SHOOT POSITIONING: EFFECT ON PHYSIOLOGICAL, VEGETATIVE AND REPRODUCTIVE PARAMETERS

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Acknowledgements: Leonard Adams, Stawie Fouché, Fanie Fouché, Cindy Benn, Dolores Wenn, Elwina Marais, Willemien Hendricks and farm personnel of ARC Infruitec-Nietvoorbij for technical assistance. The SA Vine and Wine Industry (through Winetech) and the University of Palermo for financial support.

Key words: Merlot, shoot positioning, vegetative growth, reproductive growth, photosynthesis, water potential, light interception, grape composition.

Abstract

The effect of vertical shoot positioning and topping at different times during two growth seasons (2002/03 and 2003/04) on physiological, vegetative and reproductive parameters was investigated in a vertically trellised Merlot/R99 vineyard located in the Stellenbosch area. Vines were spaced 2.7 x 1.5 m in north-south orientated rows. Micro-sprinkler irrigation was applied at pea size berry and at véraison stages. Shoots were positioned at berry set, pea size, véraison and post-véraison stages (3 weeks after véraison). After being positioned, they were immediately topped. Before positioning the canopy was in a “natural” condition with shoots hanging freely. Soil water typically varied according to the progress in the season and with soil depth, decreasing towards the end of the season and increasing with depth. The primary shoot length of the positioned shoots was on average approximately 100 - 115 cm, being restricted by the relatively low trellising system. Shoot positioning and topping had no marked effect on the growth of secondary shoots, but they had a noticeable effect on the position of secondary shoots along the length of the primary shoots. Pea-size shoot positioning induced slightly lower light conditions in the bunch zone, because of the low position of secondary shoot development on primary shoots. In spite of this, pre-vèraison shoot positioning treatments allowed good all-round light distribution, which would promote uniform bunch ripening and grape quality. The basal and apical stem and leaf water potential and photosynthetic activity decreased during the season as the leaves aged and the plants lost water. A significant correlation was found for apical leaves between stem and leaf water potential.

Earlier shoot positioning (up to véraison) significantly increased the °Balling level of the must. Early shoot positioning (up to véraison) increased malic acid and sucrose contents, whereas tartaric acid contents were slightly reduced and glucose contents were higher in pea size and véraison treatments. No significant differences between treatments were found for must pH. The earlier shoots were positioned, the more water was lost by the skins, resulting in a concentration of skin contents. Pre-véraison shoot positioning and topping improved the colour of the skins.

No practical difficulty was experienced when shoots were positioned early in the season, i.e. at berry set and pea size stages, whereas at and after véraison proper vertical positioning was primarily restricted by shoot lignification and the tightness of tendrils on the wires. Bunches were also very sensitive to damage, which led to bunch rot and a reduction in yield. These are important considerations in terroirs where timely management is difficult.

Résumé

On a étudié durant deux saisons de croissance (2002/2003 et 2003/2004) l'effet de l'orientation vertical des rameaux sur les paramètres physiologiques, végétatifs et reproductifs dans la région de Stellenbosch dans un vignoble du cépage Merlot sur 99 R conduite à espalier et taillé a cordon

coursonné. Les vignes étaient espacées 2.7 x 1.5 m. L'irrigation a été appliquée quand la baie avait la dimension d’un pois et a la véraison.
Les rameaux ont été placés verticalement à la nouaison ,à la dimension d’un pois de la baie, à la véraison et trois semaines après la véraison. Après leur placement vertical les rameaux ont été tout de suite écimés à 100-155cm. Le positionnement vertical et l’écimage des rameaux n'ont pas eu aucun effet sur la croissance des entre cœurs, mais ils ont eu un effet fort sur la position de les entre coeurs sur la longueur du rameau principal. Depuis la nouaison et jusqu’à la véraison on a eu une bonne distribution de la lumière qui a favorit l’uniformité de la maturation et la qualité du raisin. Le potentiel hydrique foliaire et le potentiel de tige des feuilles basales et apicales et l'activité photosynthétique sont diminués durant le cycle végétatif. Une régression significative a été trouvée pour les feuilles apicales entre la tige et le potentiel de tige et le potentiel hydrique foliaire.

Le placement vertical des rameaux jusqu'à la véraison a induit un’augmentation significative du degré °Brix, du contenu d'acide malique et du saccharose, et une faible diminution de l'acide tartrique. Le niveau du glucose a été le plus haute dans les traitements dimension d’un pois et véraison. Aucune différence significative entre les traitements a été trouve pour le pH. L’époque de traitement pre-véraison a amélioré la couleur de la peau de la baie.

Aucune difficulté pratique a été vérifiée quand les rameaux ont été manipulés dans les première époque tandis que à les époques véraison et post-véraison on a eu difficulté à manipuler les rameaux a cause de la lignification et de la présence des vrilles. Les grappes sont très sensibles aux dommages et à la pourriture. Il s’agit de considérations importantes dans les terroirs où la gestion soigneuse du vignoble est très difficile.

Introduction

Grapevine shoot growth is normally confined to a limited growth volume, as dictated by the trellising system and vine spacing. This necessitates careful winter pruning and summer management to ensure that sufficient room is available for each individual shoot to develop in a suitable environment that would guarantee the best grape and wine quality. However, too narrow spur spacing, excessive shoot length, crooked growth, etc. often result in very dense canopies that are difficult to rectify and which are characterised by unfavourable canopy microclimate, leading to reduced photosynthetic activity of leaves (Hunter & Visser, 1988a, 1988b, 1988c; Smart, 1985, 1988), and a decrease in yield (Smart *et al.*, 1982) as well as grape and wine quality (Smart, 1985; Smart *et al.*, 1990). Therefore various canopy management practices (e.g. suckering of infertile and sub-standard shoots carrying clusters, shoot positioning, partial defoliation, tipping and topping) are normally applied during summer in order to create a suitable canopy microclimate for the improvement of grape and wine quality (Kliewer *et al.*, 1989; Koblet, 1988; Hunter *et al.*, 1995; Hunter, 1999, 2000).

Shoot positioning can be defined as the positioning of shoots in line with their bud origin, whether the trellising system dictates a horizontal, slanted or vertical orientation. Information on the effect of shoot positioning *per se* is scarce and mostly deducted from the combined effects of seasonal canopy management practices and practical experience. Benefits include a more stable canopy that restricts wind damage, an improvement in canopy and bunch microclimate, a more homogeneous shoot microclimate environment, less variation in the level of ripeness of the bunches, less bunch rot, improved mechanization, etc. (Catania *et al.*, 2001; Volschenk & Hunter, 2001; Di Lorenzo *et al.*, 2003). In a study that was done on Chenin blanc in the Robertson region of South Africa by Volschenk & Hunter (2001) (to our knowledge, the only experiment on the effect of each individual canopy management practice), the benefits of shoot positioning that emerged from practical experience were confirmed and shoot positioning being highlighted as having a significant impact on the canopy light distribution and grape quality. Shoot positioning seemed indispensable for the production of high quality grapes and wine.

This study firstly aimed to provide more information on the physiological, viticultural and oenological effects of shoot positioning, particularly on red cultivars. Secondly, since shoot positioning is normally started prior to bloom and continued until the end of the growth season, a further aim of the study was to determine the outcome of initiating shoot positioning at different stages during the growth season in order to establish a window(s) during which shoot positioning would be to the benefit of a particular requirement, be it high quality grapes and wine or just healthy grapes, as well as the most cost-effective way of managing shoot positioning.

Materials and Methods

Vineyard

Seven-year-old Merlot vines, grafted onto 99 Richter, were studied in the Western Cape on the experiment farm of the ARC Infruitec-Nietvoorbij, Stellenbosch, during two growth seasons. Vines were spaced 2.7 x 1.5 m in north-south orientated rows and trained to a vertical trellis system with two sets of movable wires. They were pruned to two-bud spurs, spaced approximately 14 cm apart on the split cordon. Suckering was applied (removing at 30 cm length all shoots not situated on two-bud spurs). Micro-sprinkler irrigation was applied at pea size berry and at vèraison stages (12 hours @ 32L/hour).

Treatment and experiment design

Four treatments, four times randomly replicated with 20 – 30 vines per treatment, were applied: shoot positioning at berry set; shoot positioning at pea size; shoot positioning at véraison; and shoot positioning three weeks post véraison. Shoots were topped immediately after being positioned at approximately 110 cm length (dictated by the trellising system). For all treatments, measurements were performed at all developmental stages following the treatment (pea size, veraison, three weeks after veraison and ripeness). In this paper, only values obtained at ripeness stage are presented.

Vegetative measurements

Primary and secondary shoot length (cm), leaf area (cm^2), number of secondary shoots, and total shoot length (cm) were measured at berry set, pea size, vèraison, three weeks after vèraison and ripeness stages. At ripeness (2003/04 season), the secondary shoot node number per secondary shoot were counted at each primary shoot node position. Twelve shoots per treatment were randomly selected and used to obtain the bunch mass:shoot mass ratio, shoot length (primary and secondary shoots) and leaf area (primary and secondary shoots). Leaf area was determined with a LI-COR LI 3000 portable area meter.

Yield and grape composition

Bunches of twelve randomly selected shoots per treatment were harvested and the mass (g), volume (cm^3), length (cm) and rachis mass (g) determined. Berries were stored at –20°C until required for further analyses. For phenolic and anthocyanin determination in grape skins, 100 berries were sampled and the skins separated from the pulps by gentle squeezing between thumb and forefinger. Any pulp adhering to skins was removed. Skins were then rinsed in distilled water, blotted dry and their fresh mass determined. Dried skins were weighed, ground in a Sorvall Omni-mixer and stored at room temperature. Phenolics and anthocyanins were extracted and determined spectrophotometrically as described by Hunter *et al.* (1991). Extraction and determination of sugars and organic acids by gas liquid chromatography were done at ripeness stage as described by Hunter & Ruffner (2001).

Physiological and microclimate measurements

Rate of photosynthesis ($\mu mol/m^2/s$), rate of transpiration ($mmol/m^2/s$), stomatal conductance ($mmol/m^2/s$), and leaf and stem water potential (kPa) were measured on basal leaves (3rd to 4th nodium) and apical leaves (12th nodium). Rate of photosynthesis, rate of transpiration and stomatal conductance were measured using an ADC portable photosynthesis meter (The Analytical Development Co., England). The photosynthesis apparatus consisted of an infra-red CO_2 analyser, a data logger, a Parkinson broad leaf chamber (volume = 16 cm^3, area = 6,25 cm^2) and an air supply unit (length of sample tube = 4 m). The airflow rate through the open system was adjusted to 300 cm^3/min. Measurements were carried out between 10:30 and 11:30 on the day scheduled. Leaf and stem water potential were measured at mid-day (13:30). Leaves used for determination of stem water potential were wrapped in a double layer bag (inside plastic and outside aluminium foil). Stem and leaf water potential was measured using a Scholander-type pressure chamber. Ambient light intensity between the vine rows as well as light intensity just above and below the cordon were determined with a LI-COR Line Quantum Sensor during late morning. Light intensity was expressed as percentage of the ambient light level.

Statistical analyses

Data of all variables at each measurement stage were submitted to a two-way analysis of variance (year, treatment). No significant differences were found for the interaction (year x treatment). Data represent the means of two years. Differences between treatment means were tested using a Tukey HSD test.

Results and Discussion

Soil water

Soil water contents varied according to the differences in climatic conditions of the seasons (Figs. 1a & 1b). It also changed as the season progressed. Interestingly, the first season started off with higher soil water content and then typically continued to dry out despite the low intensity irrigation. However, during the second season the initial soil water content was lower and because of frequent precipitation the soil water content was maintained. Despite this, the typical pattern of increasing soil water with increasing soil depth was still evident.

Vegetative growth

The primary shoot length of positioned shoots was on average approximately 100 - 115 cm (data not shown), being restricted by the relatively low trellising system. At ripeness, the post-véraison (PV) treatment had higher values of total secondary (lateral) shoot length (Table 1a) and leaf area as well as number of secondary leaves (Table 1b) compared to that of the berry set (BS) treatment. As there were no differences in the number of secondary shoots, this can most probably be ascribed to the development of markedly longer lateral shoots closer to the base of the primary shoots of the PV treatment (Fig. 2), the primary shoots of this treatment having been in the geotropical orientation for a much longer time than those of the BS treatment (Pisciotta *et al.*, 2004) and being earlier and more frequently topped (Pastena, 1976; Hunter, 2000). No differences in secondary shoot length were found between pea size (PS) and véraison (V) treatments. Similar differences were found for total shoot length (Table 1a) and total shoot leaf area (Table 1b).

Shoot positioning and topping clearly had a noticeable effect on the position of secondary shoot initiation along the length of the primary shoots. In the BS treatment more than 50% of the total secondary shoot length occurred on the basal part (<7th nodium) of the primary shoot. In the PV treatment the basal secondary shoots represented more than 60% and the apical (>14th nodium) shoots only 8% of the total length. This is contrary to the general belief that earlier topping induces more secondary shoot development in the bunch zone. Shoot orientation and positioning up to véraison induced better uniformity of distribution along the primary shoot (Fig. 2). The distribution of secondary shoots along the length of the primary shoot and correct vertical positioning of the primary shoots apparently affected the light interception above and below the cordon (Figs. 3 & 4). Since the secondary shoots would have re-orientated themselves after the re-orientation (positioning) of the primary shoots, the results indicated that positioning from véraison probably was too late to allow a marked re-positioning of the secondary shoots and protection from radiation was therefore impeded. Lignification of the secondary shoots probably played a role, affecting their elasticity.

Yield and grape composition

Although the bunch mass and volume of the PS treatment tended to be higher, no significant differences were found for any of the productive parameters among the different treatments (Table 2). The PV treatment had a significantly lower ^{0}B level as well as sucrose and malic acid content (Figs. 5 & 6). No significant differences among treatments were found for glucose and tartaric acid contents and must pH (Figs. 5 & 7). The earlier shoots were positioned, the more water was lost by the skins (Fig. 8), resulting in a concentration of skin contents; this was particularly noticeable for BS and PS treatments. The pea size shoot positioning (and topping) also significantly improved the colour and the total phenolic content of the skins (Fig. 9), whereas the lowest values were found for the PV treatment. In general, the BS and PS treatments seemed to result in the best grape composition.

Microclimate, leaf gas exchange and water potential

At ripeness stage, significantly lower net photosynthesis, transpiration and stomatal conductance were found for the basal leaves (3rd to 4th node) compared to the apical leaves (12th node) at all measurement stages (data not shown) and for all treatments (Table 3). This is in agreement with the findings of Hunter & Visser (1988c, 1989). However, basal leaves made a constant contribution to the sucrose production of the canopy (also Hunter *et al*., 1994). The BS and PS treatments apparently stimulated the photosynthetic activity of apical leaves, whereas the BS treatment also increased the activity of the basal leaves compared to the rest of the treatments. This treatment had fewer lateral leaves and less lateral leaf area (Table 1b) which probably were better accommodated on the restricted trellising system.

Stem water potential was always higher than leaf water potential. Considering all treatments, better regression was found between leaf and stem water potential of apical leaves than in the case of basal leaves (Figs. 10 & 11). The variability in the basal leaves was apparently higher than in the apical leaves. Being closer to the permanent structure of the plant and source of water, a higher buffer against environmental effects on stem water potential in the basal part of the canopy would probably have existed. In contrast, the basal leaves would have been subjected to more variable light conditions in comparison to the apical leaves.

Practical considerations

No practical difficulty was experienced when shoots were positioned early in the season, i.e. at berry set and pea size stages, whereas at and after véraison proper vertical orientation and positioning were primarily restricted by shoot lignification and the tightness of the tendrils on the wires. This would impact on the application of cultivation practices such as mulching, spraying, mechanical harvesting, winter pruning, spur orientation, etc. Bunches were very sensitive to damage, which led to bunch rot and a reduction in yield. These are important considerations in terroirs where timely management is difficult. Even though late shoot positioning could have been done if only production is considered, serious future complications would have resulted and the high labour inputs would have made it an economically non-viable option.

Conclusions

Shoot positioning and the timing of shoot positioning had marked effects on the physiology, vegetative and reproductive growth, and grape composition of the low trellised Merlot/R99 vineyard. Later shoot positioning induced markedly longer secondary shoots in the basal part of the canopy, having been in the geotropical orientation for a much longer time. This finding is contrary to the general belief that earlier shoot positioning stimulates secondary growth lower in the canopy. Shoot positioning up to véraison resulted in better uniformity of distribution of secondary shoots along the primary shoot, which led to better light distribution and a stimulation in photosynthetic activity. The earlier shoot positioning (berry set and pea size stages) also resulted in the best overall grape composition. Lignification of shoots and the binding of tendrils to the foliage wires made it extremely difficult to properly position the primary shoots from véraison onwards. This has many practical complications that should be thoroughly considered, particularly on terroirs that are not cultivation-friendly and when a very tight canopy management schedule which affects the timing of practices, is used.

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Table 1a – Vegetative parameters

Measurement stage	**RIPENESS**			
Treatment	**BS**	**PS**	**V**	**PV**
Total lateral shoot length (cm)	104.8 b	133.1 ab	130.0 ab	151.9 a
Total shoot length (cm)	221.5 b	240.8 ab	234.0 ab	263.8 a
Total number of lateral shoot	13.6	13.3	12.2	12.8 n.s.

Values designated by the same letters do not differ significantly ($p<0.05$) Tukey HSD test

Table 1b – Vegetative parameters

Measurement stage	**RIPENESS**			
Treatment	**BS**	**PS**	**V**	**PV**
Total lateral leaf area (cm^2)	1771.1 b	2306.0 ab	2250.3 ab	2785.9 a
Total shoot leaf area (cm^2)	3928.5 b	4270.2 ab	3989.8 ab	4611.7 a
Total lateral leaves (n°)	38.4 b	51.5 ab	48.7 ab	56.1 a

Values designated by the same letters do not differ significantly ($p<0.05$) Tukey HSD test

Table 2 – Reproductive parameters

Measurement stage	**RIPENESS**				
Treatment	**BS**	**PS**	**V**	**PV**	
Bunch length (cm)	16.6	17.4	17.3	16.6	n.s.
Bunch volume (cm^3)	208.1	217.3	208.1	211.1	n.s.
N° berries/bunch	153.0				
Bunch mass (g)	229.3	242.9	226.5	226.8	n.s.
Berry mass (g)	1.4	1.5	1.4	1.4	n.s.
Rachis mass (g)	5.9	7.2	6.2	6.4	n.s.
Total leaf area/bunch mass (cm^2)/g	8.9	9.2	8.2	10.6	n.s.

n.s.= no significant

Table 3 – Physiological parameters

Measurement stage	**RIPENESS**				
Treatment	**BS**	**PS**	**V**	**PV**	
Apical Photo (µMOL/m^2/s)	6.6	6.7	5.8	5.7	n.s
Basal Photo (µMOL/m^2/s)	4.8 a	3.4 b	2.9 b	3.9 ab	
Apical ψ (KPa)	-1185.0	-1041.2	-1188.7	-1071.2	n.s
Basal ψ (KPa)	-1106.2	-1071.2	-1216.2	-1135.0	n.s
Apical STEM (KPa)	-1063.7	-918.7	-1048.7	-953.7	n.s
Basal STEM (KPa)	-1036.2	-923.7	-1128.7	-875.0	n.s
Apical Trans (µMOL/m^2/s)	2.7	2.8	2.7	2.7	n.s
Basal Trans (µMOL/m^2/s)	1.7	1.5	1.3	2.0	n.s
Apical Stom Cond (mMOL/m^2/s)	87.2	90.9	88.6	89.2	n.s
Basal Stom Cond (mMOL/m^2/s)	52.0	43.2	38.9	65.8	n.s

Values designated by the same letters do not differ significantly ($p<0.05$) Tukey HSD test
n.s.= no significant

Fig. 1a - Soil water 2002/03

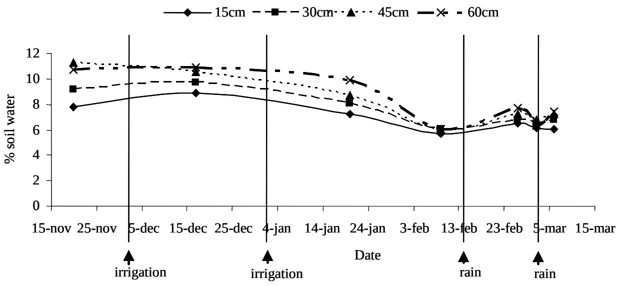

Fig. 1b - Soil water 2003/04

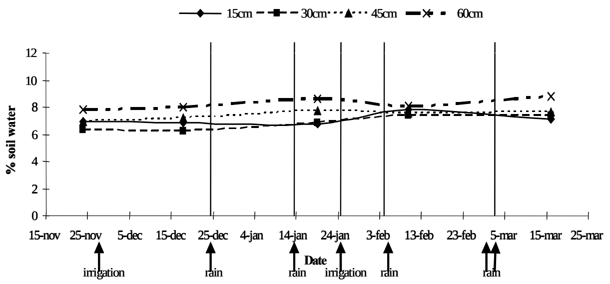

Fig. 2 Mean of length of lateral shoot versus node position of the primary shoot

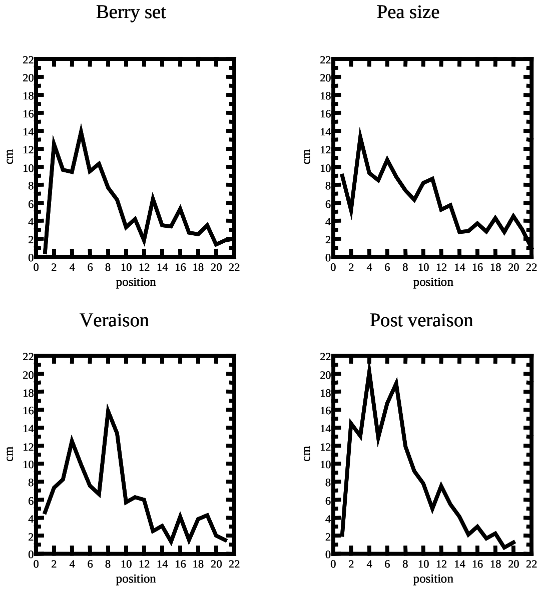

Fig. 3 % Light interception above the cordon

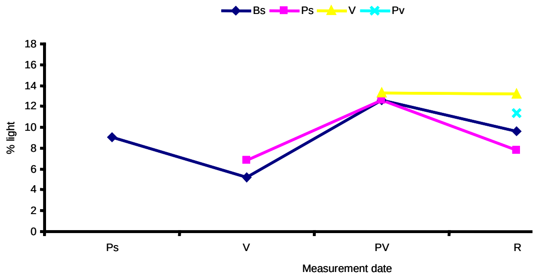

Fig. 4 % Light interception below the cordon

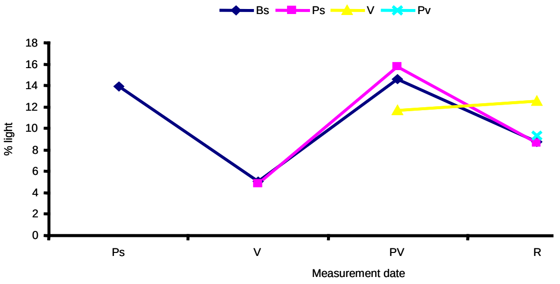

Fig. 5 Brix level at ripeness stage

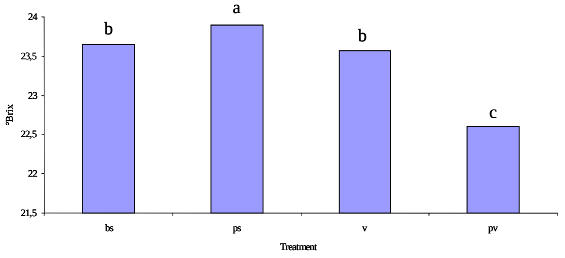

Fig. 6 Sugars and acids content at ripeness measurement stage

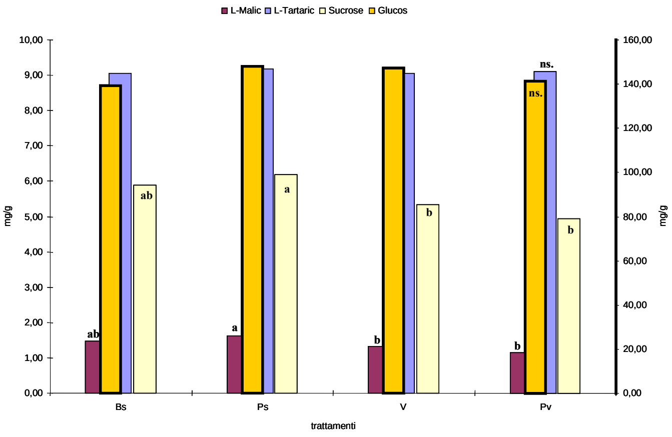

Fig. 7 pH at ripeness stage

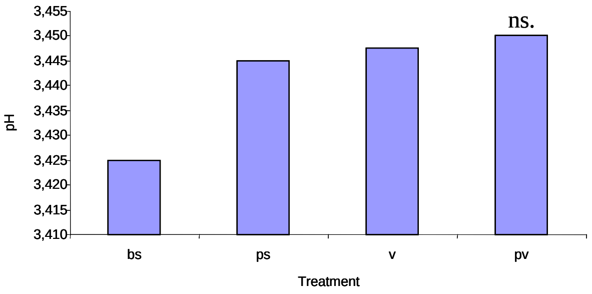

Fig. 8 - % water in the skins

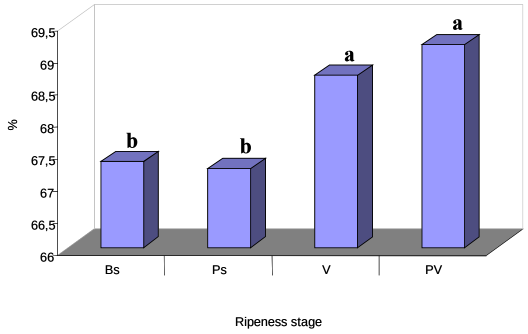

Fig. 9 Absorbance

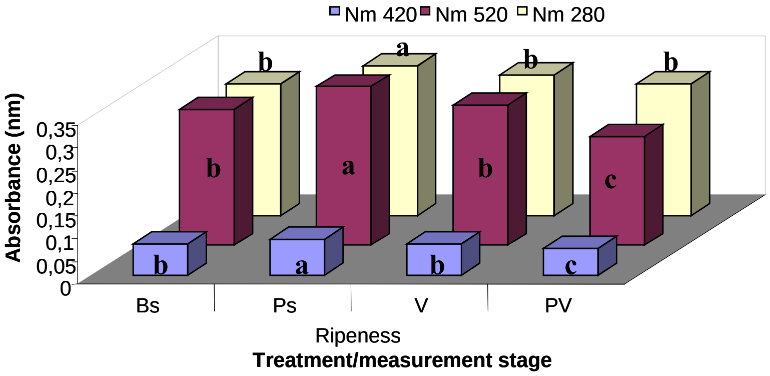

Fig. 10. Linear regression between basal leaves and stem water potential

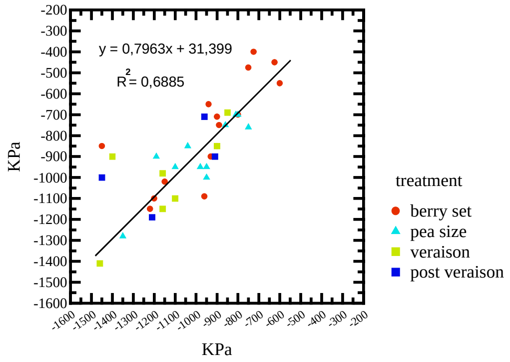

Fig. 11. Linear regression between apical leaves and stem water potential