be a tool to improve the expression of “terroir”?.

The answer could be easily found by revisiting the large number of papers on the subject on mechanical pruning in grapevine published over the last 30 years (Shaulis et al. 1973, Freeman and Cullis 1981, Dry 1983, Morris 1985, Intrieri et al. 1988, Reynolds 1988, Clingeleffer 1993, Possingham 1994). However, here we shall summarize a specific experience (Poni et al., 2004) involving Croatina (Vitis vinifera L.), a cultivar marked by the low fruitfulness of basal buds (varying between 0.3 – 0.6 inflorescence/shoot within the 1-to-4 basal nodes) (Figure 3).

Four pruning treatments—hand pruning (HP), short mechanical pruning followed by severe or light manual follow-up (SMP-SF; SMP-LF) and medium mechanical pruning followed by light manual follow-up (MMP-LF)—were compared in a 10-year-old “Croatina” vineyard trained to high free cordon and planted at 1.1m x 2.5 m. The mechanical hedging was performed by a cutter bar unit side-mounted on a tractor featuring an over-row reverse-U cut profile; manual follow-up was performed by two crewmen with pneumatic shears working from the tractor-drawn-platform. “Severe” and “light” follow-up were defined as number of machine runs per row (two and one, respectively), thereby allowing the crew more or less time for shortening and/or thinning of machine pruned wood. “Short” mechanical pruning was defined as cuts made as close as possible to the cordons; MMP-LF was set by maintaining the cutter bars at approximately 10 cm above and sideways the cordon.

A summary of the main results recorded over 2000-2003 is reported in Table 4 and can be discussed as it follows:

A. SMP + hand finishing retaining 50-60 nodes/vine achieved about 25% higher yield than HP at similar quality and 50% time saving;

B. Yield compensation was manifested here primarily as reduced budbreak beyond the threshold of 60 nodes/vine and was indeed aided by the natural low fruitfulness of the basal nodes of this cultivar;

C. The breakpoint in this study was represented by MMP-LF (>60 nodes/vine) which started to show a depressant effect in vine capacity paralleled by a contraction of soluble solids and anthocyanins.

D. Mechanical pruning here turned out to be an excellent tool to identify the vine balance which sets the maximum cropping level at the desired quality.

Point D best clarifies how mechanization can affect “terroir” expression. The highly competing wine market demands a balance wherein remunerative yield, desired quality and reduce costs can coexist. There are several cases in which growers artificially limit the yield level of their vineyard through either severe pruning and/or cluster thinning due to the worry that grape quality may become impaired. However, certain “terroirs” could bear some yield increase without detriment to quality simply because the site potential allows it. Mechanical pruning is an exceptionally viable tool for identifying the yield threshold beyond which quality starts to decline, a factor that, in our view, is a primary component of the “terroir” concept.

4. Summer mechanical pruning and “terroir”

At first glance, the link between mechanization of summer pruning and “terroir” seems less direct than mechanical winter pruning simply because summer pruning might also be a “one-off” operation. A case in point is shoot trimming, which may be needed once or more over a warm and wet season for vegetative growth but may not be necessary if the season develops cool and dry (Poni and Intrieri, 1995). On the other hand, we are aware that summer pruning causes significant changes in canopy architecture and physiology and in the compositional and sensorial traits of the grapes (Poni and Giachino, 2000). Our attention should thus be directed here to those mechanical summer pruning runs that are performed every year to induce specific grape quality traits so as to contribute to the expression of a “terroir”.

Over the last decades, there have been impressive advances in the field of mechanical summer pruning (Rühling, 1997). Any of the world’s trade exhibition invariably features a large array of machines suitable for summer pruning interventions (shoot trimming and positioning, bud, shoot and berry thinning, de-suckering, tying, leaf removal); the only exception is cluster thinning, which is still primarily manual. Two of these operations–shoot trimming and leaf removal–are particularly effective in modifying a natural "terroir" which, due to intrinsic unfavourable climate features (too warm or too wet) is considered a non-premium wine area.

4.1. Shoot trimming

Shoot trimming is one of the easiest operation to mechanize and it can be performed in about 1-1.5 hours/ha with machines mounted either with cutter bar or rotating knives (Intrieri and Poni, 1990). A fundamental distinction needs to be made between shoot trimming done on traditional VSP hedgerow trellises or on free-hanging canopies (i.e high single-wire trellis).

In the former case, mechanical trimming has to be performed when the shoots begin to outgrow the top wire and manifest the tendency to bend downward. If so, cut severity and timing become variables of scant flexibility. In fact, if the cutter bar has to operate above the top foliage wire and the trellis is correctly managed (canopy height of al least 1-1.2 m above the main wire), a minimum number of main leaves likely suitable for adequate ripening is automatically retained and the timing is very much decided by the shoot-growth rates imposed by the pre-trimming weather course. Yet, this operation represents an important diagnostic tool for investigating vine balance in a vineyard: the ideal vegetative regrowth would be represented by some laterals developing mostly in the apical part of the trimmed stem which, on one hand should grow enough to reach maturity around veraison and, on the other not grow too much to make necessary a second (or even a third) trimming with the attendant risk of excessively prolonging vegetative growth.

Io our opinion, mechanical shoot trimming performed on free-hanging trellises has a much greater impact than former case in altering grape characteristics and, hence, "terroir" expression. This is because canopy characteristics (direction of shoot growth, leaf and cluster microclimate, leaf demography) are much more drastically modified by this intervention than in the case of trimming VSP canopies. Indeed, a shoot trimming applied to a single-wire trellis by mechanically removing at bloom a few apical leaves from a still mostly upright canopy brings about key modifications as follows.

I. A more upright growth habit is induced with better penetration of light in the cluster area and the basal shoot zone. Yet, the clusters are somewhat screened by the overlying leaves and this contributes to a sort of "intermediate" cluster microclimate (i.e. prevalent diffuse light enriched with occasional sunflecks), which has proved to be the best option for pigment accumulation in a few red varieties (Price et al., 1985; Haselgrove et al., 2000);

II. The early trimming triggers lateral formation that, if well balanced, leads to a change in leaf demography (rejuvenation), which is able to maximise, at veraison, the fraction of functional, yet non senescing, leaf area over total. A younger grapevine canopy over the ripening period would mean not just higher photosynthetic activity but even more chances to synthetise tartaric acid which is notoriously produced primarily by immature organs (namely young leaves).

Given these modifications, it is conceivable that grapes harvested from the same plots, and differing only for presence or absence of trimming, would lead in a final product that might mimic differences related to "terroir".

However, published reports (Poni et al. 2002) have highlighted that the early cut on which this technique is based triggers the problem of the unpredictability of lateral regrowth following trimming. This concept is better clarified in Figure 4 A-D, where data from a three year trial on Pinot Noir/3309 trained to high single-wire cordon are reported (Poni et al, 2002). The canopies were trimmed yearly at either 7 (T 7) or 11 (T 11) main leaves at pre-bloom as compared to untrimmed canopies (control). Mechanical shoot trimming was usually performed in late May, when the majority of shoots were still erect.

While yield levels were similar between treatments (no significant year x treatment interaction for this parameter), the weather course markedly influenced the post-trimming lateral formation, which was weak and moderate in 1999 and 2001, respectively, and strong in 2000 (Fig. 4A). As a result, in 1999 and 2001, the leaf-to-fruit ratios, calculated on a per vine basis (Fig. 4D), were lower than one m^2/kg of fresh mass in both trimmed treatments and this corresponded to lower °Brix and total anthocyanins as compared to the untrimmed vines (Fig. 4B,C). These results send a warning signal about the "high risk rate" of this technique, which should be aided, whenever possible, by supplemental irrigation as a tool for correction of weak growth in dry years.

4.2. Leaf removal

Leaf removal of the fruiting area, whether manual or mechanical, is one of the most frequently applied summer pruning operations in winegrape growing (Percival et al., 1994; Reynolds et al. 1996). Although this cultural practice may have different goals, it is usually performed from fruit-set and veraison on high density canopies to improve light exposure and air circulation around the clusters, with remarkable benefits in terms of pigmentation and tolerance to rot (Bledsoe et al., 1988). Yet, improved quality is not a constant of leaf removal studies and, when present, it does often appear to be an indirect consequence of improved cluster microclimate. As a matter of fact, excessive leaf removal resulting in overly exposed clusters have led to lower berry colour in red varieties (Price et al., 1995), and a recent paper by Petrie et al. (2003) reports that leaf removal from the lower quarter of the canopy during the lag phase of berry growth caused a significant decrease of whole-vine photosynthesis even on a per-unit leaf area basis, thus suggesting that the lower portion of the canopy contributed more than the upper portion to the whole-vine carbon budget. Likewise, the effects of leaf removal on yield are quite variable depending upon its timing and severity.

Since it is very well know that carbohydrate supply at flowering is a primary determinant of fruit set (Caspari and Lang, 1996), early leaf removal (i.e within the 4 weeks after flowering) quite typically reduces berry weight and the amount of total sugar per vine (Kliewer and Antcliff 1970; Hunter and Visser, 1990b). However, if leaf removal is performed later or at a milder level, yield might show either no significant changes (Bledsoe et al., 1988) or even occasional increases as compared to non-defoliated vines (Zoecklein et al., 1992).

Let us return to the issue of "terroir" and, hence, grape quality. It does appear from the above literature review that the variability of the effects brought about by this operation is too high to note that the same can be consistently used to ameliorate quality. However, more recently, a particularly early leaf removal (pre-bloom and/or first week after fruit set) carried out on the basal shoot zone has been tested on high productive varieties bearing big, compact clusters to verify if the expected decrease in fruit set, and hence cluster compactness, is also accompanied by enhanced quality (Poni et al, 2004).

The preliminary results, albeit still in reference to controlled (manual) leaf removal applied at 50% and/or 100% on the 1-to-8 node shoot zone, has led in cvs. Barbera and Trebbiano to a spectacular reduction in cluster compactness (Figure 5) and, most importantly, to increased quality (higher °Brix in both varieties and higher anthocyanins in Barbera) (Table 5). The improved quality in the defoliated vines is partially due to the increase in the leaf-to-fruit ratio (shoot basis) induced by a more than proportional yield reduction as compared to the source limitation induced by the defoliation and, quite likely, by the fact that the "younger" canopies exhibited by the defoliated vines at veraison (median and apical shoot leaves at this time are now mature and more lateral leaves can be present as a compensating reaction to early main leaf removal) may in turn lead to higher photosynthesis late in the season.

Thus, preliminary evidence exists that such early leaf removal might represent an interesting tool to achieve both yield control (thereby eliminating the need of costly manual cluster thinning) and improved quality which, besides the physiological mechanisms cited above, can rely also upon less susceptibility to bunch rot due to looser clusters.

Work in already in progress to test the mechanical feasibility of this early leaf removal. The major concern is that, especially for pre-bloom leaf removal, the similarity in specific weight of leaves and inflorescence might determine high damage to the latter. A preliminary experience (Intrieri, personal communication) performed on COMBI-trained Sangiovese grapevine was encouraging, suggesting that if the machine is correctly set up and the trellis adequately managed, the damage to the inflorescences is minimal and the percent of foliage removed from the basal shoot zone (approximately node 1 to 6) can vary from about 43% for the earliest defoliation (1 June) to 50% for the defoliation carried out after fruit-set (15 June). The fact that the machine can probably not reach defoliation levels higher than 50-60% (on a main leaf basis) might turn out to be a positive feature for the following reasons:

- ☐ Based on the preliminary physiological results of early manual leaf stripping, a leaf removal percentage of about 40-50% may likely be sufficient to get some effect of cluster loosening; and
- ☐ Maintenance of some leaves after the machine passage would soften negative effects on bud initiation the next cropping year and allow also some degree of cluster shading.

5. Concluding remarks

Defining the role that mechanization will have on “terroir” expression over the last decades is not an easy task. As a matter of fact, the use of machines is primarily linked to the availability of hand labour, an issue which ranges from situations where no such labour is available at all (large vineyards in under-populated areas of South Australia) to cases where availability of low-payed workers makes the use of mechanical harvesting (huge properties in the Neuquen area, Argentina) economically unviable.

However, we think that the interaction of vineyard mechanization and “terroir” will stronger in the future within the grounds of grape quality and vine balance. Richard Smart (1996) has stated that it is almost impossible to establish a direct relationship between quality of wine and soil composition or content of any nutritive element. Conversely, there is evidence (Seguin, 1986) that the soil physical properties which regulate the water supply to the vine is a key factor for a great “terroir”. Light soils which drain freely and are associated with deep vine roots reaching a not too deep water table are those conditions more likely to lead to the ideal state of mild water stress with vine growth stopping on schedule around veraison. This is a nice example of a naturally-regulated vine balance leading, in turn, to good-to-excellent quality. Mechanization, if properly conducted and fit to training systems, can aid in “terroir” expression.

Mechanical harvesting carried out at night under cooler temperatures associated with a more effective harvest schedule as a function of cultivar, ripening stages and/or maturity requirements, as compared to a manual work plan, can become an important quality factor; the same applies also to mechanical winter pruning, especially when the technique is used as a “correction factor” for high vigour sites, where quite often increasing the yield level to a certain level contributes to balance the vine (Keller et al., 2004).

Even clearer is the role that mechanical summer pruning can play here. A perfect “terroir” can be imagined as a site where vine growth naturally fades and arrests at veraison and no summer pruning is needed; this “ideal” scenario is far from reality and in a great number of cases summer pruning is mandatory to correct vine shape, canopy orientation and excessive growth. Then, mechanical practices, like shoot thinning, trimming and positioning, leaf removal, and so on, properly applied as timing and severity are of the utmost importance for recovering grape quality levels.

Furthermore, technological progress is indeed broadening the interaction between mechanization and other vineyard operations. Research is active in assessing the effectiveness of summer pruning (e.g. leaf removal) combined with spraying (Balsari et al., 2004) as well as evaluating grass mowing machines able to coax the sward under the vine strip to build up an organic mulch (Intrieri et al. 2002). Our feeling is that in a not too distant future the traditional concept of “terroir” will have to deal more directly with the mechanization of vineyard operations.

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Figure captions

Fig. 1. Percentage distribution of Italian wine export (year 2003) valued as €/L. (from Pedron, 2004).

Fig. 2. Front-view of a COMBI-trained vine row and an inter-row mechanical harvester operating with a vertical impactor on one side of the row (from Intrieri and Filippetti, 2000).

Fig. 3. Frequency distribution (grey histograms), mean budbreak (shoots/node, ●) and fruitfulness (inflorescences/shoot, ○) for each type of bearing unit left on cordons of cv. Croatina (Vitis vinifera L.). Data have been averaged over four years of observations (2000-2003) and different pruning regimes (see table 4 for explanation). Taken from Poni et al. 2004, in press.

Fig. 4. Effects of early shoot trimming (7 or 11 leaves retained on main shoot as compared to untrimmed) on total leaf area development (main + lateral), soluble solid concentration, total anthocyanins and leaf-to-fruit ratios of Pinot noir grapevines trained to high single- wire. Taken from Poni et al., 2002.

Fig. 5. Representative clusters of Trebbiano vines subjected to the defoliation treatments described in Table 5. I = pre-bloom defoliation. II = beginning of fruit-set defoliation. 50%: removal of one every two leaves the basal shoot zone (node 1 to 8). 100%: removal of all leaves within the basal shoot zone (node 1 to 8). Taken from Poni et al., 2004 (in press).

Table 1. Composition of mechanically harvested grapes according to variety and harvest principle (reworked from Intrieri and Poni, 2004)

	Harvesting principle	Berries (%)	Bunch or part of (%)	Free must (%)	Debris (%)
White cultivars (Tocai friulano, Chardonnay, Pinot b.,Verduzzo f., Verduzzo trev.)	**Horizontal shaking**	**86.1**	**3.5**	**9.3**	**1.1**
	Vertical shaking	**80.5**	**15.7**	**3.6**	**0.2**
Red cultivars (Pinot g., Pinot n., Merlot, Carmenére, Cabernet S., Cabernet f., Raboso piave, Raboso veronese)	**Horizontal shaking**	**81.8**	**9.9**	**6.8**	**1.5**
	Vertical shaking	**73.0**	**23.7**	**2.9**	**0.4**

Table 2. Free-running juice as percentage of total mechanically-harvested mass collected over 30' minutes in different cultivars (from Intrieri and Poni, 1989)

Harvesting method	Free juice index		
	Trebbiano r. (%)	Pignoletto (%)	Sangiovese (%)
Trinova vertical shaking	6.2 a	5.3 a	3.2 a
Conventional horizontal slapper	14.5 b	9.1 b	3.1 a

U-Mann Withney test within colums, 5% level

Table 3. Composition of mechanically harvested (vertical impact) grapes in different Vitis vinifera cvs. (from Intrieri and Poni, 2004)

V. Vinifera cvs.	Berries (%)	Bunch or part of (%)	Free must (%)	Debris (%)
Barbera	86.2	7.3	6.5	traces
Bonarda	77.8	20.1	2.1	"
Sangiovese	94.0	5.5	0.5	"
Shiraz	79.1	20.6	0.3	"
Avg.	84.3	13,4	2.3	-

Table 4. Influence of manual and mechanical pruning on vegetative growth, yield and grape quality of "Croatina" vines. Data averaged over 2000-2003. Data taken from Poni et al. 2004 (Amer J. Enol. Vitic. In press).

Source of variation *Pruning*	**Nodes/vine**	**Budbreak (shoots/node)**	**TLA/vine (m^2)**	**Yield/vine (kg)**	**TLA/yield (m^2/kg)**	**Soluble solids (°Brix)**	**Anthocyanins (mg/g FW)**	**Phenolics (mg/g FW)**
HP	37.5 d	0.91 a	4.79 b	2.82 c	1.70	20.7 a	1.34 a	2.96 a
SMP-SF	50.5 c	0.89 a	5.02 b	3.48 b	1.44	20.4 ab	1.34 a	2.93 a
SMP-LF	60.0 b	0.81 b	5.88 a	3.67 ab	1.60	20.4 ab	1.28 a	2.95 a
MMP- LF	75.2 a	0.74 c	5.10 b	4.19 a	1.22	19.7 b	1.18 b	2.79 b
Significance [zy]	**	**	*	*	ns	*	*	*
Pruning x year interaction [y]	ns	**	*	*	ns	ns	ns	ns

[z] Means separated within columns by Student-Newman-Keuls test. [Y] *,**, ns: Significant at p ≤0.05, 0.01, or not significant, respectively.

Table 5. Effects of the defoliation treatments on cluster weight, grape quality and leaf-to-fruit ratio in Barbera (pot study) and Trebbiano r. (field study) grapevines. Taken from Poni et al. 2004 (in press)

	Barbera – Pot study					**Trebbiano – Field study**			
	Cluster weight (g)	Solubile solids (°Brix)	TA (g/L)	Total anthocyanins (mg/g FW)	Final LA/yield (cm^2/g)	Cluster weight (g)	Soluble solids (°Brix)	TA (g/L)	Final LA/yield (cm^2/g)
Control	159 a	17.2 b	10.8 a	0.76 b	15.1 b	321 a	17.2 c	5.8 b	7.8
I – 50%	112 b	19.6 ab	8.3 b	0.98 a	21.8 ab	-	-	-	-
I – 100%	113 b	20.5 a	8.7 b	0.90 a	17.9 ab	142 b	19.6 a	5.8 b	10
II – 50%	99 bc	21.4 a	8.4 b	0.98 a	23.6 ab	-	-	-	-
II – 100%	87 bc	19.2 ab	9.5 b	1.02 a	23.2 ab	167 b	19.1 ab	7.3 a	7.7
I – II – 50%	83 c	20.1 ab	9.0 b	0.99 a	29.5 a	180 b	18.6 b	6.4 ab	9.0
Sig.[1]	*	*	ns	*	*	*	*	*	ns

[1]. Mean separation within column by DMRT. ns, *, **; non significant, significant at 5% and 1% level, respectively.

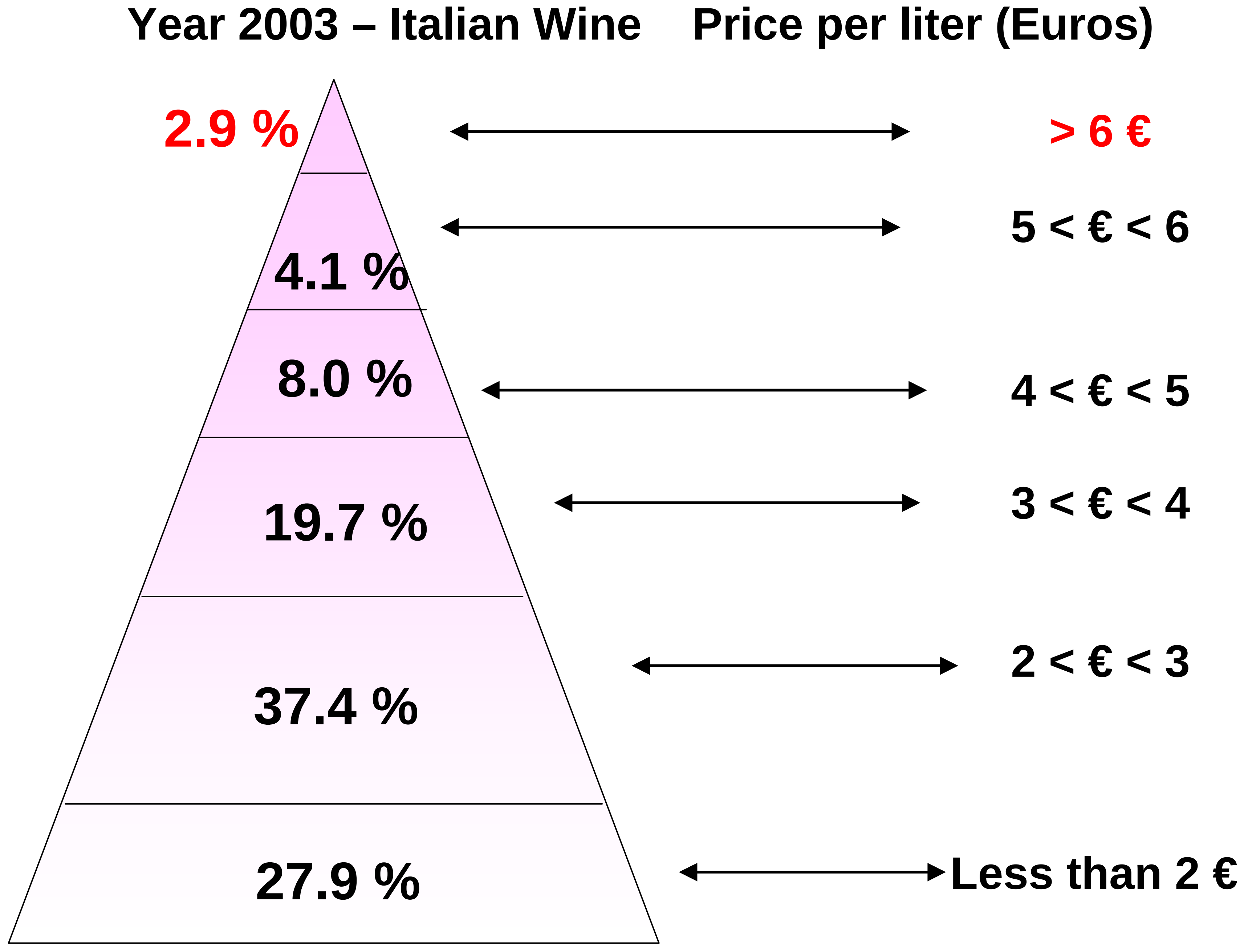
Year 2003 – Italian Wine
Price per liter (Euros)
2.9 %
> 6 €
4.1 %
5 < € < 6
8.0 %
4 < € < 5
19.7 %
3 < € < 4
37.4 %
2 < € < 3
27.9 %
Less than 2 €

Fig. 1

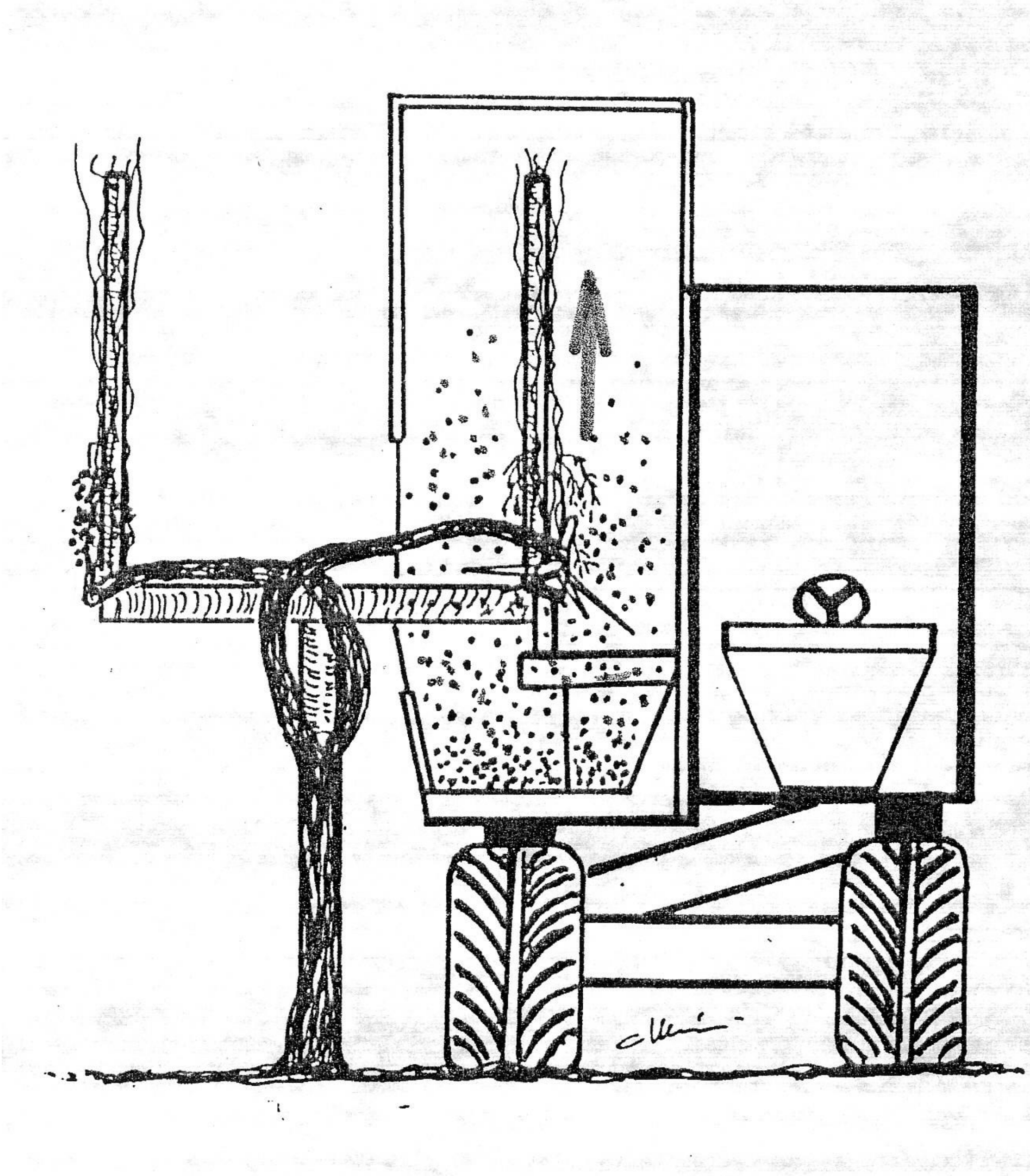

Fig. 2

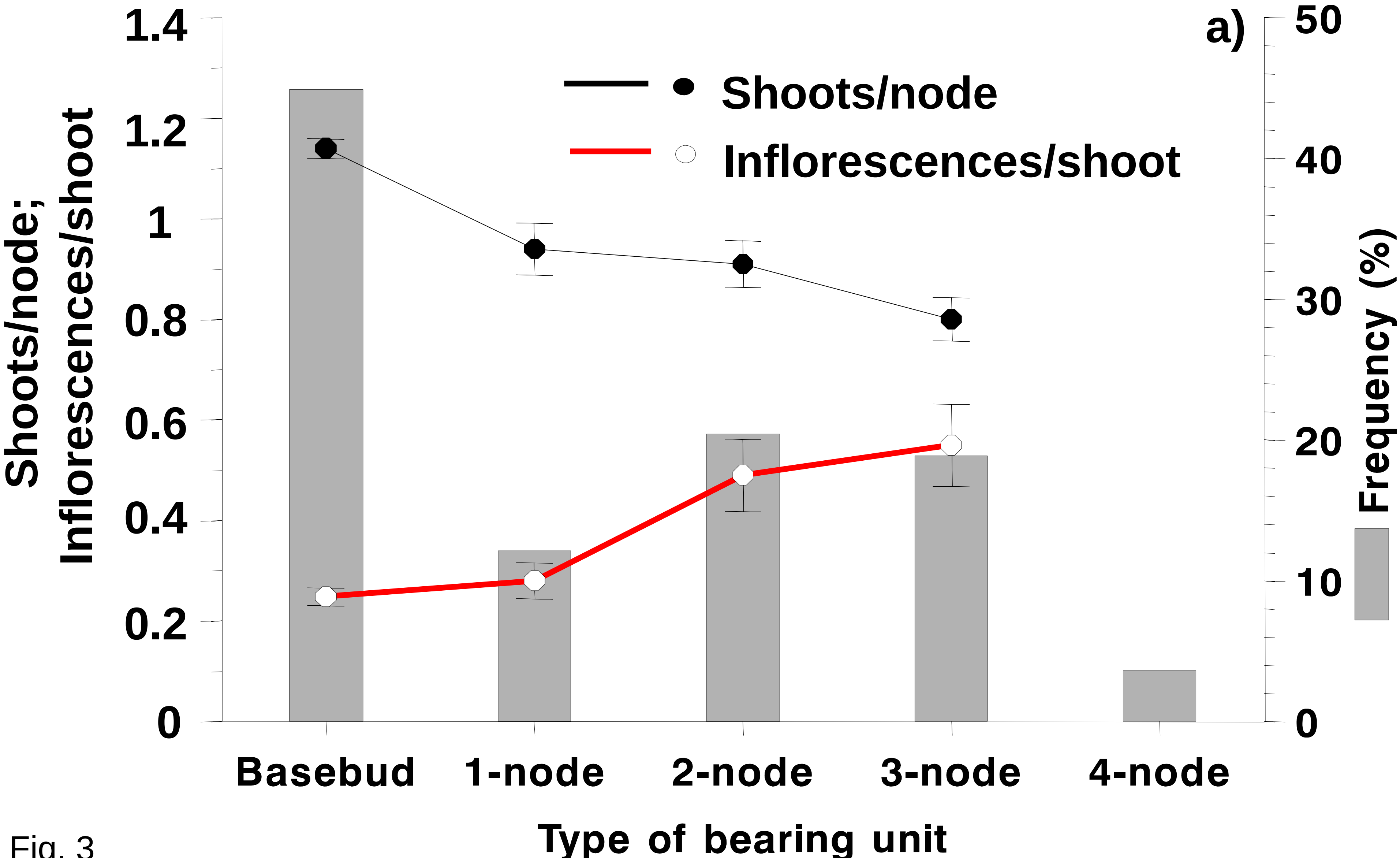
a)
Shoots/node
Inflorescences/shoot
Shoots/node;
Inflorescences/shoot
1.4
1.2
1
0.8
0.6
0.4
0.2
0
50
40
30
20
10
0
Frequency (%)
Basebud
1-node
2-node
3-node
4-node
Type of bearing unit

Fig. 3

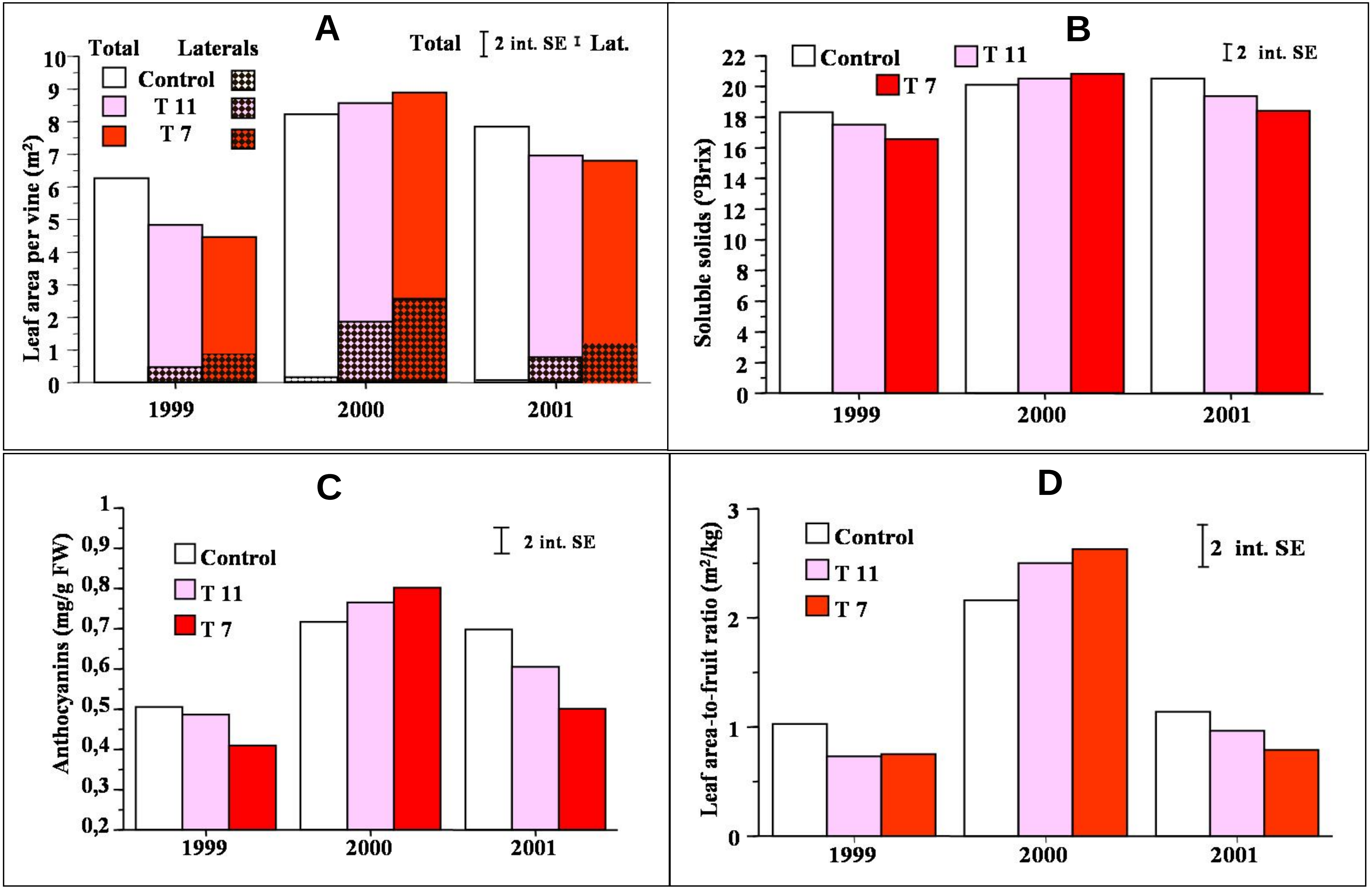
A
Total
Laterals
Control
T 11
T 7
Total
2 int. SE
Lat.
Leaf area per vine (m²)
10
9
8
7
6
5
4
3
2
1
0
1999
2000
2001
B
Control
T 11
T 7
2 int. SE
Soluble solids (°Brix)
22
20
18
16
14
12
10
8
6
4
2
0
1999
2000
2001
C
Anthocyanins (mg/g FW)
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
Control
T 11
T 7
2 int. SE
1999
2000
2001
D
Leaf area-to-fruit ratio (m²/kg)
3
2
1
0
Control
T 11
T 7
2 int. SE
1999
2000
2001

Fig. 4

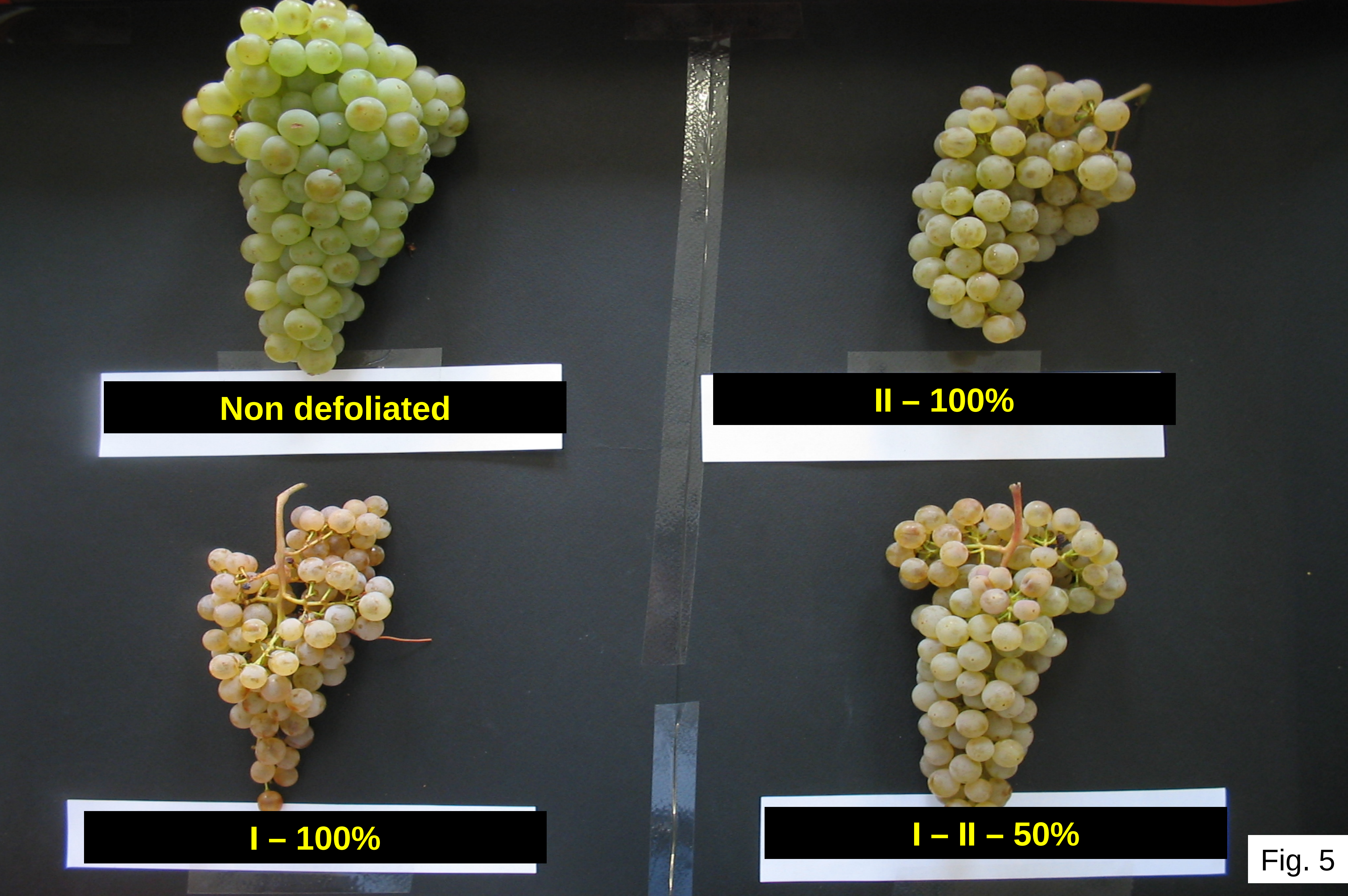

Fig. 5