1993 Honorary Research Lecture

Integrated Evolution of Trellis Training Systems and Machines to Improve Grape Quality and Vintage Quality of Mechanized Italian Vineyards

CESARE INTRIERI[1*] and STEFANO PONI[2]

*Professor Intrieri presented the ASEV 1993 Honorary Research Lecture at the 44th Annual Meeting of the American Society for Enology and Viticulture in Sacramento, California (June 1993). Professor Intrieri is a member of the Italian Academy of Vines and Wines and the National Academy of Agriculture. His major research has been in the fields of growth regulators, mechanization of pruning and harvesting, canopy management and microclimate, and clonal selection and breeding. The text of his presentation has been edited for publication.

Italy's viticulture acreage stood at 1.4 million hectares in 1970. According to a survey undertaken at the time by the National Academy of Agriculture, the vineyards were essentially of two types: a high-yield model situated in the fertile lowland soils, with a yearly production of about 18 tonnes (t) per hectare at 530 man-hours of labor (46% of which used for harvesting and 36% for winter pruning), and a low-yield model found mainly in drier soils and hillside areas, with a yearly production of about 8 t per hectare at 450 man-hours labor (37% for harvesting and 36% for winter pruning). Today, two decades later, while the country's total vineyard acreage has dropped to about 900 thousand hectares (27), little else has changed in the overall profile of its viticulture. For example, more than 80% of vineyards are less than one hectare in size and nearly 60% are planted in hillside areas. Under these conditions the above-mentioned amounts of human labor have not markedly changed.

Of these 900 thousand hectares, one-third are located in the country's northern and central areas, including the Emilia-Romagna, the Veneto, and those surrounding regions that fall within the Po and Adige Valleys and run from the Alps in the north to the Apennines in the south.

The viticulture of the Po Valley: The Po Valley is marked by very fertile soil and a climate that ranges on Winkler's heat summation index from 1200 to 1400 degree days (dd) centigrade in the foothill areas to 1800 to 2000 dd in mid-valley (38) -- a range that matches regions 1, 2, and 3 in California. The Po Valley vines grow vigorously, and the traditional hedgerow systems, mainly trained to long arched cane, are markedly tall, planted at low density and provide high yield per vine and per hectare (17,22).

However, the terrain and soil conditions of this valley, unlike those for high-yield vines in other areas of the country, are more conducive to mechanized pesticide treatments and soil management and enable increased efficiency of pruning and harvesting by the use of platforms.

While these factors combined to lower the labor demand, the valley's vineyards not mechanized for harvesting and pruning still need about 380 man-hours labor yearly per hectare (Fig. 1).

The mechanization of harvesting: The need to increase vineyard mechanization arose in the Po Valley before other areas of the country because the marked expansion of industrial development in northern Italy in the early 1970's sharply decreased the seasonal labor

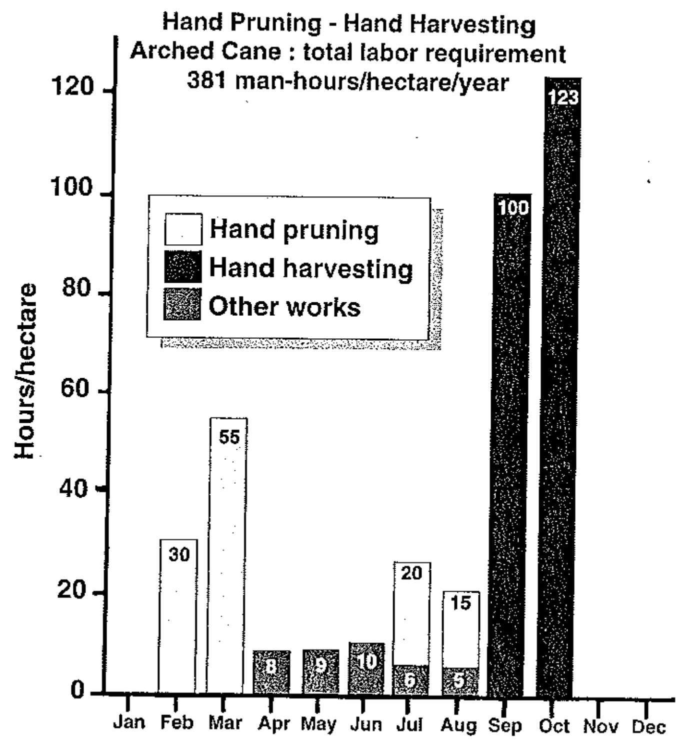


Fig. 1. Yearly labor demand in hand-managed arched-cane vineyard (15).

[1,2]Dipartimento di Colture Arboree, University of Bologna, Via Filippo Re 6, 40126 Bologna, Italy

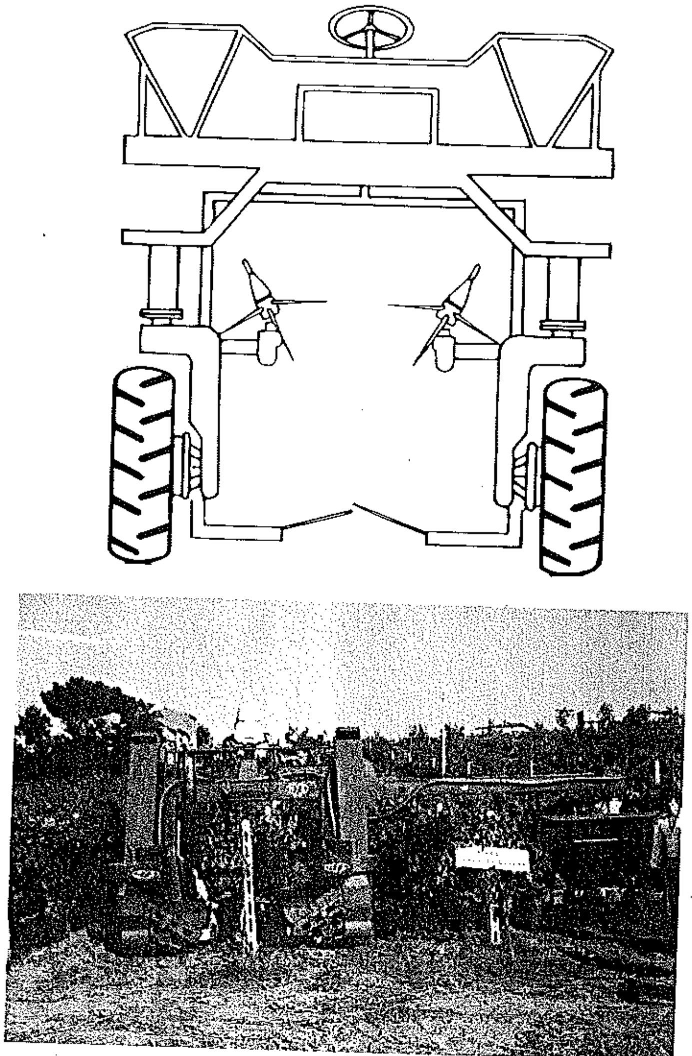


Fig. 2. Italian version of over-row vertical shaking harvester.

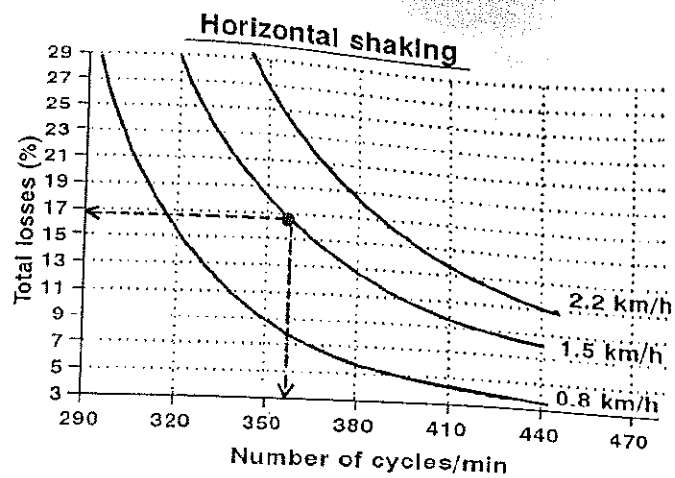


Fig. 3. Inter-relationship of drive speed, slapper frequency and total crop losses (37).

supply there.

The first attempt to address this and related problems was directly linked to the development at Cornell University of the Geneva double curtain (GDC) - a system designed specifically for mechanical harvest employing over-row machines fitted with vertical-shaking head pickers (33,34). GDC vineyards were thus established, either as new plantations or as conversions from the traditional systems (13,14,16,31,32), and a commercial prototype harvester (Fig. 2), almost identical to the model manufactured in the US by Chisholm-Ryder, was built and extensively tested in them (28). Yet, despite the fact that harvested vintage quality was good, the overall performance of the Italian machine exhibited definite limits (2) because of its marked width, which made it difficult to handle on roads and in field, and the difficulty in keeping the spiked-wheel picking heads concurrently aligned along the two curtains. The end result was that the machine never went into commercial production.

Meanwhile, over-row harvesters fitted with horizontal slappers for hedgerow systems were introduced from US and France (5).

However, in order to employ these units in the tall, vigorous hedgerows of the Po Valley, it was necessary to shorten the posts. This proved unviable because the excessive growth of the shoots covered fruiting areas of the canopy, resulting in a loss of vintage quality and machine efficiency as well as in damage to vines hit by the slappers (2).

The use of this machine was thus limited to less vigorous vines. Here, extensive testing on the interrelated working speed, slapper frequency, total yield loss and injured vines showed that the best balance of these factors, *i.e.*, a running speed of about 1.5 km per hour and a slapper frequency of 360 cycles per minute, resulted in yield losses of about 17% (Fig. 3). The losses can be broken down into several parts: while on-vine and on-ground fruit loss was limited to about 4%, juice loss was over 12%. Yield quality, too, was compromised as the free-running juice index from harvested fresh mass was just over 18% (6).

At the same time as these tests were being run, the

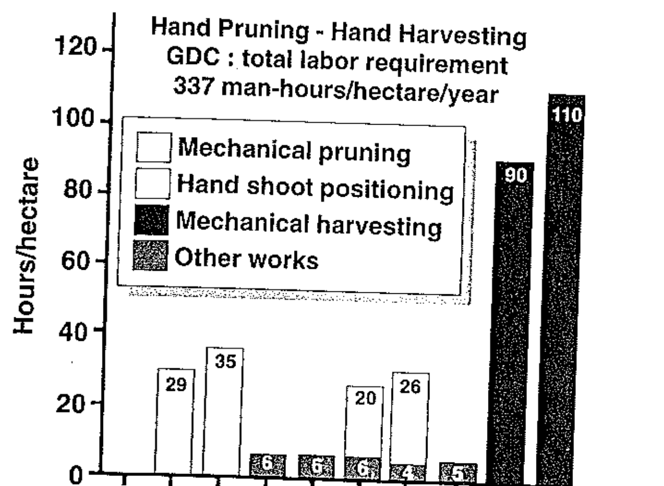
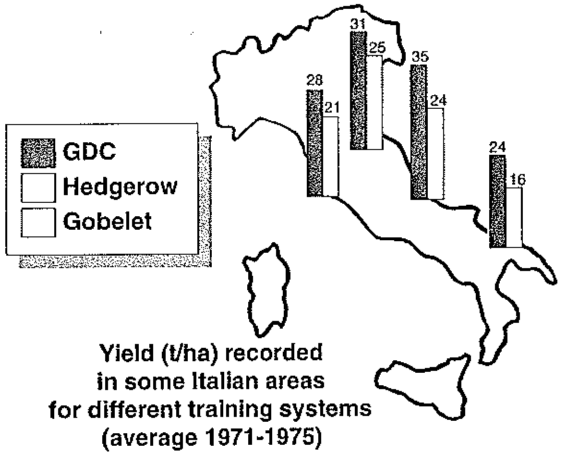
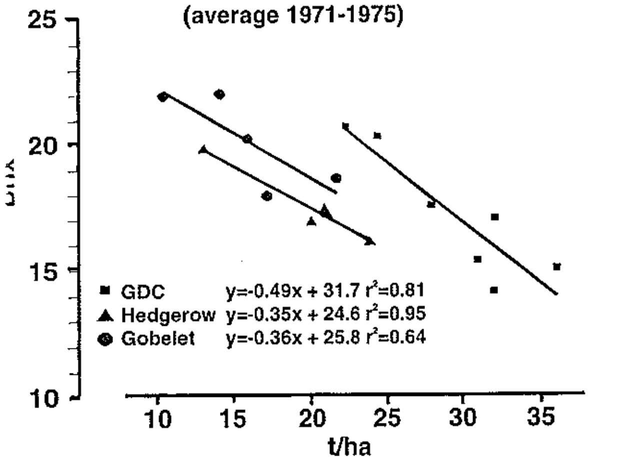


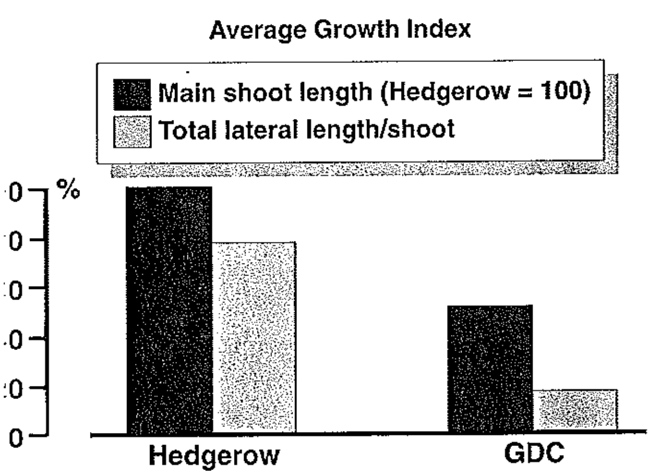
Fig. 4. Yearly labor demand in hand-managed GDC vineyard (3,4).





. 5 ter-relationship of yield and soluble solids (reworked from 14 .1,32).

ablished GDC vineyards were also being studied in ms of labor demand, cropping habits and plant growth. e GDC's cluster and spur position made it possible, en under hand harvesting and pruning, to cut yearly or demand from 380 in the traditional hedgerow stem to about 335 man-hours (Fig. 4). In addition, the ting against the traditional systems, which was now ended to southern and central Italy as well as being



. 6. rage shoot growth index of hedgerow and GDC (reworked from

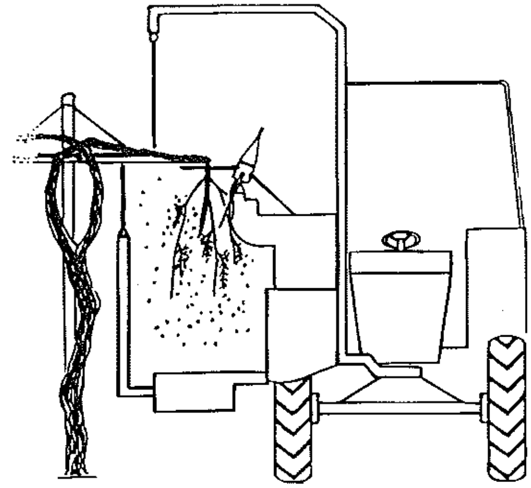


Fig. 7. Tractor-mounted half-row vertical shaker.

conducted in the north, showed that GDC registered higher yields at the same sugar contents (Fig. 5). This response was attributed to the enhanced light interception by clusters and leaves as a result of canopy division and shoot hanging.

Another notable physiological response of these trials was the control of vine growth exerted by the hanging shoots (Fig. 6). This finding, together with the others, pointed on the one hand to GDC's potential for higher planting densities and on the other renewed interest in harvesting mechanization by vertical shaker. Thus, in the mid-1970's, a project was undertaken to test a new approach based on an upgraded integration of GDC system and harvester.

The half-row harvester and modified GDC trellis: The basic project concept was to integrate a machine of relatively simple design and GDC system (2). The prototype unit developed for it (Fig. 7) was mounted on one side of the tractor and fitted with a single, vertical spiked-wheel shaker to harvest a single GDC curtain per run (10,11).

The ensuing trials were designed not only to test harvester efficiency but also to study the stroker effect on the crop (11). The slow-motion film used to record a single stroke of the stationary harvester showed a very limited area of berry drop in front of and behind the point of impact. For comparison, this effect was then monitored with the unit running by recording shaker oscillation and by filming cluster movement at varying shaker amplitude and cycles per minute (36,39). The best performance (Fig. 8) was found at a 14-cm amplitude and 300 rpm, a combination that dampened the impact-induced oscillation about three meters ahead of the shaker, yet left it strong enough to detach the berries over a distance of about one meter in front of the moving head. Thus, the advancing stroker detaches by inertia the berries one meter ahead of it, *i.e.*, without physical contact between shaker and berries (20). Higher or lower amplitudes, as well as cycles, extended the berry drop zone either too far ahead or too close to the

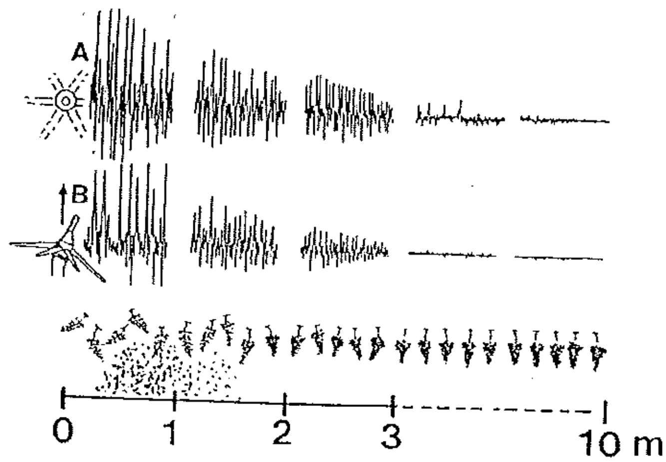


Fig. 8. Vine cordon oscillation on horizontal (A) and vertical (B) plane and cluster movement induced by the vertical shaker (reworked from 6,36,39).

shaker (20).

This unit was then integrated with a GDC trellis that was modified from its original Y- to a T-shape so as to increase the catch-gondola's coverage and to reduce on-ground fruit losses (Fig. 9). This T-configuration consists of two independent, upward-moving horizontal arms, whether wire-supported at arm mid-point or self-supporting, that feed into the overlapping, flexible 'fish scales' of the catch gondola as the unit advances along the row (12). The other main changes were the use of coiled wire (6), to keep the cordon straight and eliminate tying, and the S-shape of the two cordons, which oriented each to the harvester's drive direction (Fig. 10).

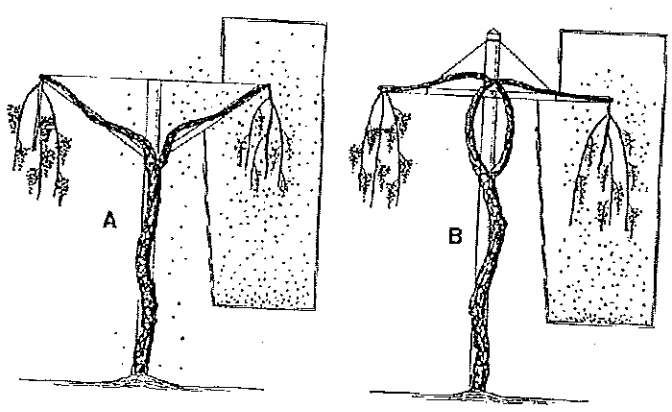


Fig. 9. Vertical shaker with harvesting gondola in original (A) and modified (B) GDC (20,1).

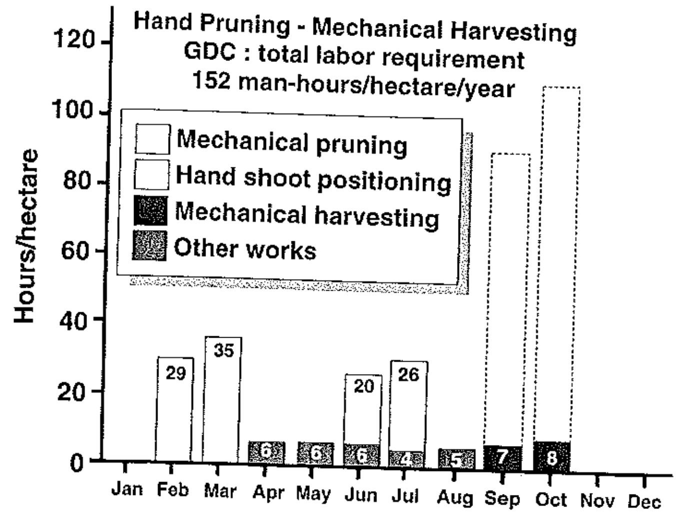


Fig. 11. Yearly labor demand in hand-pruned and mechanically harvested GDC vineyard (3,4).

The commercial machines built from this prototype, whether tractor-mounted or self-propelled, were always designed for GDC half-row harvesting. Extensive trials of the harvester with the modified GDC trellis showed, in comparison to the horizontal slapper, that overall yield losses averaged about 9% against 17%, juice losses were reduced from 12% to 6% and vintage quality increased as the free-running juice index of harvested free mass dropped from about 18% to 6% (6). The vertical unit also cut labor demand from about 335 to about 150 man-hours yearly per hectare (Fig. 11). Since these labor data clearly indicated that winter and mid-summer pruning claimed the largest share of the work load, the scope of the project was accordingly expanded to mechanize all pruning operations.

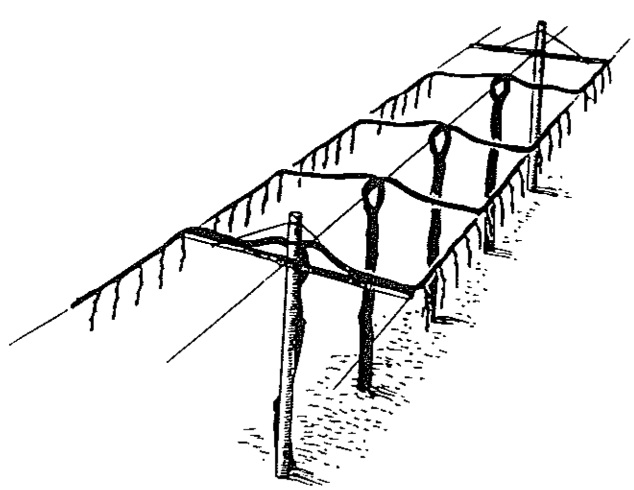


Fig. 10. S-shape cordon for half-row harvester in modified GDC (9).

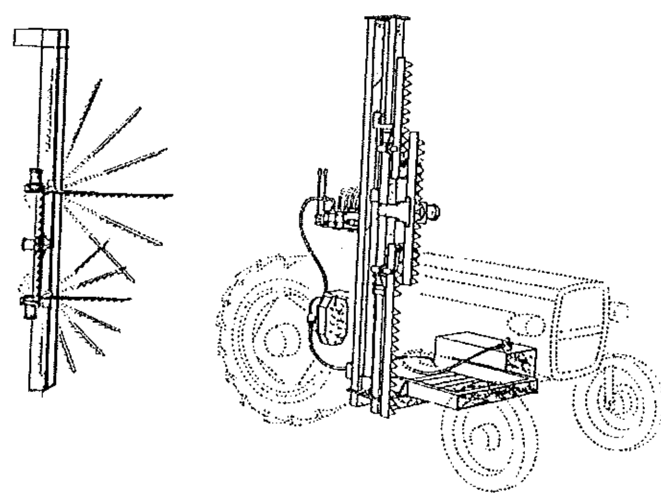


Fig. 12. Multi-purpose cutter unit with height and angle adjustable bars.

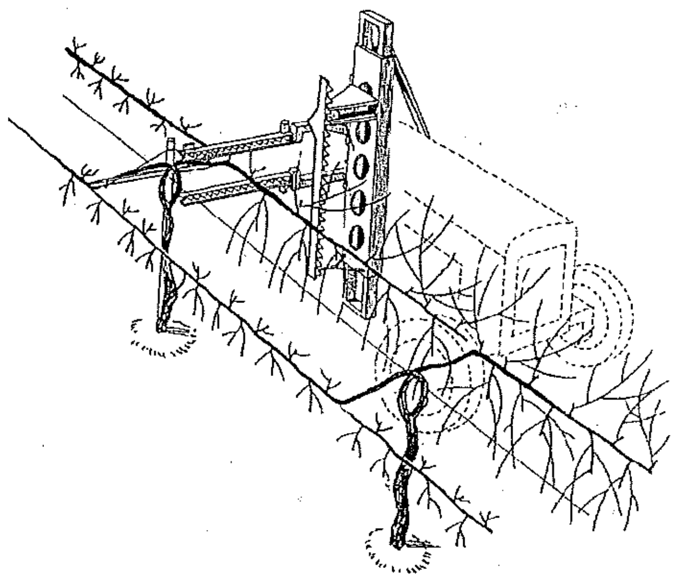


Fig. 13. Multi-purpose unit in winter pruning.

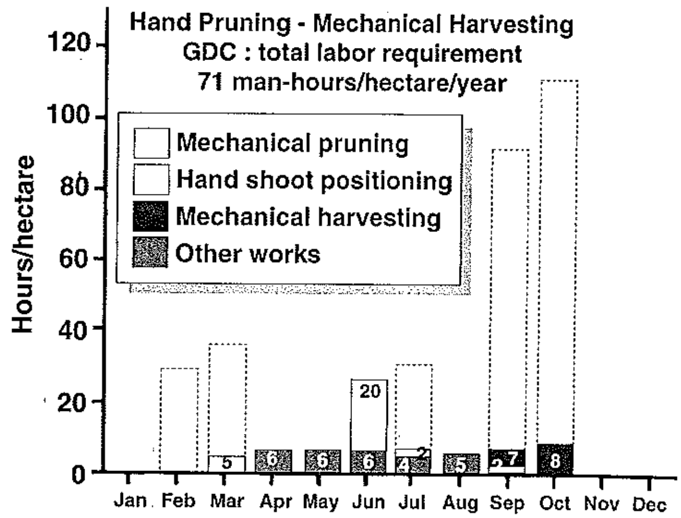


Fig. 15. Yearly labor demand in mechanically pruned and harvested GDC vineyard (3,4).

The modified GDC trellis integrated with machine pruning: The trellis modification from Y- to horizontal T-arms proved essential to the design and manufacture of a pruning unit to be integrated with it (7).

The pruner consists of three tractor-mounted cutter bars (8) adjustable in height and cutting angle (Fig. 12) so as to enable pruning above, below and on the external side of each GDC cordon in winter (Fig. 13) and in summer.

The original unit was later altered by the addition of a fourth, pivot, bar that can cut the internal cordon shoots and swing away to avoid hitting arms, posts, support wires, or other rigid obstacles in its path (21).

The cutter unit was tested in a long-term trial (1981-1987) designed to compare winter and summer manual against machine pruning with and without hand-finishing in adult vines (25). While the first-year results showed that the mechanically pruned vines had higher yield than hand control, as a result of the higher bud number left by winter machine pruning, the data over the next six years showed no significant differences among treatments (25).

These findings demonstrate the ability of machine-pruned vines to regulate in this case by diminishing bud-burst, bud fertility and bunch weight so as to maintain the same grape yield as achieved by hand cutting despite the always higher bud number left by the machine. These responses also explain why, from the second year on, soluble solids as an index of grape quality was comparable in all tests.

It is important to note that, when analyzed in detail, machine pruning achieves in the end an effect comparable to hand cutting. This because driver errors, irregularities in the terrain and varying shoot growth angles determine not a linear cut pattern, as might be expected of a machine, but one with a sinusoidal configuration of alternating short and long cuts along the cordon (Fig. 14).

The more severe cuts thus provide the renewal shoots and the longer ones carry the buds for current year production.

The use of mechanical harvesters and pruners cuts the labor demand in a GDC vineyard to a mere 70 hours yearly per hectare (Fig. 15), the only major manual work consisting of about 20 hours for shoot positioning. Since these trials, shoot positioning has been greatly facilitated by the use of platforms, their input being especially noticeable in terms of enhanced canopy division and the resulting enhancement of overall machine efficiency as well as grape and vintage quality (18). A more recent attempt to facilitate shoot positioning even

Fig. 14. Sinusoidal pattern of machine cuts along the GDC cordon (23).

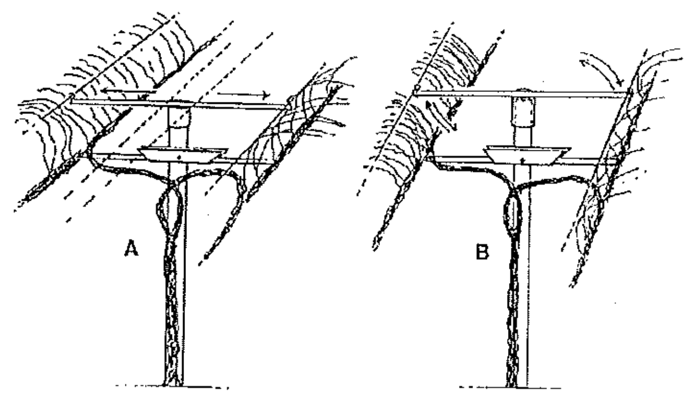


Fig. 16. Fixed (A) and pivot (B) T-bar with flexible plastic wires for curtain shoot separation in modified GDC trellis.

further consists of a T-bar capped to posts standing above the GDC (one T every 5 to 6 GDC posts) through which are run two 'Bayco' flexible plastic wires that can be shifted laterally from the row's central axis to keep the shoots of the two curtains separated. An improvement of this system is to secure the plastic wires at the end of the T arms and to allow the rotation of the T-arms 90° in towards the central axis at the end of the season so as to eliminate obstacles to mechanical harvesting and pruning (Fig. 16).

Another unit has also been devised to perform disbudding and suckering from the arms and trunk of GDC vines. It consists of three brushes that are interchangeable with the cutter bars, being fitted to the pruning unit.

The integration of the modified GDC and the technical advances in machinery have led to the expansion of GDC. For, although the traditional hedgerow systems still account for over 50% of the country's vineyards, GDC is progressively increasing in importance, its total acreage as of 1993 being estimated at 20 thousand hectares, most of which in the Po Valley.

Training systems and machinery performance and evolution: The success in all-round mechanization of the GDC because of its obvious advantages over traditional systems has spurred research into systems that eliminate its disadvantages. Principal among the latter are its relative trellis complexity, training young vines to a divided cordon and, especially, the need for yearly shoot positioning to retain a good canopy light micro-climate. Shoot positioning is critical in preventing quality loss and it is sometimes neglected by growers although it has been recently greatly facilitated.

Of the innovative training systems developed over the past few years as potential alternatives to the GDC, the most promising is the simple curtain (24). Unlike the GDC, it has one spur-pruned cordon and a simpler trellis but, like it, no foliage wires, so that shoots are free to extend downwards, and fruiting area on top if it (Fig. 17). The simple curtain (SC), which is thus designed to eliminate yearly shoot positioning, has confirmed its

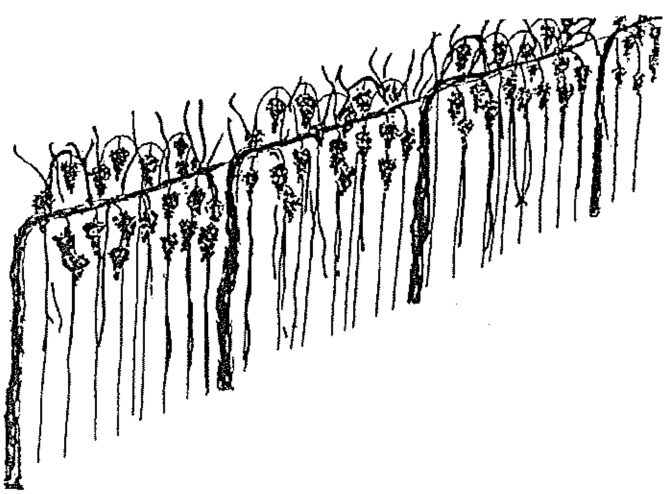


Fig. 17. Free-growing shoots and top fruiting area of simple curtain (40).

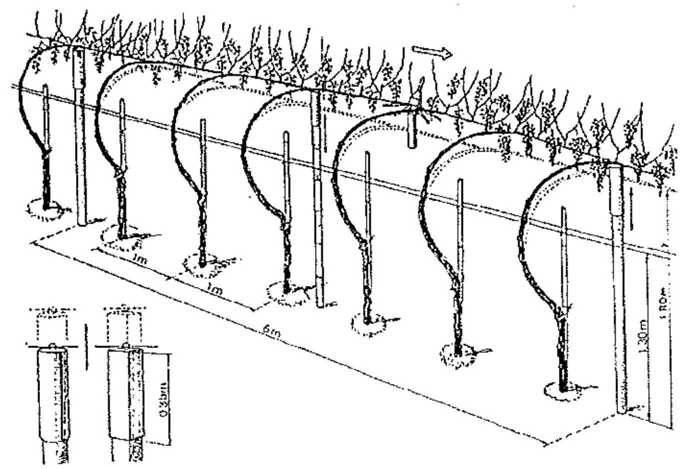


Fig. 18. Changes to simple curtain for vertical shaker harvesting.

trellis viability and aptitude for quality grape produc tion.

The simple curtain and machine integration The simple curtain (SC) was originally designed as a vertically trained trunk that develops into a single horizontal, spur-pruned cordon tied to a wire secured to the main post 1.7 meters from the ground. Prope training requires that spurs be oriented upwards to facilitate standard cutting along the top trellis plane Yet, because of its concentrated cropping zone, the SC system is well adapted to the standard over-row har vester with horizontal slappers, which has proved a serious drawback to both vintage quality and vine frame. So, before SC could be seen as a viable improvement over GDC, it also had to be modified to accommo date vertical-shaker machines (24).

The first step was to use a coiled horizontal suppor wire that retained cordon linearity and kept shoots a well as clusters on top. This solution had the adde advantage of facilitating mechanical pruning and en hancing light micro-climate in the fruiting zone.

To accommodate the system to vertical shaker har vesting, the coiled wire was run through moveabl plastic caps fitted over the post tops and the trunks wer bowed in order to follow the upward travel of the cap (Fig. 18). So, when the wire is pushed up 15-20 cm by th vertical shaker, the caps and cordon move freely up an down.

The second step was to design a multi-purpose un integrated with the modified SC for the full mechaniza tion of pruning, harvesting and spraying (Figs. 19, 20 The 1986 prototype featured four main components The self-propelled over-row vehicle is the main body an incorporates, one at a time, three modules (19,24).

The pruning module features two forward vertica cutter bars, adjustable to pruning height and angle, an four central horizontal ones, two per side, adjustable t pruning height. The harvester module includes tw spiked-wheel, vertical shaking heads that are aligne one behind the other and open away from or close i upon the vine from below. The spray module, which

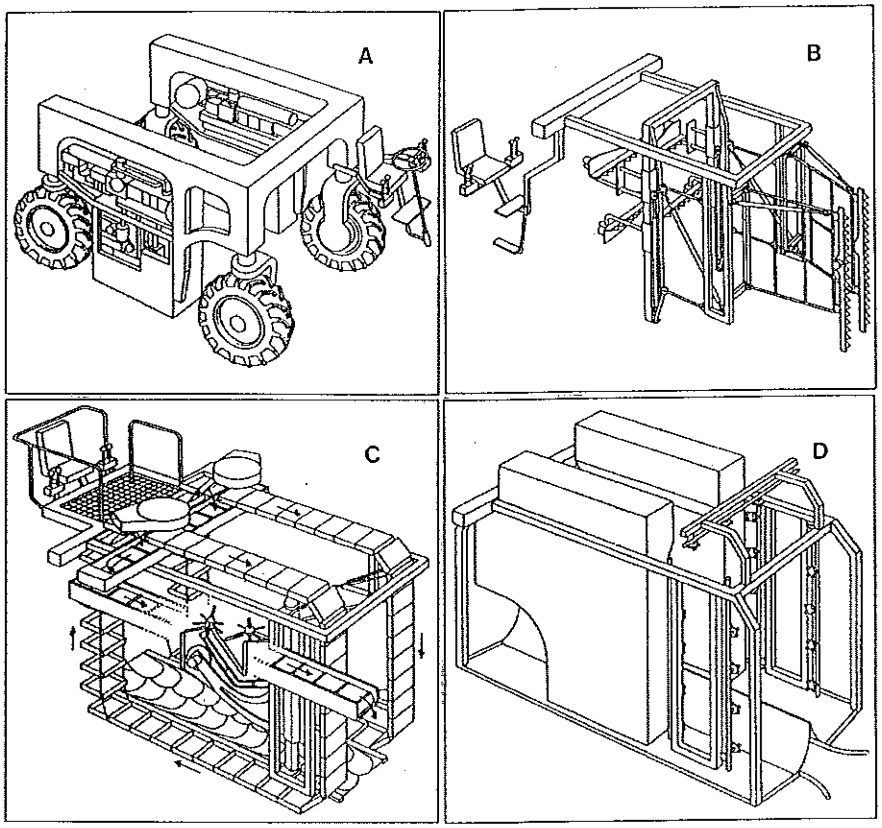


Fig. 19. Trinova carrier (A) and operational modules (B, C, D).

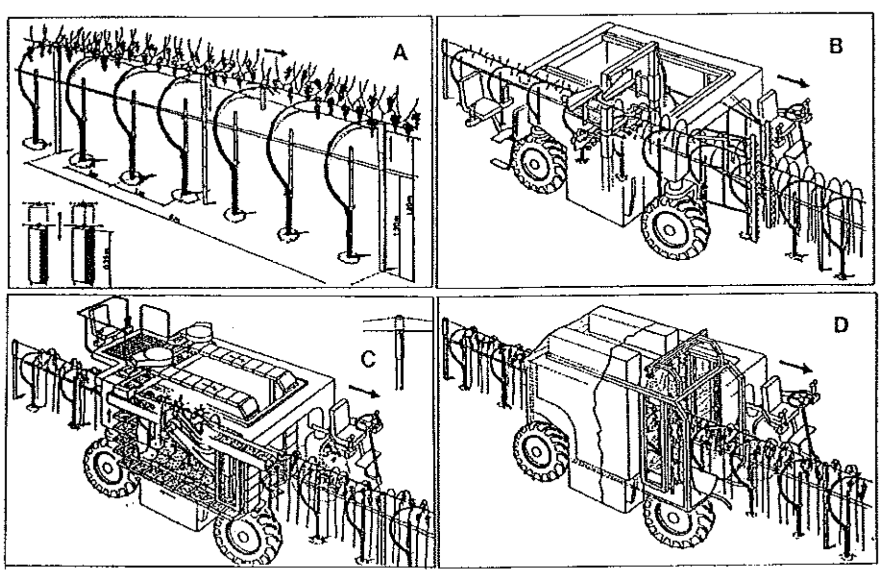


Fig. 20. Trinova pruning (B), harvesting (C), and spray modules (D) in modified SC (A).

designed to reduce and recover spray drift and ground drip as the unit advances, consists of an open-ended gondola with canvas-covered roof and sides, one tank and vertical spray bars on either side, a flooring of two overlapping flexible rubber skirts and run-off-spray recycling tanks on each side of the floor (19,24).

The concept of three modules fitting into one carrier vehicle was at the time an innovation in farm machine design, hence the name 'Trinova'. The Trinova's performance in all three configurations was extensively tested (24).

The pruning module was rated for both summer and winter cutting. The summer profile of the cutter bars is a square horseshoe, their distance from the cordon depending on the severity of the cut. Overall pruning efficiency is here enhanced by a pair of rubber paddle-wheel devices, situated at the bottom of the horizontal bars, that push the hanging shoots outwards to the cutters. The unit's drive speed for summer pruning is about 2 km per hour, or about 2.5 to 3 hours per hectare. The winter pruning profile is also a square horseshoe but the bars are set very close to the cordon. The unit's drive speed is here about 1 km per hour, or about 5-6 hours per hectare. Its winter pruning effectiveness is shown by the fact that over 80% of the post-cut spurs had no more than four buds (Fig. 21). If necessary, the pruner can be fitted with two platforms for rapid hand finishing.

The harvester module was initially tested with a provisional catcher frame featuring ten extractable bins per side, the amount of grapes collected being recorded to plot berry drop point with respect to shaker-head position.

The tests were run with three cultivars and the results showed that 60% to 80% fell forward of the catcher (Fig. 22), the range depending on cultivar. The data confirm the inertial effect induced by the vertical shaking, which causes the berries to drop ahead of the advancing shakers. The second important finding was the very restricted area of berry drop, which led to the final design of a very compact, 3.5-meter-long catch system (Fig. 22).

The definitive shaker unit was then tested against a commercial horizontal slapper to compare vintage quality of the cultivars Sangiovese, Pignoletto, and Trebbiano. Grape samples were dropped into paired bins, placed one above the other with the top bin having a perforated bottom, to assay all the free juice in the fresh mass.

While the results showed no differences in the free juice index for the easy-to-harvest cultivar, Sangiovese, they showed a much higher value in both the more

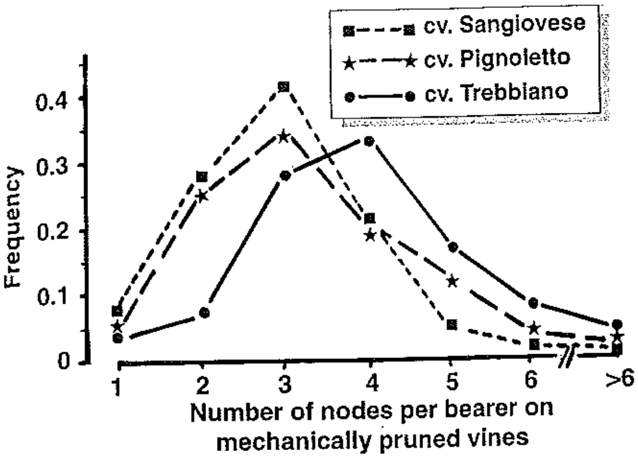


Fig. 21. Bearer distribution by node number in three cultivars after mechanical winter pruning.

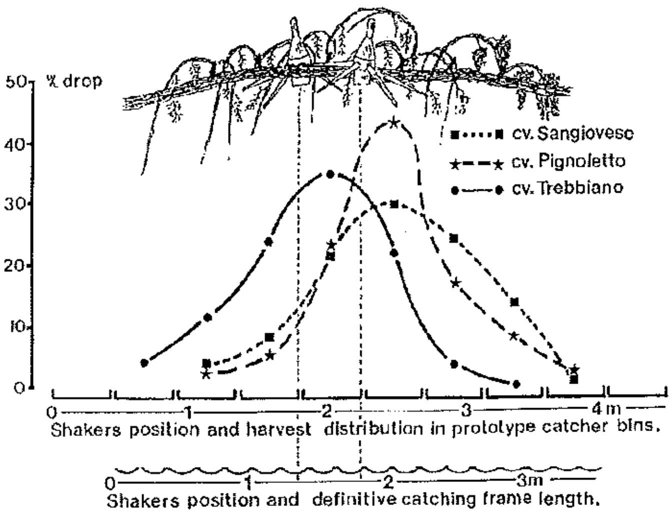


Fig. 22. Drop profile (%) for cultivars of varying berry removal force.

difficult to harvest cultivars for the conventional slapper than for the vertical shaker, thereby evincing that its inertial effect provides enhanced vintage quality in cultivars having a higher berry removal force. The horizontal slapper also splashed a higher amount of juice on the leaves, as shown a day or two after harvest by the greater number of necrotic spots on the canopy leaves. This necrosis is an obvious effect of must sugar concentration, which draws off leaf moisture by osmosis and induces tissue necrosis. A similar effect can be reproduced by spraying the leaves with a buffer solution containing 20% sugar, regardless of pH value.

The spray module was mainly tested for gondola drift-recovery by monitoring sprayer performance against canopy gaps, which repre-

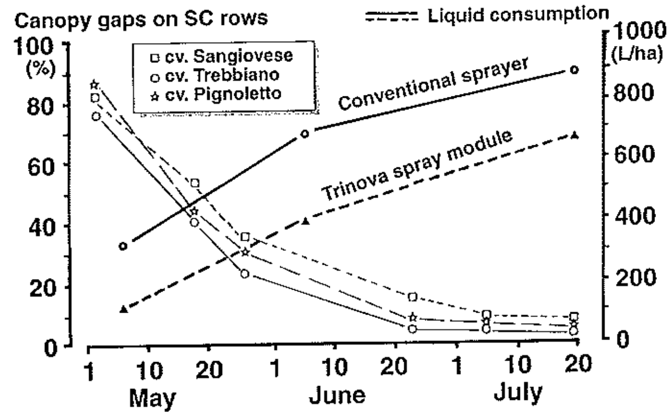


Fig. 23. Increasing liquid consumption as a function of decreasing canopy gaps with conventional and TRINOVA sprayers at the same drive speed.

sent variations in the target area, throughout the growing season. The Trinova module was tested against a conventional sprayer at the same drive speed, nozzle number and delivery rate. Early in the season, when these gaps are more than 70% of the canopy, consumption, which theoretically should have been the same for both sprayers, was markedly lower for the Trinova because of its recovery capability. The same performance trend was evinced throughout the season, although to a gradually diminishing extent as a result of the diminishing gaps (Fig. 23).

The integrated system of the modified SC and the Trinova is a successful innovation in the panorama of vineyard mechanization. The Trinova prototype has been further perfected since these trials and is today employed in a 30-hectare vineyard of adult SC vines. This farm has already planted another 15 hectares of the modified SC-trained vines as the Trinova requires about 50 hectares to make it cost-effective.

As a system in its own right, the SC, like the

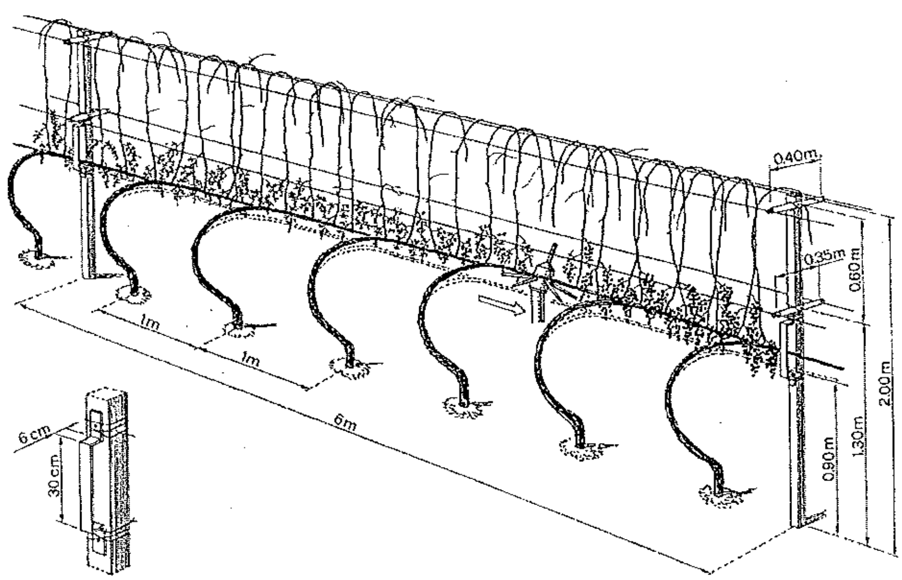


Fig. 24. Modified SPC: cordon bowed and run through brackets for vertical shaking.

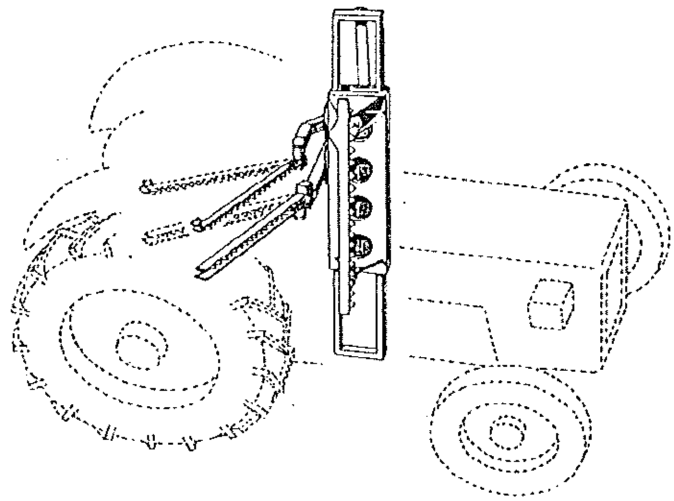


Fig. 25. Pruning unit with horizontal pivot bars (6,29).

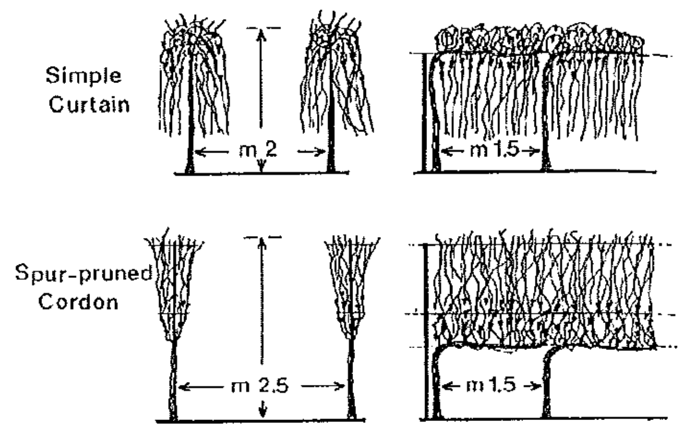


Fig. 27. SC and SPC system profiles.

modified GDC, is suited to the use of the disbudding brushes along the trunk. In addition, various solutions can be envisaged in regard to the SC wire mobility, which is essential to vertical shaking. For example, cement posts with either closed or open-ended slits can be employed.

This same principle can even be applied to harvest by vertical shaking of the traditional spur-pruned cordon (SPC). For instance, in established vineyards, the cordon can be made moveable by bending the vine trunk and running it through brackets (Fig. 24). In new SPC plantations, on the other hand, slotted posts can be used to the same effect.

Performance enhancement of pruner units: The same concept of the pivot-bar employed in the GDC pruner has been applied to the other bars of the cutter unit (Fig. 25). This innovation enables a full range of cuts even in the hedgerow systems. Thus, in summer, the shoots can be cut both along the side of and within the row. The cutting profile can also be changed as desired. In winter, if the vines are trained to permanent cordon, the shoots can be cut close to it. For this latter pruning, the cutter bar was fitted with a specific 'feeler' device. It is basically a wide- toothed comb with small wheels at the tip of each tooth (Fig. 26). As the cutter bar advances along the cordon, the teeth are wide enough to let the shoots enter the gaps between them for pruning but small enough to keep out bigger obstacles like posts, which they roll around, thereby causing the cutter bar to swing away from the obstacle. This pruner unit, too, can be coupled to a drawn platform for rapid hand finishing.

Comparison of the performance of the simple curtain and spur-pruned cordon: Given its proven adaptation to full mechanization, SC was tested for grape quality against the spur-pruned cordon (SPC) (Fig. 27), which is generally considered one of the best systems for this parameter. Because the main difference between the two is shoot position, which in the SC is free and in the SPC is supported by foliage wires, the first trial tested throughout the season canopy shape

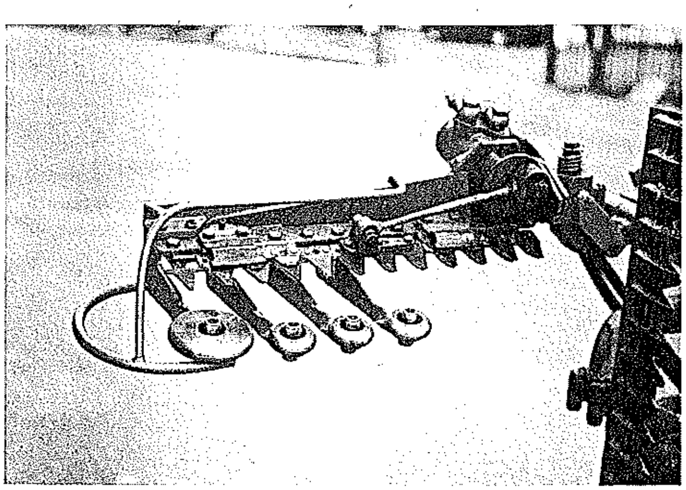


Fig. 26. The pivot-bar employed to negotiate rigid obstacles fitted with a specific feeler device (24).

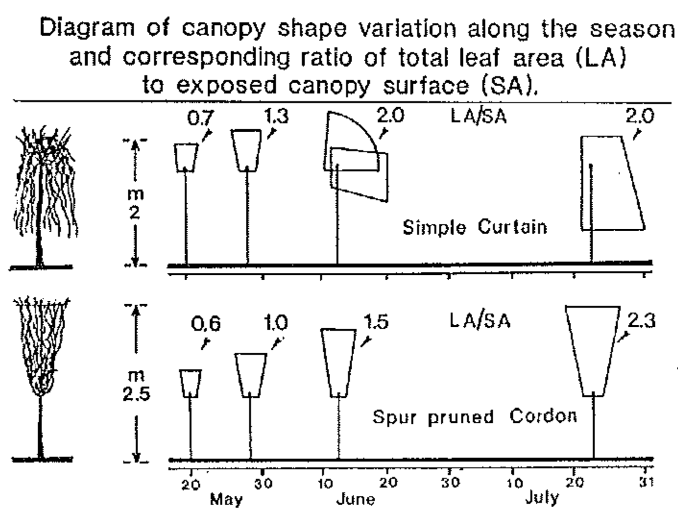


Fig. 28. Seasonal development and variation of canopy shape and the LA/SA ratio in SC and SPC (26).

% of canopy gaps at full shoot development (July 20)
Mean of observation taken at 9.00 and 15.00 h.

Training system / Canopy zone (Interactive SEM • 0.69)	Simple Curtain (2 m)	Spur-pruned Cordon (2.5 m)	Mean
Cluster-zone	3.3	1.0	2.1
Shoot mid-zone	1.7	0.7	1.2
Shoot apical-zone	15.9	4.3	10.1
Mean	7.0	2.0	

Fig. 29. SC and SPC canopy gaps in cropping and non-cropping areas (35).

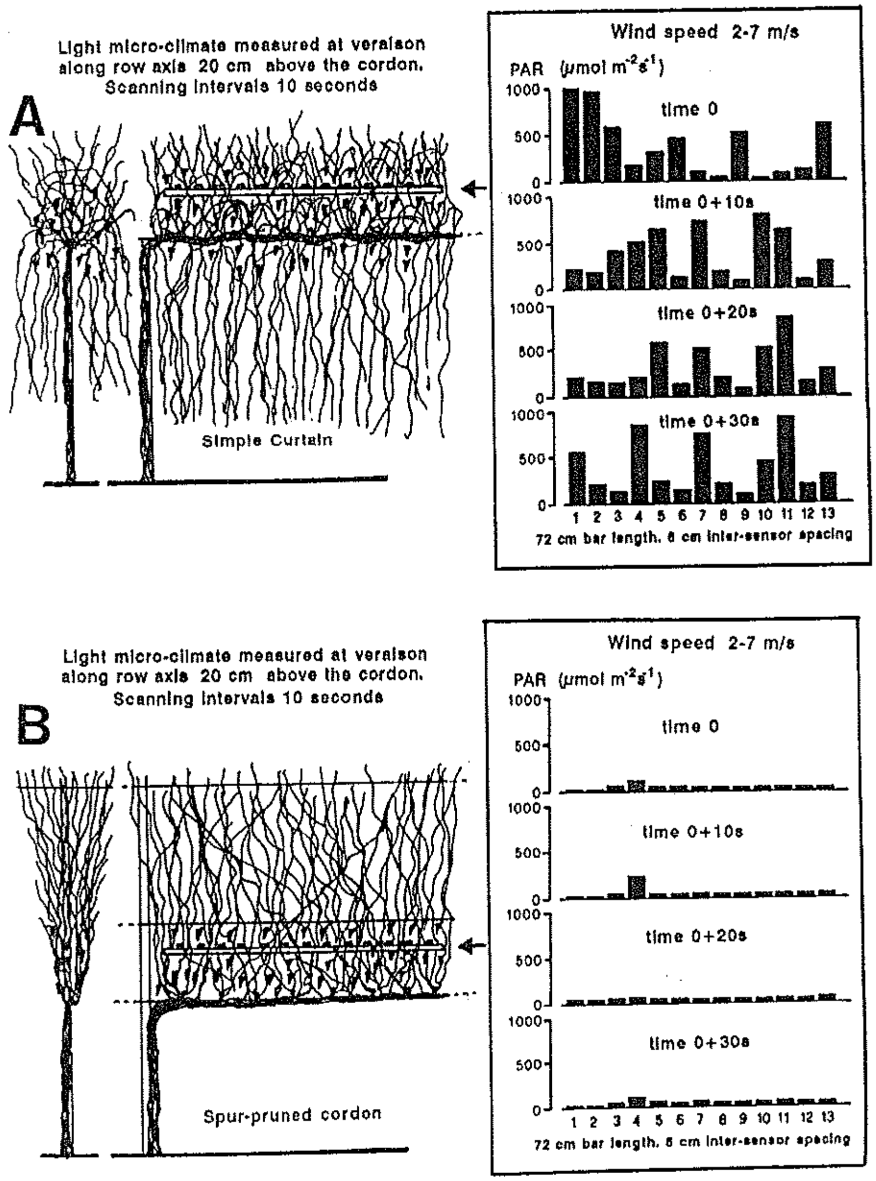


Fig. 30. (A) Changes induced by wind speed in the light microclimate of a SC canopy (35). (B) Changes induced by wind speed in the light microclimate of a SPC canopy (35).

variation and leaf density, expressed as the ratio between total leaf area (LA) and light-exposed leaf surface area (SA). The results (Fig. 28) indicated a very similar LA/SA ratio for each, the peak values recorded in July at maximum shoot development being 2.0 for SC and 2.3 for SPC. These ratings are in a range considered optimum for quality grape production in that the lower the index value is, the lower the shading within the canopy.

Canopy density was also evaluated using a photographic approach to measure and plot canopy gaps at full shoot development, expressed as the light-to-shade ratio. The data (Fig. 29) show that the SC always had more gaps in both cluster and shooting zones, likely as a result of free-growing shoots. Accordingly, at comparable yield per vine, sugar accumulation tended to occur earlier in the SC vines, suggesting that the free-growing habit may increase light penetration and possibly sunflecks under windy conditions.

Sunflecks were thus monitored at veraison on a day when wind speed ranged from 2 to 7 meters per second, rather typical conditions for late July in the Po Valley (35). The detector was placed inside the canopy of the two systems and consisted of a bar, placed 20 cm above the cordon, housing 13 PAR sensors, spaced 6 cm apart. One-second scans were taken every ten seconds for several minutes.

The data for four representative, consecutive scans in SC (Fig. 30A) indicate significant wind-induced variations of the PAR-measured light microclimate at each sensor. By contrast, the light in the inner SPC canopy, under the same wind conditions, remained unchanged (Fig. 30B), *i.e.*, where low, it remained low. The next step was to determine the effects of lightflecks in terms of leaf photosynthetic activity on potted vines in laboratory. Photosynthetic activity was measured in a CO_2-exchange chamber above which were placed light-intercept rotating filters to vary the lightfleck frequency at constant light-dark ratio (30).

The resulting data (Fig. 31) indicated that, excluding continuous dark, at light-dark intervals from about three seconds and lower photosynthetic activity increasingly approached the rate it evinces under saturating continuous light. Although the role of sunflecks in the ripening process needs to be more fully investigated, these findings may help to explain the better use of radiant energy by a canopy with free-growing shoots.

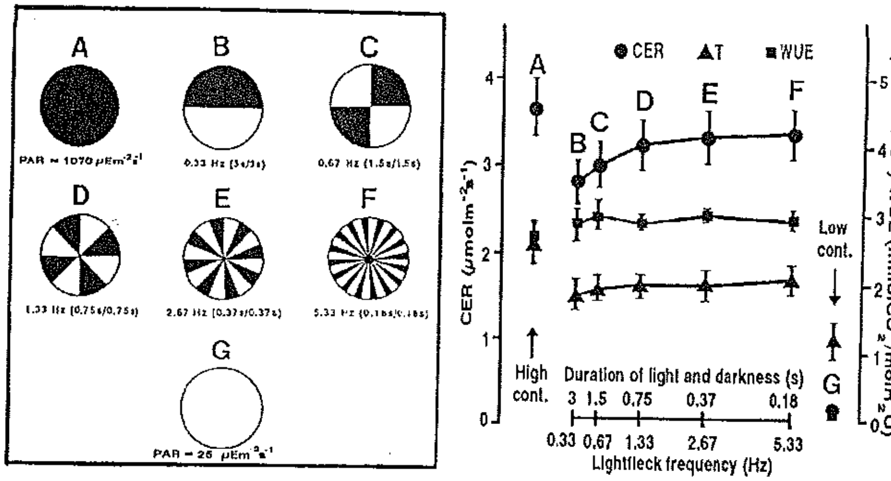


Fig. 31. Leaf gas-exchange under high light, low light and lightflecks of varying frequency.

Conclusions

The studies we have conducted over the last fifteen years have helped to sustain two main achievements. The first is the full mechanization of the GDC system, which, with its modification to a T-arm and integration with an inter-row vertical shaking harvester and multiple-bar pruning unit, is well established in northern and central Italy.

The second, which we think can be improved even further, is linked to a simpler, more advanced system integrated with full mechanization that is designed to eliminate the major drawbacks of the GDC. It consists of the SC hedgerow, featuring moveable cordon wire to enable vertical shaking of the fruiting area, in combination with the Trinova multi-purpose unit. This innovative solution projects itself as an integrated model to meet the demands of growers, consumers and the environment throughout the current decade and beyond. In addition, overall mechanization systems have been much improved, and the concepts employed in these innovations can even be applied to some traditional training systems. It should also be noted that, although these studies were primarily aimed at improving the techniques used in vineyard planning and management, a certain amount of information was acquired on the basic physiology of the grapevine.

Literature Cited

1. Baldini, E. Italian experiences on double curtain training systems with special reference to mechanization. *In:* Proc. Int. Symp. Grapes and Wines, Davis, 1980.

2. Baldini, E., and C. Intrieri. La raccolta meccanica dell'uva: considerazioni per la pianura emiliano romagnola. L'Inf. Agr. 37 (1972).

3. Baldini, E., and C. Intrieri. Full mechanization of harvesting and pruning of grapevines trained to the Geneva Double Curtain system. Proc. XX[th] Int. Hortic. Congress, Sydney (1978).

4. Baldini, E., and C. Intrieri. Meccanizzazione integrale della vendemmia e della potatura in vigneti allevati a doppia spalliera tipo GDC. L'Inf.Agr. 34(20):1721-1727 (1978).

5. Baldini, E., and F. Scaramuzzi. Aspetti agronomici della vendemmia meccanica. Atti Conv. Naz. Vend. Mecc. in Italia, Firenze 22 giugno (1978).

6. Baldini, E., and C. Intrieri. Meccanizzazione della vendemmia e della potatura (1[st] ed.) 150 pp. Clueb Bologna (1984).

7. Baldini, E., C. Intrieri, and B. Marangoni. Potatura meccanica: una nuova prospettiva per la viticoltura. L'Inf. Agr. 31:23563-23569 (1976).

8. Baldini, E., C. Intrieri, andn B. Marangoni. P.I.Emme-V: potatrice integrale monofilare per vigneti a doppia spalliera. L'Inf.Agr. 38:24075-24080 (1976).

9. Baldini, E., C. Intrieri, and B. Marangoni. 1976: una tappa fondamentale per la viticoltura dell'Emilia Romagna Vitivinicoltura 5:5-20 (1976).

10. Baldini, E., C. Intrieri, B. Marangoni, and A. Zocca. V. i. Emme: un prototipo sperimentale di vendemmiatrice integrale monofilare. Italia Agricola, 7/8:3-9 (1973).

11. Baldini, E., C. Intrieri, B. Marangoni, and A. Zocca. Prove di raccolta meccanica dell'uva con la vendemmiatrice integrale monofilare V. I. Emme. Atti Accad. Ital. Vite e Vino, XXVI:89-93 (1974).

12. Baldini, E., G. Costa, C. Intrieri, and E. Magnanini. Prove operative e funzionali di raccolta meccanica dell'uva con una vendemmiatrice monofilare portata a scuotimento verticale. L'Inf. Agr. 35(13):5187-5194 (1979).

13. Di Collalto, G., G. Di Marco, S. Greco, and D. Tricoli. Ricerche comparative tra sistemi di allevamento della vite. 3. Differenze nell'accrescimento dei tralci e delle foglie. Atti incontro viticolo SOI, Foggia, (1976).

14. Donno, G., A. Godini, and V. Giorgio. Primi risultati delle forme di allevamento della vite a doppia spalliera nel Brindisino. Atti Accad. Ital. Vite e Vino, XXVI, (1974).

15. Federazione Nazionale Consorzi Agrari. Aspetti tecnici ed economici della viticoltura. Atti XV Giornata di meccanica agraria, Bari, (1970).

16. Godini, A., and V. Giorgio. Risultati dell'allevamento di 4 vitigni da vino a doppia spalliera (G.D.C. e Duplex) nel Brindisino. Atti incontro viticolo SOI, Foggia, (1976).

17. Intrieri, C. Linee di sviluppo della viticoltura emiliano-romagnola. Vignevini, 4:13-22 (1978).

18. Intrieri C. Experiences on the effect of vine spacing and trellis training system on canopy microclimate, vine performance and grape quality. Acta Hortic. 206:69-87 (1987).

19. Intrieri, C. Trinova: nuovo mezzo polivalente per la meccanizzazione dei vigneti a Cortina Semplice. L'Informatore Agrario 43:91-106 (1988).

20. Intrieri, C., and E. Baldini. Advances on harvesting and pruning mechanization of G.D.C. trained vineyards. 11° Conf. internacional de mecanizacion agraria, Zaragoza (1979).

21. Intrieri, C., and E. Baldini. Le potatrici da vigneto. L'Inf. Agr. 39:22724-22730 (1982).

22. Intrieri, C., and O.Silvestroni. Evoluzione delle forme di allevamento della vite nella pianura padana. Atti Convegno sull'evoluzione delle forme di allevamento della vite in situazioni di piano e di colle. Torino, 28 gennaio, pp.13-45 (1982).

23. Intrieri, C., and O. Silvestroni. Esperienze sulla potatura meccanica della vite: principi ed evoluzione. Atti Accad. Ital. Vite e Vino, XXXV:169-194 (1983).

24. Intrieri, C., and S. Poni. A new integrated approach between training system and mechanical equipment for full mechanization of quality vineyards. *In:* Proc. of the 7[th] Australian Wine Industry Technical Conference, Adelaide, 13-17 August. P. J. Williams, D. M. Davidson and T. H. Lee (Eds.) pp 35-50 (1989).

25. Intrieri, C., O. Silvestroni, and S. Poni. Long-term experiment on mechanical pruning of grapes. *In:* Proc. of the 2[nd] Int. Seminar on Mechanical Pruning of Grapes. Villa Rietti Rota, Villanova, Italy. Rivista di Ingegneria Agraria (Ed.) pp 163-167. February (1988).

26. Intrieri, C., O. Silvestroni, B. Rebucci, and I. Filippetti. Effects of training system and row orientation on canopy growth, light interception and grape quality. 3[rd] Int. Cool Climate Symp. June 8-12 (1992).

27. Ismea informazioni. Vino 113:21-25 (1993).

28. Montanari, D., and G. Bubani. Esperienze pratiche di tre anni di vendemmia meccanica. Atti Acc.It.Vite e Vino, XXVI (1974).

29. Poni, S., and G. Bellanti. La potatura meccanica dei vigneti. Vignevini 6:19-27 (1988).

30. Poni, S., L. Marchiol., C. Intrieri., and G. Zerbi. Gas-exchange response of grapevines leaves under fluctuating light. Vitis 32:137-143 (1993).

31. Scaramuzzi, F. Risultati di un triennio di osservazioni sull'allevamento della vite a "doppia spalliera" in ambienti diversi. Atti Accad. Ital. Vite Vino, XXVI (1974).

32. Scaramuzzi, F., G. Di Collalto, and R. Bandinelli. I sistemi di allevamento per la vendemmia meccanica. Sette anni di indagini comparative in ambienti diversi. Conv. naz. vendemmia meccanica in Italia, Firenze (1978).

33. Shaulis, N., E. S.Shepardson, and J. C. Moyer. Grape Harvesting Research at Cornell, NY. State Hortic. Soc. Proc., Proc. 105th Meeting, January (1960).

34. Shaulis, N., E. S. Shepardson, and T. D.Kordan. The Geneva Double Courtain. Bull. 811 N.Y. State Agric. Exp. Sta., Geneva, Cornell Univ. (1967).

35. Silvestroni, O., C. Intrieri, and S. Poni. Dinamica della funzionalità fogliare e rilievi ecofisiologici in alcune forme di allevamento della vite. Frutticoltura 10:25-36 (1994).

36. Stefanelli, G. Prime misure accelerometriche sulle accelerazioni indotte nel vigneto da macchine vendemmiatrici. Atti Acc. Ital. Vite e Vino, XXVI (1974).

37. Stefanelli, G. Nomogrammi di prestazione per vendemmiatrici: applicazioni per tipi scavalcatori e a scuotimento laterale. Conv. naz. vendemmia meccanica in Italia, Firenze (1978).

38. Turri, S., and C. Intrieri. Mappe isotermiche ed insediamenti viticoli in Emilia-Romagna. Atti Simp. Int. La gestione del territorio viticolo sulla base delle zone pedoclimatiche e del catasto. Santa Maria della Versa - Broni, Pavia 29-30 giugno 1987:137-153 (1991).

39. Uzielli, L. Primi rilievi con cinepresa ultraveloce sulle vibrazioni indotte in un vigneto da una vendemmiatrice a scuotimento verticale. Conv. naz. vendemmia meccanica in Italia, Firenze (1978).

40. Volpelli, P., and S. Poni. Le forme di allevamento della vite adatte alla meccanizzazione. Vignevini 7/8:45-55 (1988).