EVALUATION OF YIELD, FRUIT QUALITY AND PHOTOSYNTHESIS OF TWO TRAINING/ TRELLIS SYSTEMS AND CANOPY MANAGEMENT PRACTICES FOR CARLOS AND NOBLE MUSCADINE GRAPES IN FLORIDA

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Abstract

Aims: The study was designed to evaluate and recommend most suitable training/trellis systems, canopy management practices and vine spacing for commercial muscadine grape varieties in Florida.

Methods and results: During 3rd growing season of 'Carlos' and 'Noble' muscadine grape cultivars biometrical data for “photosynthetic rate”, “vine balance”, “yield components”, “fruit composition” and “fruit ripening pattern ” were evaluated as a result of the vine spacing, and training/trellis system treatments. The mean values for the varieties indicated variation between “yield components”, “fruit ripening pattern” and “fruit composition” of single wire, double cordon (SWDC) and Munson T-cross arm, double cordon (MTDC) training/trellis systems. The training/trellis system and the leaf position had a statistically significant effect on photosynthetic active radiation (PAR) and photosynthetic rate for 'Noble' variety. Leaves adjacent to the cluster on a single wire presented higher PAR and photosynthesis rate at 1% level of significance. Leaves immediately downward to the cluster had also a superior photosynthesis rate ($p \leq 0.01$) in the T- trellis/training system compared with the same class of leaves in our SW system.

Conclusion: Carlos and Noble muscadine varieties demonstrated significant variation between the photosynthetic rate, yield components, fruit ripening pattern and fruit composition of single wire, double cordon (SWDC) and Munson T-cross arm, double cordon (MTDC) training/trellis systems, with better performance of the divided canopy.

Significance and impact of study: The ongoing research will provide essential information to some of the fundamental questions on the use of training/trellis system and canopy management practices for hot climate grapes and will improve the viability and competitiveness of commercial grape growing in Florida and southeastern states.

Keys words :*Muscadinia (Vitis) rotondifolia*, best management practices (BMP), yield components, fruit composition, fruit ripening

Résumé

Objectifs : Cette étude a été menée de manière à évaluer et à recommander les systèmes d'architecture de la vigne et de gestion de feuillage et d’espacement de la vigne les plus adaptés pour les raisins Muscadine en Floride.

Méthodes et résultats : Au cours de la troisième saison végétative des cultivars des raisins Muscadine 'Carlos' et 'Noble', des données biométriques pour “le taux photosynthétique”, “l'équilibre de la vigne” “les composants de la récolte”, “la composition du fruit” et “le processus de maturation du fruit” ont été évaluées en fonction de l'espacement de la vigne et des traitements des systèmes de l'architecture de la vigne. Le système d’'architecture de la vigne et la position de la feuille ont eu un effet statistiquement significatif sur la radiation photosynthétique active (PAR) et sur le taux photosynthétique pour la variété 'Noble'. Les feuilles adjacentes au cluster sur un fil unique ont manifesté une radiation et un taux photosynthétiques plus élevés au niveau d'1% de signification. Les feuilles immédiatement au-dessous du cluster ont également présenté un taux photosynthétique supérieur ($p \leq 0.01$) dans le système de l'architecture de la vigne T, en comparaison avec la même classe de feuilles dans notre système SW.

Conclusion : Les raisins Muscadines 'Carlos' et 'Noble' ont montré une variation significative entre le taux photosynthétique, les moyennes des composants de la récolte, le processus de maturation du fruit et la composition du fruit des systèmes d’architecture de la vigne de fil unique à double cordon et de Munson T-cross à double cordon, avec une meilleure performance de la gestion du feuillage.

Signification et impact de l’étude : La recherche en cours fournira des informations essentielles sur les systèmes d'architecture de la vigne et de gestion de feuillage et d’espacement de la vigne, ce qui améliorera la viabilité et la compétitivité commerciale des raisins de Floride et des États du Sud-Est.

Mots clés: : *Muscadinia (Vitis) rotundifolia*, optimisation des pratiques, composants de la récolte, composition du fruit, maturation du fruit

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INTRODUCTION

Muscadinia rotundifolia (Michaux) Small, the common muscadine grape is native to the Southeastern United States and has been cultivated for more than 400 years. Although the local grape industry is relatively small, there is tremendous room for commercial growth, based on increasing consumer interest in healthier diets and changing lifestyle. The discovery of high volume anti-oxidant compounds in muscadine juice and wine has brought lately more attention to muscadine grape, not only as an alternative cash value crop for the Southeast, but a new healthy food as well.

The grape industry in Florida is an exception to the general rule that the grapes grow and ripen in dry weather. Plants are more susceptible to disease during the fruiting season and also during moist, hot weather. This constraint is faced by all grape growers in Florida, and requires the utmost ingenuity in viticultural skill and science to overcome.

Training/Trellis system and canopy management are an integral components of vineyard management because of their impact on the canopy microclimate and respectively efficient pest and disease control over the grapevine. It is extremely important to understand and master the science of canopy management because the proper canopy management improves vine vigor and enhances fruit quality and wine quality of grapes and reduces incidence of diseases in the vineyard and minimizes unnecessary vegetative growth. Field studies have shown that unmanaged vines with vigorous growth have dense and crowded canopies and produce low yield and low quality grapes (SMART *et al*., 1982).

Little and almost nothing has been done concerning management practices for hot climate grapes such as muscadines and Florida hybrid grapes grown in the southeastern United States. Growers are aware of the importance of canopy management in grape production but faced a lack of specific knowledge to create a desired microclimate for the grapevines. In most cases they tried to adapt practices that had been developed specifically for the cool climate grapes: dominated in the world vinifera type, labrusca and American-French hybrids (BRAVDO *et al*., 1985; KLIEWER and DOKOOZLIAN, 2000; INTRIERI and FILLIPPETTI, 2000; REYNOLDS *et al*., 1989; 1995; 2000; SMART *et al*., 1982, LANE, 2002).

The general objective of this study was to evaluate and recommend most suitable training/trellis systems, canopy management practices and vine spacing for commercial muscadine grape varieties in Florida. This paper presents for the first time data for photosynthetic rate of muscadines (to the best extend of our knowledge) and preliminary biometrical data for vine balance and yield components of two muscadine grape cultivars 'Carlos' and 'Noble' as a direct result of two treatments: training/trellis system and planting density.

MATERIALS AND METHODS

1 - Experimental design and plant material

Two 0.28 ha experimental plots were planted as a monoculture respectively with 'Carlos' and 'Noble' muscadine vines at the beginning of May 2003 at Florida Agricultural & Mechanical University/ Center for Viticulture & Small Fruit Research located in Leon, County, Florida. For proven authenticity and health status the planting material was obtained from a certified Florida grape nursery, Henscratch Farm &Winery, Lake Placid, Florida. 'Carlos' is a standard bronze muscadine variety in commercial use mainly for wine and juice. It has perfect-flowers and is very vigorous, with moderate susceptibility to powdery mildew, angular leaf spots and bitter rot. 'Noble' was released by North Carolina breeding program as a purple muscadine grape for juice and wine production. It has perfect flowers and is high yielding, vigorous, and winter hardy. It is susceptible to powdery mildew, angular leaf spots and bitter rot.

The experimental design was a complete randomized block with two factors: training/trellis system and planting density. Four vines in two replications per treatment were used as sampling units. In our study, the following training /trellis systems were evaluated: 1) single wire (1.5 m) double cordon training spur pruning, (SWDC); and 2) Munson narrow T- trellis (1.5 m) double cordon training spur pruning (MTDC). Three variation of vine spacing determined as: 3.60 m; 4.20 m and 4.80 m in row by 3.0 m between the rows distance were applied. The high vigor of muscadines and extremely high humidity rate (80-100%) in Florida required the planting configuration with greater in row distance. The vine balance, production efficiency and photosynthetic rate of each variety under two training/trellis systems and three vine spacings were evaluated during the 3rd growing season of the vineyard (under intense training muscadine grapes are capable to enter the fruit set on the second growing season).

2 - Vine growth

Weight of cane pruning (vine size), yield and clusters per vine were recorded. The Ravaz index (RAVAZ, 1930): the ration between the total yield per vine and the weight of the current season wood removed at pruning during the winter following the growing season was also determined.

3 - Yield components

One random 25 cluster and 100-berry sample was collected from each experimental vine at maturity for collecting biometrical data for cluster analysis: size, weight, number of berry/ cluster and berry analysis: diameter, weight, percentage of skin, seeds and juice. The number of clusters per vine was calculated by dividing the total yield per vine by the mean value of the cluster weight per vine.

4 - Fruit quality

A sample of 25 clusters per vine was collected at harvest and crushed for determination of soluble solids (°Brix), pH and titratable acidity. Soluble solids (°Brix) and pH were measured at three replication per sample on clear juice using an Abbé temperature compensating refractometer (AO Scientific Instrument, Buffalo NY) and Fisher 825 MP pH meter respectively. Titratable acidity was measured using a Brinkman 672 Titroprocessor.

5 - Photosynthetic analysis

The experimental unit consisted of a leaf position near the second cluster on a green shoot, and equally dispersed along 3 positions on each cordon for each plant. Data were collected for a leaf adjacent to the cluster (leaf A), the other one position immediately below the cluster on the same branch (leaf D) and first fully developed leaf below the shoot tip (leaf E). A total of 9 measurements for each side cordon or total of 18 per vine were performed: leaves inside of the canopy, on a shoot coming from the first spur next to the trunk of the vine; in mid cordon position; and on the periphery of the canopy at the end of the cordon. The measurements were taken when the vines were at 'fruitset' and 'veraison' phenological phases. Data were collected daily from 8:30 in the morning until the leaf blade temperature reached a value that inhibits photosynthesis, greater than 35 °C. Photosynthetic data were measured and calculated using a portable infrared gas analyzer (LCi Portable Photosynthesis System, ADC BioScientific Ltd., Hoddesdon, Herts, UK). The data recorded were for photosynthetic active radiation incident on leaf surface, atmospheric pressure, difference in CO_2 concentration, and difference in water vapor pressure, leaf chamber temperature, photosynthetic rate, stomatal conductance of CO_2, and transpiration rate. In this study we present only the data for photosynthetic active radiation (PAR) incident on leaf surface and photosynthetic rate.

6 - Statistical analysis

One-way analysis of variance (ANOVA) was performed using the JMP software (SAS Institute, Cary, USA) version 5.1.2. The treatment means were separated by Least Significant Difference (LSD) test at p = 0.05.

Table 1. Impact of training/trellis system on the yield parameters for Carlos and Noble muscadine varieties (season 2005).

Parameters	Planting density	Carlos				Noble			
		SW		T-trelis		SW		T-trellis	
		mean	signif.	mean	signif.	mean	signif.	mean	signif.
Total yield (kg)	a	10.55	ns	16.58	ns	7.87	*	6.02	ns
	b	10.26	ns	6.15	ns	10.66	*	5.82	ns
	c	9.00	ns	11.44	ns	9.63	*	5.77	ns
Cluster (g)	a	52.30	ns	55.45	ns	81.33	*	73.26	ns
	b	48.37	ns	53.12	ns	70.37	*	58.64	ns
	c	50.17	ns	56.22	ns	90.63	*	55.69	ns
Total berries/cluster	a	9.80	ns	10.17	ns	25.70	**	19.95	ns
	b	8.98	ns	9.27	ns	22.20	**	16.75	ns
	c	9.38	ns	9.80	ns	29.80	**	15.05	ns
Berry (g)	a	5.16	ns	5.19	ns	3.06	ns	3.37	**
	b	5.33	ns	5.54	ns	3.07	ns	3.37	**
	c	5.35	ns	5.62	ns	2.95	ns	3.51	**
Diameter (mm)	a	19.23	ns	19.20	ns	15.95	ns	17.51	**
	b	19.54	ns	20.03	ns	15.92	ns	17.11	**
	c	19.59	ns	20.08	ns	15.64	ns	16.65	**
°Brix	a	16.55	ns	19.00	ns	18.07	ns	17.90	ns
	b	16.95	ns	16.93	ns	19.10	ns	18.30	ns
	c	17.85	ns	18.30	ns	18.50	ns	18.90	ns
Acidity	a	0.23	na	0.24	na	0.23	na	0.27	na
	b	0.27	na	0.26	na	0.29	na	0.29	na
	c	0.24	na	0.21	na	0.18	na	0.28	na
pH	a	3.83	na	3.79	na	4.09	na	3.87	na
	b	3.78	na	3.70	na	3.87	na	3.91	na
	c	3.83	na	3.91	na	4.18	na	3.93	na
Ravaz index	a	14.4	na	8.9	na	8.7	na	4.6	na
	b	10.8	na	3.2	na	12.6	na	3.1	na
	c	16.2	na	7.3	na	7.6	na	4.1	na

[1]ns, na, *, and ** indicate not significant, not applicable, significant at the 0.05, significant at the 0.01 levels of probability, respectively.
[2]a, b, and c indicate plant density of 12, 14, and 16 feet between vines in row, respectively.

Table 2. Influence of leaf position upon photosynthetic parameters at "fruit set" for Carlos and Noble muscadine varieties.

Parameters	Leaf position	Carlos				Noble			
		SW		T-trellis		SW		T-trellis	
		mean	signif.	mean	signif.	mean	signif.	mean	signif.
PAR leaf A	1	89	ns	321.5	ns	47.5	ns	97.5	ns
	2	57.5	ns	41.5	ns	73	ns	297.5	ns
	3	100	ns	614.5	ns	96.5	ns	145.5	ns
PAR leaf D	1	112	ns	19	ns	77	ns	84.5	ns
	2	97.5	ns	62.5	ns	125.5	ns	578.5	ns
	3	111.5	ns	685.5	ns	944.5	ns	463.5	ns
PAR leaf E	1	599	ns	80	ns	721.5	ns	687	ns
	2	535	ns	56.8	ns	533.5	ns	273.5	ns
	3	356.5	ns	736	ns	804.5	ns	1099.5	ns
Photosynthesis rate leaf A	1	4.65	ns	4.80	ns	1.17	ns	1.96	ns
	2	0.89	ns	1.91	ns	3.06	ns	3.39	ns
	3	2.26	ns	4.29	ns	2.48	ns	3.16	ns
Photosynthesis rate leaf D	1	2.73	ns	1.33	ns	1.84	ns	7.81	ns
	2	1.54	ns	2.39	ns	3.02	ns	7.08	ns
	3	3.48	ns	6.74	ns	3.65	ns	5.36	ns
Photosynthesis rate leaf E	1	6.04	ns	0.46	ns	3.14	ns	7.66	ns
	2	3.68	ns	6.78	ns	4.44	ns	3.38	ns
	3	3.53	ns	8.14	ns	10.41	ns	6.60	ns

[1]ns, and * indicate not significant, and significant at the 0.05 level of probability, respectively.

[2]1, 2, and 3 indicate leaf position next to the trunk, in mid cordon position, and on the periphery of the canopy at the end of the cordon of the vine, respectively.

[3]A, D, and E indicate leaf adjacent to the cluster, leaf immediately below the cluster, and leaf totally exposed to sunlight on the same branch, respectively.

Table 3. Influence of leaf position in photosynthetic parameters at "veraison" for Carlos and Noble muscadine

Parameters	Leaf position	Carlos				Noble			
		SW		T-trellis		SW		T-trellis	
		mean	signif.	mean	signif.	mean	signif.	mean	signif.
PAR leaf A $(\mu mol^{-2}s^{-1})$	1	26.25 a	*	30.91	ns	65.25	ns	42.33	ns
	2	29.33 a	*	104.66	ns	73.41	ns	37.91	ns
	3	51.33 b	*	120.412	ns	113.58	ns	41.91	ns
PAR leaf D $(\mu mol^{-2}s^{-1})$	1	29.91	ns	32.91	ns	80.08	ns	51.33	ns
	2	29.08	ns	116.75	ns	82.08	ns	32.41	ns
	3	39.58	ns	116.25	ns	90.5	ns	85.08	ns
Photosynthesis rate leaf A $(\mu molCO2m^{-2}s^{-1})$	1	0.29 a	*	0.77	ns	1.64	ns	1.04	ns
	2	0.61 a	*	1.33	ns	2.02	ns	0.80	ns
	3	1.42 b	*	1.63	ns	1.74	ns	0.76	ns
Photosynthesis rate leaf D $(\mu molCO2m^{-2}s^{-1})$	1	0.82	ns	0.835	ns	1.76	ns	1.05	ns
	2	0.50	ns	1.16	ns	2.53	ns	0.44	ns
	3	0.84	ns	1.34	ns	2.12	ns	0.74	ns

[1]ns, and * indicate not significant, and significant at the 0.05 level of probability, respectively.

[2]1, 2, and 3 indicate leaf position next to the trunk, in mid cordon position, and on the periphery of the canopy at the end of the cordon of the vine, respectively.

RESULTS AND DISCUSSIONS

'Carlos' and 'Noble' muscadine varieties demonstrated variation between the mean values of yield components (total yield, cluster, total berry /cluster, berry, berry diameter) and fruit composition (soluble solids in °brix, titratable acidity and pH) of single wire, double cordon (SWDC) and Munson T-cross arm, double cordon (MTDC) training/trellis systems with better performance of the divided canopy (table 1). Also, vines trained under MTDC system (the divided canopy) followed a more even ripening pattern which is an extremely desirable characteristic for mechanical harvest (figure 2).

Yield/Pruning ratio (Ravaz index) is an indication of the balance level between crop and vine vigor. The mean values of Ravaz index for Carlos' variety were higher (≥12) for the vines under SWDC (table 1), which is one preliminary sign for low vigor and tendency for over cropping (table 1). Vines under MTDC maintained better performance in this ratio (5 - 10), which is an indication for moderate vigor and optimum crop load. 'Noble' vines under both training/trellis system showed values of Ravaz index at the moderate (5-12) range.

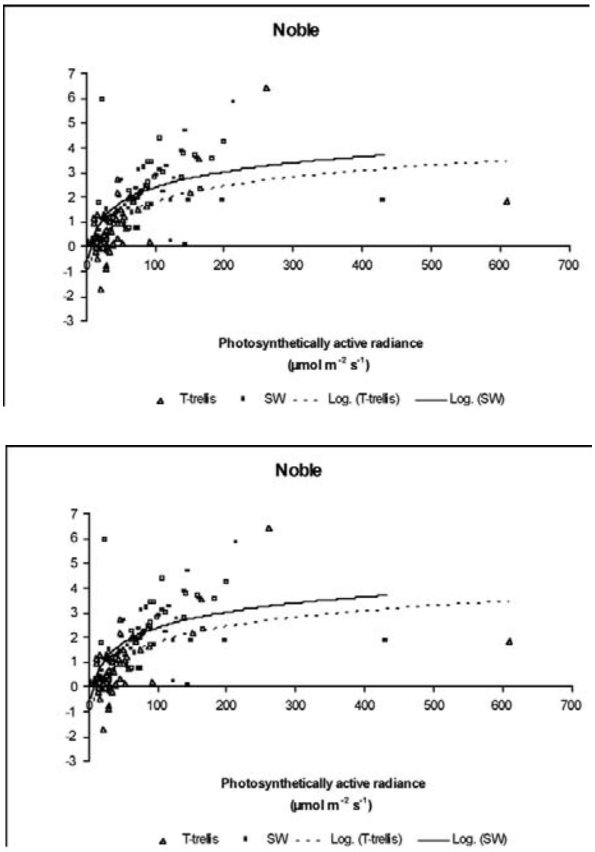

Figure 1. Photosynthetic light-response curves at "veraison" for Carlos and Noble varieties.
Each data point is the data of each measurement.

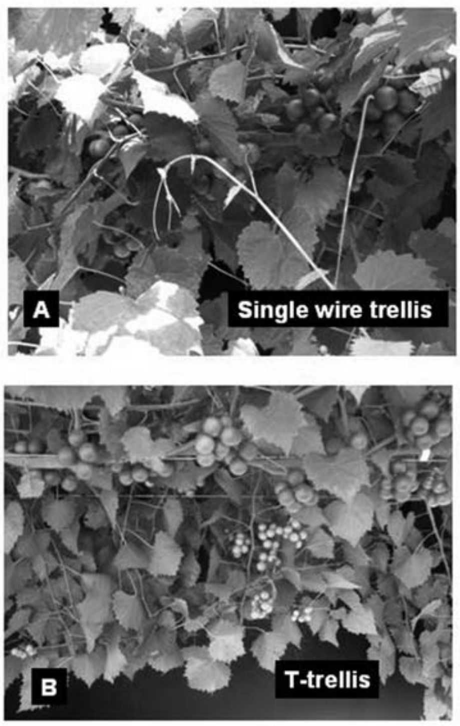

Figure 2. Fruit ripening pattern of Carlos var. A) SWDC and B) MTDC training/trellis system

Significant variation between yield components was observed only for Noble' when comparing the two trellis systems (table 1). Berry diameter and weight were significantly higher ($p \leq 0.01$) for vines in a T-trellis system than for the ones in a single wire trellis. On the other hand, vines on a single wire produced larger clusters ($p \leq 0.05$), more berries per cluster ($p \leq 0.01$), and presented the highest total yield ($p \leq 0.05$).

SMART (1987) demonstrated that because of the attenuation of light within dense grapevines canopy, it is essentially the exterior leaves that contribute to canopy photosynthesis. In our study the younger leaves at the periphery of the canopy at fruit set received a higher value of PAR and the photosynthetic rate, than the one adjacent to the cluster under both training/trellis system (table 2). CANDOLFI -VASCONCELOS (1994) reported also a higher transpiration rates and higher water use efficiency of the younger leaves at the periphery of the canopy in comparison to the one opposite of the cluster in Pinot noir grapevines.

STOEV and IVANCHEV (1977) showed that during the short period of veraison, the grapes are an extremely powerful sink, capable of rerouting the translocation of assimilates to the roots to their own growth benefit and affecting the photosynthetic rate. 'Carlos' and 'Noble' muscadine varieties at veraison demonstrated different pattern in the correlation between PAR and photosynthetic rate expressed as the photosynthetic light response curves (figure 1).

It was accepted as a principle of the canopy management of standard vinifera type varieties that shading within the canopy affects each of the yield -forming process from budbreak, fruit bud initiation and development up to fruitset and berry growth (SMART *et al.*, 1974). Poor fruitset is often experienced in the center of dense canopies of the muscadine vineyards (HEGWOOD *et al.*, 2001). In our observation the leaves adjacent to the cluster (leaf A) on a SW system presented higher PAR and photosynthesis rate at 1% level of significance for the 'Noble' variety (table 4). Leaves immediately downward to the cluster (leaf D) had also superior photosynthesis rate ($p=0.01$) when in a SW system compared with the same class of leaves in our T-trellis.

'Carlos' variety showed significant effect on PAR and photosynthesis rate ($p = 0.05$) for leaves adjacent to the cluster at the end of the cordon (leaf position 3) in a SW system when compared with leaves close to the main trunk or in the middle of the cordon (table 3). The freely hanging branches under SW system created a dense canopy which appears to be reducing the PAR and therefore the photosynthesis rate. 'Noble' variety did not show any significant difference of PAR and photosynthesis rate when comparing leaf positions.

Table 4. Influence of trellis system in photosynthetic parameters at "veraison" for Carlos and Noble muscadine varieties.

Parameters	Carlos SW mean	Carlos T-trellis mean	signif.	Noble SW mean	Noble T-trellis mean	signif.
PAR leaf A (μmol $^{-2}$s $^{-1}$)	35.63	85.33	ns	84.08	40.72	**
PAR leaf D (μmol $^{-2}$s $^{-1}$)	32.86	88.86	ns	84.22	56.27	ns
Photosynthesis rate leaf A (μmolCO2m^{-2}s^{-1})	0.78	1.24	ns	1.80	0.87	**
Photosynthesis rate leaf D (μmolCO2m^{-2}s^{-1})	0.72	1.11	ns	2.13	0.74	**

In order to validate and better identify the impact of training/trellis system and canopy management practices on vine balance, yield and fruit quality of muscadine type grapes further studies are needed including vertical and wide divided training/trellis systems.

Our research was based on the need for training and trellising muscadine grapes to maximize production, to facilitate cultural operations such as vineyard-spraying; pruning and harvesting; to improve canopy microclimate, and to reduce disease incidence. The 4 groups major factors were considered when the training/trellis system were selected: 1) Simplicity: simple trellis systems are often the most economical viable, but can restrict yield and quality; 2) Vine growth factors: the balance between vine vigor and capacity, which influences yield and grape quality; 3) Economic factors: the cost benefits of more expensive trellis systems must be considered; and 4) Environmental factors: temperature, rainfall, topography, soil.

Our guideline and understanding for the best training/trellis systems for Florida grapes was based on superior microclimate within divided canopy under the hot and humid environment; improved pest and disease management and mechanical harvest.

While, very preliminary these results for muscadine grape varieties are an indication of the importance of a carefully designed and selected training/ trellis system for maintaining the best physiological equilibrium of the particular grape variety and its optimal performance under specific environmental conditions. Although, our results are promising, due to the perennial nature of grapevine, with an extended juvenile stage before primary fruit set, it is extremely important to amplify the research for at least two more years before final conclusions and significant recommendations for the industry can be drawn.

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