Field capacity, costs and product quality in mechanical grape harvesting

by

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Between 1992 and 1995, conventional horizontal-shaking grape harvesters, improved horizontal-shaking grape harvesters, vertical-shaking grape harvesters, hand-assisted grape harvesters were tested. Horizontal-shaking harvesters had a greater field capacity and a lower labour requirement than vertical-shaking grape harvesters. Results from 1992 field tests indicated that the quality obtained from improved horizontal-shaking grape harvesters was similar to that from vertical-shaking grape harvesters, so more field tests were carried out in 1994 to confirm this. Losses were distinguished as unharvested grapes, juice retained by the foliage and juice and grapes on the ground: total losses ranged from 12.7% to 18.2%. The losses retained by the foliage ranged from 6.6% to 11.9% and were mainly correlated with the vine cultivar and the percentage of free juice. The losses on the ground averaged 2%. From 6% to 28% of shoots and from 4% to 25% of canes suffered some injuries from the shakers.

Grape harvester, juice losses, wine quality

1. Introduction

The work quality of mechanical grape harvesters is lower than hand harvest in terms of grape losses, degree of vine damage, impurity (leaves, shoots, etc.) and vineyard damage.
During the early tests in the 1970's, the losses were classified as: vine losses (bunches), ground losses (grapes) and must losses (hidden losses).
The number of bunches missed and remaining on the plant is mainly dependent or the grapes detaching resistance, the lower shaker frequency or the elevated grape harvester speed. Generally, with a shaker frequency of 350-450 cycles/min a speed of 0.8-2.1 km/h, the losses were limited to 2-3 % [11].
The ground losses are due mostly to areas not covered by overlapping plates during contact with the vine trunks or posts. Therefore most losses depend on the system's shaking action, because to cause ever breaking of grapes with a consequent production of free must. The free must may be captured by the foliage surface, fall to the ground, cross the overlapping plates, sucked in by fans and/or be discharged to the ground.
The hidden losses were identified as indirectly measured losses during test carried out in Italy in the 1970's, the level of the total losses were estimated to range from a minimum of 6% to a maximum of 18% and this range was function of the cultivar [6].
In addition to Italian tests, trials carried out in the USA in 1973 on *Concord* grapes showed a range of total losses results from 3.9% to 10% with must losses ranging from 1.2% to 3.7 [2]. In another trial carried out in Michigan, the results were 10% for total losses with 4.5% must losses, 3.5% ground losses and 2% of unharvested grapes [9]. Finally, in German trial, carried out on trailers and self-propelled grapes harvesters, total losses were 15% and unharvested grapes represented 1.5% of the crop [5].
As well as the problem of losses the high level of free must represents a major risk for starting an uncontrolled fermentation. This may cause a decrease of product quality particularly for the white wine cultivars [4, 8]. The level of free must depends both on the cultivar and the system of shaking and conveying the grapes on the harvesters. Indeed the lower losses associated with vertical shaking systems (6-10% free must) are probably due to the fact that the grapes are detached by a vertical vibration imparted on the single wire to bring the cordon to the shaker mechanism while in the cane lifter shaker system the action is imparted to the trellis/vine system by bars. The level of free must for this latter system was 20% or more [3].
The important evolution of grape harvesters with cane lifters was the adoption of the oscillatory shaker system. This system permitted a lower level of free must because the shaker system oscillates through a relatively small arc and strikes the plant material gently. This design reduces potential impact damage and reduces free must to a level comparable with results obtained by the vertical shaking system [1, 7].
The mechanisation of harvesting allows a labour saving of 90 to 95%; even though hand harvesting gives a good quality, it is a major cost (50% of total costs) and there is the problem of finding temporary workers [3].
In this paper work capacity and quality for grape harvesters equipped with both horizontal shaking systems and vertical shaking systems were analysed. Special attention was given to the problem of losses and the main objective was to quantify the level of the must retained by the foliage and on the ground after the mechanical harvester because in the literature this loss is defined as "hidden losses".

2. Materials and method

Two trials were carried out:
1) test assessment of grape quality, harvesting losses and vine damage. The grape harvesters were tested in 1992 and 1994;
2) measures and assessment of field capacity and harvesting costs. The grape harvesters were tested in 1994 and 1995.
The following variables were measured for quality assessment: yield; harvest composition; vine losses; leaf must losses; grape ground losses; must ground losses; vine damage. The leaf must losses and the must ground losses were captured by suitable collectors and directly measured by the refractometre. All losses were indicated as a percentage of the harvested sugar.
Vine damage was also measured during the 1994 and 1995 harvest to determine whether tissue damage, bud damage and cane injuries from impacts can reduce future crop productivity. Finally were also performed work capacity and working times for all the working system.
During 1992 and 1994, the following grape harvesters were tested:
a) conventional horizontal shaking system grape harvester:
- VOLENTIERI ITALIA and BRAUD 240 T: fitted with shaking rods free at one end, spring-loaded grape-catching plates, bucket conveyor belts and elevators, and two exhaust cleaning fans;
b) improved horizontal-shaking grape harvesters, featuring flexible shakers, restrained at their far end (GREGOIRE G60, GREGOIRE G90), or improved grape catchers and conveyors (VOLENTIERI AT 2000), or both (ERO SF 192, BRAUD 2720);
c) vertical-shaking grape harvesters (TANESINI MTB-VT-lB) designed for Geneva Double Curtain (G.D.C.). or for single-cordon vineyards (TRINOVA prototype, built by the University of Bologna);
d) hand-assisted grape harvesters, designed to simply convey hand-harvested grapes to a tank (DEFENDI) or to process whole fruit-bearing canes cut by hand from the vines (DIZETA). The grape harvesters were tested on 4 white (*Chardonnay, Sauvignon, Tocai Friulano* and *Pinot Grigio)* and 4 red (*Merlot, Cabernet Sauvignon, Cabernet Franc and Pinot Nero)* cultivars [10].
Unfortunately organisation problems meant that this programme was not respected by the GREGOIRE and TANESINI grape harvesters, while the TRINOVA only worked on Mobile Single Curtain and was therefore tested only on *Chardonnay.*
In addition, a sensory evaluation was performed to compare wine samples from either hand harvested or machine-harvested *Tocai Friulano* grapes.

3. Results

The grape quality results from the 1992 field tests indicated that the product harvested by the VOLENTIERI ITALIA had a higher free juice percentage (21.2%) in comparison to the BRAUD 2720, GREGOIRE G60, GREGOIRE G90 and TANESINI (5.2% to 7.5%). The quality obtained from improved horizontal-shaking grape harvesters was similar to that from vertical-shaking grape harvesters.

More field tests were carried out in 1994 to confirm the 1992 results. The juice percentage was lowest for vertical-shaking grape harvesters (3.1 from TRINOVA to 4.7% from TANESINI), medium for horizontal-shaking grape harvesters fitted with restrained shakers (6.8% from ERO to 8.2% from GREGOIRE) and highest for horizontal-shaking grape harvesters fitted with free rods (8.5% from BRAUD to 10.8% from VOLENTIERI) (Tab. 1). As far as the hand assisted grape harvester was concerned, the results showed a very low level of juice from DEFENDI (0 - 0.1%) and a very high level from DIZETA (18.8%).
The level of must depended for cultivar. The *Pinot Grigio* was the cultivar with the highest percentage of free must to cause above all his own compact bunch that to ask, in general, a highest shaking frequency.
The average impurity level in the harvested product was limited to 2%. The lowest result was obtained by the ERO grape harvester, with an impurity level of 0.4% (Tab. 2).

Table 1 - Averages of the free must and impurities percentage by grape harvester for the 1994 trials

Grape harvester	Free must (%)	Impurities (%)
Volentieri	10.8	1.7
Braud	8.5	1.5
Ero	6.8	0.4
Gregoire	8.1	1.6
Tanesini	4.7	0.8
Trinova	3.1	0.7

Table 2 - Averages of the free must and impurities by cultivar for the 1994 trials

Cultivar	Free must (%)	Impurities (%)
Sauvignon	12.0	1.4
Pinot Grigio	18.6	1.4
Chardonnay	3.8	0.7
Merlot	7.2	2.0
Cabernet Sauvignon	0.7	1.2
Cabernet Franc	3.2	0.7

The total harvesting losses were strictly dependent on the cultivar in addition to the grape harvester employed. Indeed, the results by cultivar (Tab. 3) show that the highest losses were for *Pinot Grigio* (24.3%) while the average losses for the other cultivars was 14%
The total losses by grape harvester ranged from 12.7% to 18.1 %. The best result was obtained by GREGOIRE (12.7%) but this grape harvester was not employed on the *Pinot Grigio.*
The other horizontal shaking grape harvesters had a percentage ranging from 17.2% for the ERO to 18.1% for the VOLENTIERI. These results were higher than TANESINI where the total losses were 14.1% (Tab. 4).
The total losses, expressed as a percentage of the grape weight, ranged from 9% for horizontal shaking grape harvesters to 12% for vertical shaking were comparable with the results reported in literature.
The highest percentage of the losses were retained by the foliage and they were mainly correlated with the vine cultivars and the percentage of free juice; they were also higher for the horizontal-shaking grapes harvesters (8.2 - 11.9%) than the vertical-shaking grape harvesters (6.6 - 8.1%). These losses were very high for the *Pinot Grigio* (17.3%),

which was the cultivar with the higher level of free must (18.7%), while the lowest losses were observed for the *Cabernet* and the *Chardonnay*.
The losses on the ground averaged 2%, and were mainly due to juice and berries discharged by the fans. Self-propelled harvesters had lower ground losses than trailed machines, because of better cleaning systems and longer harvest tunnels.
A percentage ranging from 2.2 to 6.5 % was attributed to unharvested grapes, with the highest values in old vineyards.

Table 3 - Averages losses for the cultivars as a percentage of the harvested sugar and grape weight in the 1994 trials

Cultivar	Losses in % of the harvesting sugar					Weight total losses
	grapes falling on the ground (%)	must on the ground (%)	must on the leaves (%)	bunches on the vine (%)	Total losses (%)	(%)
Sauvignon	0.4	0.9	10.7	3.4	15.3	10.7
Pinot Grigio	0.1	2.3	17.3	4.6	24.3	17.0
Chardonnay	0.9	0.9	7.9	4.0	13.8	9.7
Merlot	0.2	1.9	8.3	3.9	14.3	10.0
Cabernet Franc	0.4	1.2	5.7	8.3	15.6	10.9
Cabernet Sauvignon	0.2	4.3	5.5	2.5	12.6	8.8

Table 4 - Averages losses for grape harvesters as a percentage of the harvested sugar and grape weight in the 1994 trials

Grape harvester	Losses in % of the harvesting sugar					Weight total losses
	grapes falling on the ground (%)	must on the ground (%)	must on the leaves (%)	bunches on the vine (%)	Total losses (%)	(%)
Volentieri	0.6	1.8	9.2	6.5	18.2	12.7
Braud	0.4	1.9	11.4	4.2	17.8	12.4
Ero	0.1	0.5	11.9	4.8	17.2	12.0
Gregoire	0.2	2.1	8.2	2.2	12.7	8.9
Tanesini	0.2	3.2	6.6	4.1	14.1	9.9
Trinova	0.8	1.0	8.1	3.8	13.6	9.5
Averages	0.4	1.7	9.2	4.3	15.6	10.9

The vine damage ranged from 6% to 28% of shoots and from 4% to 25% of canes suffering some injuries from the shakers. However, no differences were observed between the tested grape harvesters (Tab. 5).

The field capacity in the 1992 and 1994 trials were not different between self-propelled and trailed grape harvesters. Horizontal-shaking had a comparable field capacity ranging from 0.26 ha/h by the BRAUD to 0.36 ha/h by the VOLENTIERI and GREGOIRE and a lower labour requirement (0.78 h/t to 1.07 h/t) than vertical-shaking grape harvesters ranging from 0.26 ha/h by the TANESINI to 0.42 ha/h by TRINOVA, and 1.73 h/t to 1.06 h/t, respectively). These results were confirmed in the 1995 trials where the work capacity ranged from 0.2 to 0.3 ha/h. In the 1995 trials, the hand labour employment was higher than the past trials because of a lower vineyard yield in the 1995 harvest. In this condition the horizontal shaking grape harvester also had results ranging from 1.1 ulh/t to 1.4 ulh/t (tab. 6).

Labour savings were 91% to 93%, and 83% to 89%, respectively, in comparison to hand harvesting. The hand-assisted grape harvesters saved only 29% (DEFENDI) or 59% (DIZETA) of labour.

A sensory evaluation performed on *Tocai Friulano* grapes from either hand harvested or machine-harvested (Tab. 7) was not significantly different.

Table 5 - Vine damage by the grape harvesters

Grape harvesters	Vine damage		
	Injured shoots (%)	Injured canes (%)	Number of injured buds (vine average)
Volentieri	12.9	11.3	2.3
Braud	17.0	20.7	2.5
Ero	14.5	18.4	3.1
Gregoire	12.1	12.6	2.3
Tanesini	16.5	13.0	1.6
Trinova	0.0	25.0	2.7

Table 6 - Average work capacity and average hand labour by grape harvester in trials carried out in 1994 and 1995.

Grape harvesters	Workers			Work width	Effective speed	Work capacity (TE)	Effective work capacity (TU)		Hand labour employment
	(1)	(2)	(3)	(m)	(km/h)	(ha/h)	(ha/h)	(t/h)	(ulh/t)
Volentieri VG 2000/2	1	1	1	3	1.4	0.36	0.28	2.9	1.1
Braud T240	1	1	1	3.5	1.0	0.28	0.20	2.8	1.0
Ero SF-190	1	1	2	3.5	1.4	0.34	0.28	3.6	0.9
Ero LS Italia	1	2	0	3	2.1	0.42	0.28	2.8	1.1
Gregoire G-60	1	1	1	3.3	1.5	0.50	0.36	4.5	0.4
Tanesini MTB 1V	3	2	2	2	2.3	0.48	0.32	4.5	1.4
Trinova	2	1	6	2.5	2.2	0.54	0.42	5.7	1.6

(1) To grape harvester; (2) To carry; (3) To hand harvester after grape harvester.

Table 7 - Results of sensory evaluation of 4 wine samples (*Tocai Friulano*).

Test N.	1	2	3	4
Vine training system	Simple Curtain	Simple Curtain	G.D.C.	G.D.C.
Harvest type	Hand	Mechanical	Hand	Mechanical
Appareance	12.9 A	13.3 A	11.6 A	13.0 A
Aroma	21.9 A	21.9 A	18.1 A	22.4 A
Taste	15.8 A	16.2 A	14.3 A	15.6 A
Taste and aroma	15.2 A	16.0 A	13.4 B	15.1 A
Overall judgement	6.0 A	5.9 A	5.3 A	6.0 A
Total	71.8 A	73.3 A	62.8 B	72.1 A

Averages with the same letter do not differ significantly ($p < 0.05$; test Student-Newman-Keuls).

4. Conclusions

The average total losses were larger than 10%, so an economic evaluation of the opportunity for mechanical harvesting they were not negligible.
The higher part of the total losses were attributed to the must captured by the foliage.

This was partly due to the level of free must caused by the shaking system. To reduce these losses, it would be interesting to strip the leaves before the harvest.
In the grape harvester comparison, it was observed that the improved horizontal-shaking mechanisms gave a better product quality than conventional machines, but thus were worse than vertical-shaking systems. Therefore these grape harvesters have not a wide appeal as thus require a specific vine training system (G.D.C., Mobile Single Curtain, etc.) rather than the traditional vine training system. However, both harvesting losses and vine damage were mainly affected by the vineyard age and the vine cultivars, and were similar for all tested harvesters. In the future, for an optimisation of the mechanical harvester it would be necessary to plant a new vineyard with an adequate structure (poles, trellis, wires, etc.) to obtain sufficient resistance to the shaking action.
Finally may be considered both economical view and work quality the mechanical grape harvester were ever suitability than hand harvest except in the unfit vineyard or for the vintage wines production.

Literature

1) CHALER G. *Recolte mecanique de la vigne: comportement des nouveaux dispositifs de recolte.* Progres Agricole et Viticole (1991), 108, 79-85.
2) CRISTENSEN P. *Fruit recovery of Concord grapes by machine harvesters.* Presented at the Washington State Grape Society Meeting, Prosser, WA (1973).
3) INTRIERI C., PONI S. *Integrated evolution of Trellis training systems and machines to improve grape quality and vintage quality of mechanized italian vineyards*. American J.Enol. and Vit. Vol.46 No 1 (1995).
4) IORIZZO M., MANCINI C., VITALE A.M., DELL'AGLIO F. *Effetti della vendemmia e del trasporto sulla microflora epifitica dell'uva.* Vignevini (1992), 12, 15-18.
5) MAUL D. *Ergebnisse beim einsatz von traubenvollerntern im veinbaugebiet Rheinpfalz*. Dt. Weinbau, 37:945-950. Ref. in Vitis 21:380 (1982).
6) PELIZZI G., SARCINELLI S. *Aspetti meccanici della vendemmia*. Atti del Convegno Nazionale sulla Vendemmia Meccanica in Italia, Firenze (1978).
7) PERGHER G., GUBIANI R., ZOPPELLO G. *Confronto fra diversi sistemi di raccolta dell' uva: capacità di lavoro e qualità del prodotto raccolto*. Riv. di Ingegneria Agraria, 25 (2), 1994.
8) SIMS C.A., JOHNSON R.P., BATES R.P., MOORE L.F. *Harvest method and dioxide influence the postharvest of "NOBLE " and "STOVER" wine grapes.* J.Amer. Soc. Sci. (1989), 114 (1), 77-81.
9) SNOBAR B.A., CARGILL B.F., LEVIN J.H., MARSHALL D.E. *Grape harvester recovery and losses.* Am. J. Enol. Vitic. 24:10-13 (1973).
10) VCR - *Vivai cooperativi Rauscedo. Catalogo dei vitigni ad uva da vino.* (1992).
11) ZOPPELLO G. *Risultati di un triennio di prove con la vendemmiatrice a scuotimento orizzontale "Vectur France".* Atti della XX Giornata della Meccanica Agraria (1977), Bari , 5-6 marzo.