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Simplified Mechanisms for Fruit Zone Leaf Removal and Impact Assessment of the Applied Technique in Grapevine Under Tropical Climate

Antonio Odair Santos, Cláudio Alves Moreira

***Abstract*— The importance of leaf area index on the vine fruiting zone is the influence it can have on the quality of grapes and therefore wine, due to modification on chemical properties, especially on the concentration of flavonoids. In the tropics, where the grape cultivation, not rarely, is done with the presence of high humidity from flowering to harvesting, the fruiting zone defoliation is particularly important when dealing with the incidence of plant diseases. To address this question an experiment was carried out in Jundiaí (São Paulo state, Brazil), to study the implementation of simplified mechanisms for semi-automation of defoliation of Vitis spp, and check the practical influence of the implemented defoliation on the vineyard. The results showed it is possible to manufacture a low impact leaf remover prototype with a pneumatically- generated drag force guided to inside of rotary cylinders, arranged to promote a leaf pulling without bunch damage. The effect of defoliation on the vine was more related to grape quality than yield composition.**

***Index Terms*— defoliator, grape quality, viticulture.**

I. Introduction

Viticulture is an important activity for the sustainability of small farms in Latin America. In recent years, viticulture has also become important in Brazil to generate employment in large enterprises, which produce table grapes and grapes for processing [12].

The importance of leaf area index (LAI), on the vine fruiting zone is its influence on the quality of grapes and, therefore wine. Moreover, LAI is influential on the physical and chemical properties, especially on the concentration of flavonoids [5], [14].

The flavonoid compounds, present in the berry skin and seeds, are determinants of color and flavor of wine and grape juice. Anthocyanins, flavonols and proanthocyanidins (tannins) are included in this group. In addition, these pigments are the main substrates for the oxidation of juices and wines [6]. Among many management and environmental factors that affect the concentration of flavonoids in grapes, exposure of the fruiting zone is among the major influence, and reports indicate that, under certain soil and plant conditions, the low incidence of solar radiation can reduce the level of anthocyanins and other flavonoids, while the relative increase of the radiation results in increase in their concentration in the berry skin [7], [19].

Availability of solar radiation on the vine fruiting zone has been reported to be responsible for modification in the anthocyanin profile, as well as their potential for extraction. The effects of defoliation in the fruiting zone on grape composition is dependent on the severity, on the time it occurs and the vine variety in question [13], [15].

Due to the above reasons, among many management practices of wine production, affecting the polyphenol profile of the grape, the increased exposure of the grape clusters, made by selective removal of leaves is accepted as a robust tool to manipulate the content of those substances in the fruit and its industrial derivatives [1], [8].

Nonetheless, in the tropics, where not rarely, the grapevine cultivation is done with the presence of high humidity from flowering to harvest, defoliation in the fruiting zone is particularly important when dealing with the incidence of plant diseases, in both, leaves and bunches. It is vital for spraying practices maintaining a well-ventilated canopy, aiming at proper penetration of agrochemicals. Notably in Brazil, excess rain in the stages of growth and maturation of the berries is present in the main producing areas, in the summer harvest, except for some regions as northeastern and extreme south.

The Brazilian wine industry, in recent decades, has been affected by the rising costs of land, already aggravated by the scarcity of hand labor. Emerging new clusters of winemakers suffer both, domestic and international pressure and seeks to adjust itself to the new times.

Therefore, the mechanization of the vine management processes is important to mitigate the aforementioned problems as to the sustainability of the wine industry.

The technique of defoliation currently in use in Brazil is applied manually by means of leaf pruning shears. This operation are time, labor and money consuming, having low operational efficiency, which is aggravated by the increase in the scale of cultivated area.

In this context, this research aimed at designing and developing simplified mechanisms for grapevine fruit zone leaf removal and the assessment of the influence of that technique on yield and grape quality.

Antonio Odair Santos. Education: Universidade do Estado de Santa Catarina (Lages, SC) (B.Sc); Universidade Federal do Rio Grande do Sul, Porto Alegre (RS) (M.Sc. and D.Sc.); California State University-Fresno (PostDoc.).

Cláudio Alves Moreira. Education: Universidade de São Paulo (B.Sc.); University of Illinois, Chicago (M.Sc.).

II. MATERIAL AND METHODS

A. Location, time and cultivars

The experiment was conducted at the Instituto Agronômico/Center of agricultural engineering (CEA), located in Jundiaí (SP), from the year 2013 to 2015. Tests with the leaf remover prototype were performed in a vineyard oriented for the full mechanization. The Isabel and Syrah cultivars, grafted on paulsen 1103 rootstock, were used in the experiment. The cultivars had the planting spacing of 2.50 m x 2.00 m. The vine training system was the traditional three-wire espalier with bilateral cordon. Planting lines were oriented east-west.

The pruning of the vines was done mechanically, leaving around six nodes per cane, making a straight cut along the row, using a pruner coupled laterally to a tractor [17] [18].

Vineyard management was implemented in accordance with the agrotechnical recommendations for the region, regarding soil fertility, canopy manipulation and phytosanitary treatments.

For the implementation of leaf removal treatments, the planting lines were discriminated according to the position in relation the sun path, as north and south sides. Three planting lines, 130 m long, were used for each cultivar. Each planting line had two replicates for the following treatments randomly distributed along them: a) defoliation on the the north side; b) defoliation on the south side; c) defoliation on the north and south sides; e) without defoliation. Each treatment consisted of six plants.

The leaf removal in the treatments was performed by regulating the leaf remover prototype mechanism and tractor speed aimed at non-selective removal of leaves in all canes. A leaf removal ‘window’ of 40 cm centered on the fruiting zone was observed. The application of the leaf removal was made at “pea size” stage. The experimental design was a completely randomized.

B. Yield components

Data for yield components were collected, comprising the weight and number of bunches per plant, weight of fifty berries, berry height and width and yield per plant.

C. Berry quality

At the point of harvest, samples of 200 berries were collected at random from each treatment. The berries were placed in sealed plastic bags, stored in a container with ice and transported to the laboratory. They were separated into subsamples for physical and chemical analysis:

D. Soluble solids, pH and Titratable Acidity.

The values of soluble solids in the juice were determined by a manual refractometer and the pH through automatic titratation. The titratable acidity was taken from samples previously prepared for determination of pH, using NaOH (0.1 N) up to pH 8.1. The result was expressed in grams of tartaric acid per liter [2].

E. Anthocyanins and total phenolics

To determine levels of anthocyanins and phenolics the subsamples were homogenized with 'mixer' and, on the resulted ‘macerate’, extraction was made with hydrous ethanol under stirring. Subsequently, by adding 1M HCl samples were ready for readings in the spectrophotometer [4].

F. Tannins

It was used the condensed tannins precipitation method by reaction with methylcellulose [10].

G. Prototype components for leaf removal

G1. Mechanical Elements

The prototype for leaf removal was based upon a hydraulic-pneumatic system that is positioned laterally and in front of the tractor, operating in a canopy area that includes the vine fruiting zone. The pulling out of leaves was made by drag force guided to inside a perforated hollow cylinder, which operate in tandem with another two not-pressurized cylinders (Fig. 1, Fig. 2).

An exhauster built with radial blades (Fig. 1) generates a negative pressure gradient inside the perforated hollow cylinder and, therefore, a flow of air, which pre-positions the leaves from the fruit zone towards the leaf collectors at the machine. The exhaust intake engages into the perforated cylinder (5) through connection curve (7). The perforated tube, provided with continuous rotation speed is installed contiguous to another circular rubberized rotary tube (6) of approximately equal diameter and whose direction of rotation is opposite to the first. The rubber tube (6) has the function of assisting in the tear off leaves from the canopy (5). The perforated tube initially sucks the leaves, pre-positioning them close to the frontal rotary tubes, while the rubber tube in sequence catches the leaves, so that they are conducted to the narrow space between them. The leaf pullout is achieved by breaking the petiole without damaging the grapes, which are heavier and located more internally in the canopy.

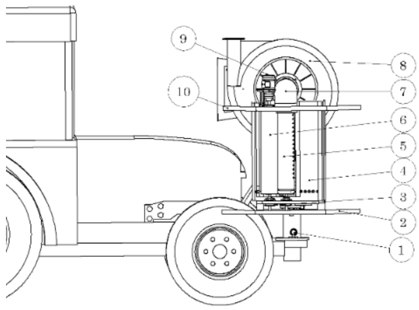

Figure. 1. **Design of the leaf remover prototype developed for the grapevine.**

The main rubbery rotary tube (6) has proper capacity to pull out leaves due to its high coefficient of friction.

A second auxiliary rubberized tube, (Fig. 2) (18) of smaller diameter than the previous cited cylinders, rotates in the same direction of the pressurized rotary cylinder with closed approximation, but without touching it.

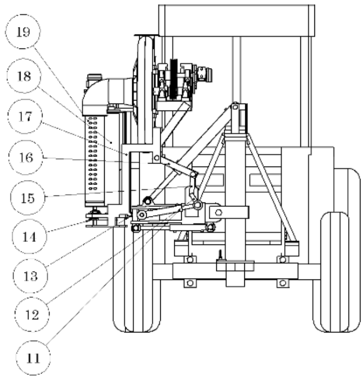

Figure. 2. **Frontal view of the prototype for leaf removal developed for the grapevine.**

The function of the second rubber cylinder is prevent returning of leaves to the pressurized capture zone, which could diminish or even eliminate the action of drag force and cause "clogging" in defoliation system. Once direction of rotation is opposite to the perforated and pressurized cylinder (5), leaves are directed out the defoliation system and discarded to the ground. The tangential speed of this cylinder is higher than the others, in order to improve the cleaning of leaves entering the system.

The hydraulic power for the defoliation system is imparted by hydraulic motor (9) directly coupled to the first rotary rubber coated tube (6). A chain and sprocket transmission drive the defoliation mechanisms (14).

The rotational speed of the hydraulic motor (9) is regulated by throttle valve that can be adjusted depending on the volume of leaves planned to be dropped down. Despite the present position, the hydraulic driving motor can be coupled to any one of the rotary cylinders.

The two rotary rubberized cylinders (6, 18) are bearing supported at the top. In turn, the pressurized one (5), is bottom bearing supported and has its upper part inserted into the curved connector coupled to the exhaust inlet. The seal between the end of the rotary tube and the connection curve was made using a graphite-filled teflon ring.

The group formed by hydraulic motor (9), exhauster (8) and rotary cylinders (5,6,18) as well as the intrinsic accessories, is nestled in a metal frame (17), which has angular movement (tilting) based on a pin ("pivot") (13) and also vertical displacement. For the tilting motion a set of cranks (12,15,16) and a double-acting cylinder (11) are in place. With these facilities one can choose the adequate position of the machine close to the canopy, following the canopy profile and maintain the verticality of the leaf remover, even when the cylinder for vertical movement of the support platform is activated (Fig. 3).

G2. Hydraulic Circuit

It consists of one pump, two motors, three double-acting cylinders and an oil reservoir. One of the motors drives the exhauster (8) by means of pulleys and belts and the other hydraulic motor drives the cylinders of the defoliation system.

A cooling system maintains the transmission fluid temperature in the optimum working range. Heat exchange is performed by means of an oil radiator and cooled by an air stream generated by a fan. A thermostat placed within the reservoir controls the cooling system.

G3. Support platform.

The leaf remover prototype is supported by a platform attached to the front of the tractor. It can rotate up to 180° in opposite directions (Fig. 3) and be locked in positon by a pin (1, 24), allowing operation in two opposite sides of the planting row.

The angular movement is made 'pivoting' the platform around a vertical round tube, whose lower end is coupled to a perforated flange (23,24,29). By means of another perforated flange, welded to the platform base and a locking pin, it is possible to adjust and maintain a lot of working position of the machine. (23, 29)

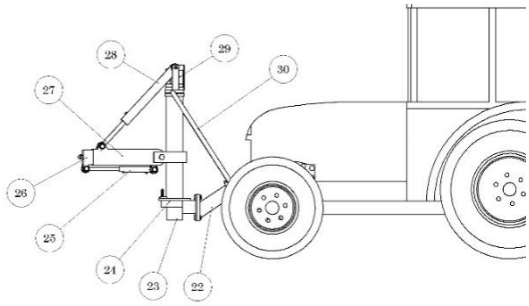

Fig. 3. **Platform for support and positioning**

The platform has vertical and horizontal movements led by two hydraulic double-acting cylinders.

III. RESULTS AND DISCUSSION

Tests carried out with the equipment in the field were considered satisfactory and served to highlight points in the project that should be studied to introduce modifications. After adjustments made the prototype performed operation on treatments in the field.

Initially it should be highlighted the fact that the equipment is light enough to be considered as of low impact. It can be mounted on a platform coupled to the front of the tractor. This feature is interesting because of the ease of coupling and uncoupling. Due to its low weight, about 1500 N (150 kgf), it does not significantly increase risks of soil compaction. This fact was confirmed by measuring the soil compaction index caused by tractor traffic in working conditions, with and without the attached equipment.

Moreover, the possibility of having the same equipment, mounted on an articulated frame, coupled laterally to a tractor, will lead to the same result, that is, the compaction ratio does not change.

Either the front or lateral coupling favors the operator's vision to safely drive the tractor, preventing its departure from the correct working position. This condition is essential for the proper pulling out of leaves, not causing excess or scarcity of defoliation.

The positioning of the machine in relation to the vine lateral is carried out by three hydraulic cylinders controlled by the operator. Thus, the uplifting/lowering, tilting and approach/departure from the line of plants can be optimized while traveling down in the row.

Regarding the pneumatic system, a depression of 30 mbar generated by the exhauster, proved to be sufficient, ensuring good grasp of leaves onto surface of the pressurized cylinder but not exerting any effect on grape bunches. The registered depression was reached with an exhauster speed of approximately 2700 rpm, relatively low, within the usual operating range of commercial exhausters.

In the 'rationale' of the developped leaf remover, the collected leaves were not crumbled after disruption of the petioles. Instead, they were discarded intact to the ground. This condition is interesting either by not requiring extra power for the operation or by slowing down the risk of spreading of fungi inoculum, which can happen through the numerous particles of leaves, scattered along the plant row.

While in the initial tests the positioning of the equipment has been dependent on the operator, the automation of this process may be implemented by inserting higher level of electronic sensoring.

The developed system can operate in any stage of growing of grapevine, including pre-flowering, where there is the greatest concern for not damaging the inflorescence and the most fragile branches. For some systems for grape leaf remover developed elsewhere [16], the leaves are attacked directly by blow pressure or suction, with the destruction of the leaf blade. In the present case, one has the opportunity to mitigate the risk of damage to the bunches by preventing collateral effects of applying pressure direct on them.

A. Influences of leaf removal on the vine

Table I shows the data obtained in 2014 and 2015 harvests, related to the chemical composition of berry in the defoliation treatments for the variety Isabel.

According to Table I, considering the average data for two harvests analyzed, there was a small effect of defoliation on the chemical composition of the berry, particularly in the defoliation made on the north side and the simultaneous defoliation of the north and south sides of the planting line. The values of total anthocyanins, total phenolics and tannins showed an uptrend in this case. In fact, the planting line orientation was east-west, which places the north side facing the sun during the morning. This favors the incidence of solar radiation on this side, being detrimental to the south side, which receives indirect sunlight during the initial hours in the morning.

The values in soluble solids (°Brix) and pH, in the two analyzed harvests showed neither down nor hightrend related to the type of leaf removal applied in the experiment. However, for titratable acidity, the data show a trend of higher values for the no-leaf removal treatments. This fact is in line with the existence of greater shading of the clusters in the treatments without defoliation. In fact, more shading in the fruiting zone generates a particular microclimate characterized by drop in the brunch temperature, which can influence the burning intensity of malic acid, resulting in higher titratable acidity values in the berry. Report about investigation on 'Graciano' and 'Carignan' wines made from early-defoliated vines shown similar results for grape phenolic composition, which was attributed to the combined effect of different outcomes. Among them the leaf/fruit ratio and the improvement of cluster exposure and canopy porosity [14].

As we are considering grapevine in tropical climate it is important to point out that increased shading in the plant fruiting zone, associated with higher water availability, may contribute to the pyrazine accumulation in the berry, particularly 2-methoxy-3-isobutylpyrazine. Above certain concentration values, an excess of herbaceous character may be imparted to the wine flavor and aroma [5]. These facts highlight the importance of defoliation of vines in tropical climates.

It is important to emphasize that, as the experiment orientation is in the East-West, for the time of year we considered, the solar declination increases in the south direction. Its maximum (approx. 23º) is reached in the summer solstice (Dec/22). Therefore, due to the experiment latitude (around 23 south), is likely the occurrence of a greater influence of defoliation on the north side, compared to the south side. In addition, the south side of the vines is influenced by the afternoon cloudiness, which in the region shortens the the global sun radiaton in later afternoon, as seem in practice.

Table I. Averaged data for berry composition for 'Isabel' in two summer harvests, in tropical climate

	Defoliation side							
	North		South		North/South		No Defoliation	
	2014	2015	2014	2015	2014	2015	2014	2015
Anthocyanin (mg/g)	1,84	2,09	1,39	1,56	1,73	1,70	1,33	1,66
Phenolics (A.U./g)	0,76	0,86	0,53	0,65	0,71	0,82	0,56	0,61
Tannin (U.A)	3,8	3,9	2,5	3,0	3,5	4,1	3,1	1,3
°Brix	19,4	19,4	18,6	19,2	19,2	19,8	19,6	19,2
pH	3,24	3,44	3,39	3,37	3,16	3,32	3,30	3,43
Titratable acidity (g/L*)	4,6	2,7	2,7	3,1	5,1	4,2	5,3	4,5

A.U. = absorbance units; *g/L of tartaric acid

The data in Table II show that for 'Syrah' there was the same trend as for 'Isabel', say, lower values of phenolic pigment accumulation in treatments without defoliation, and the south side exposition, especially for anthocyanin, in both analyzed growing seasons.

The same happens with soluble solids data, which show very close values to each other. For titratable acidity there is a trend of increased values, in treatments without defoliation. Again, it brings the same discussion of the data obtained for Isabel variety concerning the malic acid burning during ripening due to crop respiration. This is influenced by canopy microclimate, as the decreased solor radiation is likely to reduce the temperature in the fruiting zone.

In addition, it should be noted that in both harvests, 2014 and 2015, the absolut values for the total anthocyanins and total phenolics are low for 'Syrah' and the values for titratable acidity are higher than those observed for the Isabel cultivar. In the same region, other authors [18], obtained higher values for phenolic pigmentation and lower values for titratable acidity, for the same variety, in both, summer and winter cultivation.

As the variety Syrah is a ***Vitis vinifera*** cultivar**,** accumulation level in phenolic pigmentation is always greater than hybrid varieties in the tropical region of the experiment. The explanation for that is the wind velocity in the experiment wich averaged 2 to 4 m/s in the most part of the cycle of the crop. This can depress the phenolic synthesis, which is itself in accordance to the expected behavior of ***Vitis vinefera*** in windy climate.

Table II. Averaged data for berry composition for 'syrah' in two summer harvests, in tropical climate

	Defoliation side							
	North		South		North/South		No Defoliation	
	2014	2015	2014	2015	2014	2015	2014	2015
Anthocyanin (mg/g)	1,53	1,75	1,35	1,55	1,46	1,81	1,24	1,15
Phenolics (A.U./g)	0,95	0,99	0,80	0,70	0,99	0,96	0,53	0,57
Tannin (U.A)	7,21	7,96	6,24	6,15	7,51	7,32	6,71	5,14
°Brix	17,8	18,1	17,9	18,0	17,7	18,1	17,4	17,6
pH	3,25	3,33	3,24	3,31	3,28	3,37	3,21	3,25
Titratable acidity (g/L*)	7,56	8,23	7,54	9,28	8,31	8,09	8,49	11,2

A.U. = absorbance units; *g/L of tartaric acid.

Table III shows the average of the experimental data for yield components of Isabel variety, in the harvests of 2014 and 2015. According to the analysis of variance, the variability of the data is by chance and the yield components did not differ significantly among treatments of mechanized fruiting zone defoliation, with the exception of data on berry weigh in the 2015 harvest.

The results obtained in yield components in any crop are always an interaction of a number of factors such as soil, plant and climate. In the present experiment, where the prototype was developed and adjusted to remove a number of leaves, in the berry "pea size" stage, the non-selective removal of leaves had no consistent effect on the yield components of 'Isabel'. Notably, defoliation being made in berry "pea size" stage is not comparable with the same technique used in earlier stages of crop. In fact it was found consistent effect of defoliation on yield components when defoliation was applied in the pre-flowering stage [14] [19]. Probably, this fact is associated to the time when the leaf removal was applied, considering the berry growth curve. Notably, the chances of influencing yield components are greater when applying the defoliation in the early stages of the berry growth, where cell division is more important than cell expansion.

Table III. Averaged data for yield composition in 'Isabel' cultivated under tropical climate

	Defoliation side							
	North		South		North/South		No Defoliation	
	2014	2015	2014	2015	2014	2015	2014	2015
Cluster weight (g)	105,8 a	111,4 a	111,1 a	115,9 a	98,7 a	98,6 b	98,7 a	115,7 a
50 berries weight (g)	134,1	129,5	134,1	129,5	132,7	142.2	132,5	130.5
Berry height (mm)	17,3 a	18,1 a	17,3 a	15,9 a	16,9 a	12,9 a	16,8 a	17,3 a
Berry width (mm)	15,4 a	16,3 a	15,3 a	15,7 a	14,9 a	12,1 a	14,9 a	14,4 a
Cluster/plant	35 a	36 a	36 a	39 a	34 a	41 a	36 a	34 a
Yield/plant (kg)	3,7	4,0	3,9	4,5	3,3	4,0	3,5	3,9

In the lines, for the same year, data with the same letter are not different at 5% (anova).

Table IV shows that the same trend occurred for the Syrah variety, analyzed in two growing seasons. The average data for yield components did not differ significantly according to the analysis of variance for the data of all yield components.

The results obtained in the analysis of the chemical composition of grape berry, as compared with the results of the yield composition, shown that the defoliation in the "pea size" stage, caused relative fluctuation in berry quality, but it did not affect the yield components in any of the cultivars and growing season.

Moreover, due to the soil water availability throughout the growing seasons of grapevines in the south and southeast Brazil, defoliation discussed in this project affects the efficiency of phytosanitary control of the vine. A regular monthly water availability of 150 mm, unconcentrated [3], facilitates plant diseases incidence and defoliation contributed to a better aeration of the fruiting zone, keeping it drier. This contributes to the reduction in the use of agrochemials in the vineyard.

Table IV. Averaged data for yield composition in 'Syrah' cultivated under tropical climate

	Defoliation side							
	North		South		North/South		No Defoliation	
	2014	2015	2014	2015	2014	2015	2014	2015
Cluster weight (g)	152,3 a	133,6 a	159,4 a	132,9 a	149,5 a	140,9 a	149,9 a	141,3 a
50 berries weight (g)	79,9	78,15	76,90	79,56	78,11	80,58	74,42	76,58
Berry height (mm)	14,4 a	15,8 a	14,8 a	14,2 a	15,4 a	16,1 a	14,2 a	15,2 a
Berry width (mm)	13,0 a	13,2 a	12,9 a	12,9 a	12,8 a	14,2 a	12,7 a	12,2 a
Cluster/plant	31 a	33 a	32 a	35 a	35 a	39 a	31 a	37 a
Yield/plant (kg)	4,7	4,4	5,1	4,7	5,2	5,5	4,7	5,2

In the lines, for the same year, data with the same letter are not different at 5% (anova).

IV. Conclusions

A prototype for the grapevine fruiting zone defoliation can be developed based on the pre-positioning of the leaves made by a negatively pressurized rotary cylinder and leaf tear off by the joint action of three rotary cylinders with high friction, installed on a hinged side platform.

For tropical climate defoliation applied in the berry "pea size" stage had a relative influence on berry quality, which varied according to the planting line exposition to the sun.

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Antonio Odair Santos. Education: Universidade do Estado de Santa Catarina (Lages, SC) (B.Sc); Universidade Federal do Rio Grande do Sul, Porto Alegre (RS) (M.Sc. and D.Sc.); California State University-Fresno (PostDoc.).

Cláudio Alves Moreira. Education: Universidade de São Paulo (B.Sc.); University of Illinois, Chicago (M.Sc.).