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Performance of *Vitis vinifera* cultivar Flame Seedless Grapevines under Different Node Load per Centimeter Square of Trunk Cross-sectional Area

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ABSTRACT

Performance of grapevines and cluster quality of cultivar. Flame seedless grape under different node load cm^{-2} Trunk Cross-Sectional Area (TCSA) were studied in the 2009/2010 and 2010/2011 seasons. Treatments comprised 2, 3, 4 or 5 nodes cm^{-2} TCSA under double T-type trellis system. Parameters such as bud behavior, vegetative growth, nitrogen, phosphorus and potassium leaf content, clusters and berries characteristics, yield and total carbohydrates in the canes were measured in an effort to establish the best node load level cm^{-2} TCSA for this cultivar. A negative relationship was found between node load levels cm^{-2} TCSA and most parameters such as bud behavior, vegetative growth, leaf mineral content, weight, length and width of clusters, weight and diameter of berries, Soluble Solid Content (SSC), SSC/acid ratio, total anthocyanin and total carbohydrates in canes, but the other estimated parameters such as titratable acidity and yield showed a positive relationship in this respect. Considering all parameters, the node load level of 2 or 3 nodes cm^{-2} TCSA showed the best performance of grapevines and cluster quality of cultivar Flame seedless.

Key words: Flame seedless, node load, trunk cross-sectional area, grapevines performance, cluster quality

INTRODUCTION

Grape is considered the first deciduous fruit crop in the world and the second major fruit crop in Egypt after citrus. Egypt takes an important position in viticulture of the world and ranks 13th place in grape production, where the total cultivated area of grape in Egypt reached about 64034 hectares (1582576.4 feddan) producing about 1360250 tons according to the last statistics of the FAO (2010).

The quantitative and qualitative performance of grapevines is greatly affected by the node load per vine, so pruning or node load is an obvious management technique developed to regulate the balance between vegetative growth, fruit quality and productivity of grapevines. The improper application of pruning by leaving a lower or higher number of nodes per vine was always accompanied by some negative effects on productivity of all grapevine cultivars. The adjusting vine load seems to be very important for achieving a good balance between growth and fruiting of vines, maintaining the vines in the desired shape that will enhance productivity and facilitate various horticultural operations. Furthermore, this lead to distribute the proper amounts of shoots over the vines and between vines according to vine capacity for maintaining higher yield of high berry quality (Dvornin and Ipatii, 1986; Possingham, 1993; Howell and Striegler, 1998).

Yield and berry quality of the grapevine is related to the number of nodes which retained after winter pruning in such cultivars, i.e. Flame Seedless, King Ruby and Roumi Red

(Al-Saidi and Al-Wan, 1990; Hussain and El-Dujaili, 1990; Murisier and Ziegler, 1991). However, controlling yield via pruning is an important way for increase the table grapes seedless quality (Coban and Kara, 2002).

There is some literature information on pruning or node load of several grapevine cultivars (Shahein *et al.*, 1998) on Flame seedless and Ruby seedless grapevine (Omar and Abdel-Kawi, 2000) on Thompson seedless grapevines (Keller *et al.*, 2004) on Concord grapes (Fawzi *et al.*, 2010) on Crimson seedless cultivar. However, to the best of our knowledge, there is no available information on the relationship between different node load cm^{-2} trunk cross-sectional area and bud behavior, vegetative growth, yield, cluster quality and total carbohydrates of the canes of Flame seedless grape vines. Therefore, the aim of the present study is (1) to explore the optimum node load per vine for Flame seedless grape referring to trunk cross-sectional area and (2) to study the effect of node load cm^{-2} trunk cross-sectional area on bud behavior, vegetative growth, leaf mineral content, cluster quality, yield per vine and total carbohydrates of Flame seedless grapevines under the newly reclaimed lands.

MATERIALS AND METHODS

Plant materials and experimental procedure: During 2009/2010 and 2010/2011 growing seasons, seventy two vines were chosen for this study, almost uniform in growth and vigor and in good physical condition. The experiment was conducted on 10-year-old Flame seedless grapevines growing in a sandy soil, drip irrigated and cultivated at 1.7 m within rows and 2.7 m between-rows with supporting by double T-type trellis system and receiving normal cultural practices at a commercial vineyard, located at El-Khatatba city, Monifia Governorate, Egypt. The experiment was designed as a completely randomized block design with three replicates (six vines for each replicate). During the last week of December of each experimental season, four levels of node load were employed; therefore the studied vines pruned (spur pruning method 2-3 nodes per spur) to 2, 3, 4 or 5 nodes cm^{-2} TCSA. The number of nodes per vine was counted and the circumference of the trunk measured 30 cm above soil level during both seasons, to calculate TCSA. The experiment was blocked by the number of nodes cm^{-2} TCSA.

Bud behavior: In both experimental years, during pruning time (last week of December) the total number of unopened buds per vine for all studied vines was recorded. Also, after a month of bud bursting (mid-February) of each season, number of burst buds, fruitful buds and clusters per vine were counted, then the percentages of bud burst, fertility and fruitfulness were calculated according to Bessis (1960) as follows:

$$\text{Bud burst (\%)} = \frac{\text{No. of burst buds per vine}}{\text{Total number of buds per vine}} \times 100$$

$$\text{Bud fertility (\%)} = \frac{\text{No. of clusters per vine}}{\text{Total number of buds per vine}} \times 100$$

$$\text{Fruitfulness (\%)} = \frac{\text{No. of fruitful buds}}{\text{No. of bursted buds}} \times 100$$

Vegetative growth: In both growing seasons, at full bloom stage the following parameters were determined.

Internode length: The third basal internode length was measured for each replicate and the average was expressed in cm.

Internode thickness: The third basal internode thickness was determined in the same canes for each replicate and the average was expressed in cm.

Leaf area: Samples of 20 leaves from each replicate were taken from the top of the growing shoot (6th or 7th leaf) to measure the average leaf area using the following equation: Leaf area (cm^2) = 0.587 (L×W). where, L = length of leaf blade and W = width of leaf blade according to Montero *et al.* (2000) and the average was expressed as cm^2.

Nitrogen, phosphorus and potassium leaf content: At full bloom, samples of 24 leaf petioles were taken from opposite side of the clusters and cleaned with tap water, dried at 70°C to constant weight and finally grind to determine N, P and K content.

Total nitrogen percentage: It was determined by using micro-Kjeldahl according to the method described by Jones (2001).

Phosphorus percentage: It was estimated calorimetrically using the stannus-reduce molybdophosphoric blue color method in sulphuric system as described by Jones (2001).

Potassium percentage: It was determined in the digested plant materials using flame photometer according to Jones (2001).

Yield: In both growing seasons, average yield per vine was determined by multiplying an average of number of clusters per vine by average weight of clusters per vine in kilograms. Average yield per feddan was estimated by using yield per vine and the number of vines per feddan in tons at harvesting date (20th June).

Characteristics of clusters: Representative samples from each replicate (four clusters) were harvested with firm berries having crimson red color when average soluble solids content percentage (SSC%) in berry juice reached about 15-16% and SSC/acid ratio ranged about 22:1 and taken to laboratory to determine the following characters:

- Average cluster weight (g)
- Average cluster length and width (cm)

Physicochemical characteristics of berries: Samples of 100 berries from each replicate were collected at random to determine an average berry weight (g) and berry diameter (mm) as physical characters. Berry juice was extracted and filtered through two layers of cheese cloth to determine chemical characteristics of the berries such as Soluble Solids Content (SSC) using a manual temperature-compensated refractometer. The results were expressed as a percentage (%). Titratable acidity was obtained through the titration of 10 mL juice from a representative sample, with 0.1 N NaOH until achieving the neutralization of the organic acids. In this case, results were expressed as a percentage of tartaric acid equivalents according to AOAC (1980) in addition, SSC/acid ratio was calculated by dividing the soluble solids content percentage to acidity.

Finally, total anthocyanin content in berry skin was determined according to the method of Mazumdar and Majumder (2003) by extracting half gram of fresh berry skin in 10 mL of ethanolic-hydrochloride acid mixture which prepared by mixing 85 parts of ethanol 95% and 15 parts of hydrochloric acid 1.5 N. It is allowed to stand overnight at a temperature of about 4°C, centrifuged for 3 min and then filtered through filter paper (Whatman No. 1). The filtered aliquot was maintained in darkness for about 2 h with cover of the container. The Optical Density (OD) value of the solution was then measured through 535 nm wave length in a spectrophotometer against blank. The amount of total anthocyanin in berry skin was calculated using the following equations:

$$\text{Total absorbance value for the berry skin (per 100 g)} = \frac{e \times b \times c}{d \times a}$$

Where:

a = Weight of sample
b = Volume made for color measurement
c = Total volume made
d = Volume of aliquot taken for estimation
e = Specific OD value at 535 nm wavelength

The 1 mg mL^{-1} of the solution is equivalent to the absorbance of 98.2. Therefore, the amount of total anthocyanin present in the sample (mg/100 g) = Total absorbance for the sample/98.2.

Determination of total carbohydrates in the canes: At winter pruning, samples of ripened canes were collected and used the middle portion of the cane for determination: Total carbohydrates (g/100 g dry weight) were determined using Anthrone method. Green colors intensity was measured by a spectrophotometer at 630 nm wave length according to Hedge and Hofreiter (1962).

Statistical analysis: The obtained data were statistically analyzed as a completely randomized blocks design with three replicates by analysis of variance (ANOVA) according to the procedure outlined by Snedecor and Cochran (1982), using the statistical package software SAS (SAS Institute Inc. Cary, NC, USA). Comparisons between means were made by using the newly least significant differences test (N-LSD) at 5% level of probability as mentioned by Waller and Duncan (1969).

RESULTS

Bud behavior: Data presented in Table 1 showed a negative relationship between bud behavior (bud burst%, bud fertility% and fruitfulness%) and number of nodes cm^{-2} trunk cross-sectional area (TCSA) of Flame seedless grapevines during the both seasons of the study. The highest significant effect in bud burst, bud fertility and fruitfulness percentages were obtained with 2 nodes/TCSA cm^2; hence, the percent attributed due to this treatment was 81.74 and 83.99% for bud burst, 74.59 and 80.95% for bud fertility and 93.08 and 96.69% for fruitfulness in the two seasons, respectively. Reversely, 5 nodes/TCSA cm^2 induced significantly the lowest percent in this respect; thus, the percent leveled due to this treatment was 69.17 and 70.11% for bud burst, 50.40 and 51.16% for bud fertility and 53.20 and 54.80% for fruitfulness in the two seasons, respectively. Furthermore, 3 and 4 nodes/TCSA cm^2 treatments showed a significant effect on bud behavior. Indeed, 3 nodes/TCSA cm^2 treatment significantly increased the bud burst, bud fertility and fruitfulness percentages than those obtained with 4 nodes/TCSA cm^2 of Flame seedless grapevines.

Table 1: Effect of different node load cm^{-2} trunk cross-sectional area (node cm^{-2} TCSA) on bud behavior of Flame seedless grapevines during 2009 and 2010 seasons

	Bud burst (%)		Bud fertility (%)		Fruitfulness (%)	
Treatment	2009	2010	2009	2010	2009	2010
2 nodes cm^{-2} TCSA	81.74	83.99	74.59	80.95	93.08	96.69
3 nodes cm^{-2} TCSA	75.58	75.59	58.42	58.96	71.63	73.20
4 nodes cm^{-2} TCSA	74.59	74.63	58.02	58.07	66.56	67.08
5 nodes cm^{-2} TCSA	69.17	70.11	50.40	51.16	53.20	54.80
N-LSD at 5%	1.84	0.77	1.71	0.99	1.34	3.19

Vegetative growth: An increase in vegetative growth (internode length, internode thickness and average leaf area) was occurred at the lowest node load levels cm^{-2} TCSA (Table 2).

Table 2: Effect of different node load cm^{-2} trunk cross-sectional area (node cm^{-2} TCSA) on vegetative growth of Flame seedless grapevines during 2009 and 2010 seasons

	Internode length (cm)		Internode thickness (cm)		Average leaf area (cm^2)	
Treatment	2009	2010	2009	2010	2009	2010
2 nodes cm^{-2} TCSA	6.70	6.92	0.72	0.73	120.47	122.55
3 nodes cm^{-2} TCSA	6.23	6.27	0.66	0.67	117.43	119.55
4 nodes cm^{-2} TCSA	5.49	5.74	0.63	0.65	99.87	102.63
5 nodes cm^{-2} TCSA	4.84	5.09	0.54	0.58	82.12	84.86
N-LSD at 5%	0.41	0.17	0.03	0.02	1.64	1.69

Internode length and thickness: The longer and thicker internodes detected at the level of 2 nodes cm^{-2} TCSA. The values of internode length and thickness due to this treatment were 6.70 and 6.92 cm for internode length and 0.72 and 0.73 cm for internode thickness in the two seasons, respectively. Whereas, the level of 5 nodes cm^{-2} TCSA decreased significantly the internode length and thickness compared to the other treatments; hence, the values of internode length and thickness due to this treatment were 4.84 and 5.09 cm for internode length and 0.54 and 0.58 cm for internode thickness in the two seasons, respectively (Table 2).

Leaf area: The values of leaf area were significantly increased by decreasing the level of node load cm^{-2} TCSA. Therefore, vines pruned to 2 nodes cm^{-2} TCSA resulted in a higher significant values than the other levels; on the contrary, vines pruned to 5 nodes cm^{-2} TCSA gave the lowest average leaf area during the both seasons of study (Table 2).

Leaf mineral content: Reducing node load levels cm^{-2} TCSA of Flame seedless grapevines generally increased the mineral nutrient concentration in leaf petioles during both seasons of the study. It is obvious that treatment of 2 nodes cm^{-2} TCSA increased the content of nitrogen, phosphorus and potassium in leaf petioles significantly than the others; it recorded 2.79 and 2.81% for nitrogen, 0.34 and 0.36% for phosphorus and 1.54 and 1.56% for potassium contents in the two seasons, respectively. While, the treatment of 5 nodes cm^{-2} TCSA diminished the content of nitrogen, phosphorus and potassium in leaf petioles than the others; it recorded 2.37 and 2.39% for nitrogen content, 0.24 and 0.25% for phosphorus content and 1.24 and 1.27% for potassium content in the two seasons, respectively (Table 3).

Table 3: Effect of different node load cm^{-2} trunk cross-sectional area (node cm^{-2} TCSA) on N, P and K leaf content of Flame seedless grapevines during 2009 and 2010 seasons

	N (%)		P (%)		K (%)	
Treatment	2009	2010	2009	2010	2009	2010
2 nodes cm^{-2} TCSA	2.79	2.81	0.34	0.36	1.54	1.56
3 nodes cm^{-2} TCSA	2.51	2.53	0.32	0.33	1.47	1.48
4 nodes cm^{-2} TCSA	2.47	2.49	0.27	0.29	1.39	1.41
5 nodes cm^{-2} TCSA	2.37	2.39	0.24	0.25	1.24	1.27
N-LSD at 5%	0.05	0.04	0.01	0.01	0.02	0.03

Number of clusters per vine and average cluster weight: A positive relationship was found obviously between node load levels cm^{-2} TCSA of grapevines and number of clusters per vine during both seasons of the experiment. Consequently, the level of 2 nodes cm^{-2} TCSA gave the lowest significant effect in this respect; it resulted in 20.67 and 21.00 cluster/vine in the two seasons, respectively. Reversely, the level of 5 nodes cm^{-2} TCSA showed the highest significant effect for this parameter; it resulted in 49.00 and 50.00 cluster/vine in the two seasons, respectively (Table 4).

Regarding to the effect on average cluster weight, the data reveal that vines pruned to 2 nodes cm^{-2} TCSA gave a higher average cluster weight than those obtained under the other node levels cm^{-2} TCSA; it recorded 634.56 and 636.38 g in the two seasons, respectively. While, vines pruned to 5 nodes cm^{-2} TCSA gave a lower average cluster weight than the other node levels cm^{-2} TCSA; hence, it recorded 331.91 and 339.24 g in the two seasons, respectively. Furthermore, vines pruned to 3 nodes cm^{-2} TCSA or 4 nodes cm^{-2} TCSA indicated so closely results in this respect but 3 nodes cm^{-2} TCSA level was higher. Thus, it recorded 591.52 and 593.84 g in the two seasons, respectively (Table 4).

Table 4: Effect of different node load cm^{-2} trunk cross-sectional area (node cm^{-2} TCSA) on number of clnsters and average cluster weight of Flame seedless grapevines during 2009 and 2010 seasons

	Number of clusters per vine		Average cluster weight (g)	
Treatment	2009	2010	2009	2010
2 nodes cm^{-2} TCSA	20.67	21.00	634.56	636.38
3 nodes cm^{-2} TCSA	26.00	26.33	591.52	593.84
4 nodes cm^{-2} TCSA	35.33	35.33	583.57	585.44
5 nodes cm^{-2} TCSA	49.00	50.00	331.91	339.24
N-LSD at 5%	1.31	1.73	1.33	2.15

Yield per vine and per feddan: The fresh grapes yield was affected by using different node load levels per cm^2 TCSA. The highest significant yield was found in vines pruned to level of 4 nodes cm^{-2} TCSA (20.62 and 20.68 kg/vine and 18.86 and 18.93 ton/feddan in both seasons, respectively) followed by 5, 3 and 2 nodes cm^{-2} TCSA, respectively. Also, data showed a positive relationship between yield and node load levels cm^{-2} TCSA for all treatments; nevertheless, 5 nodes cm^{-2} TCSA level gave a lower yield than 4 nodes cm^{-2} TCSA (Table 5).

Table 5: Effect of different node load cm^{-2} trunk cross-sectional area (node cm^{-2} TCSA) on yield of Flame seedless grapevines during 2009 and 2010 seasons

	Total yield/vine (kg)		Estimated yield/feddan (ton)	
Treatment	2009	2010	2009	2010
2 nodes cm^{-2} TCSA	13.11	13.36	12.00	12.23
3 nodes cm^{-2} TCSA	15.38	15.64	14.07	14.31
4 nodes cm^{-2} TCSA	20.62	20.68	18.86	18.93
5 nodes cm^{-2} TCSA	16.26	16.96	14.88	15.52
N-LSD at 5%	0.64	0.90	0.59	0.83

Cluster length and width: Cluster length and width are very important parameters for table grape quality and these parameters were significantly affected from different node load levels cm^{-2} TCSA during both seasons under the study; in particular, level of 2 nodes cm^{-2} TCSA presented higher cluster length and width than the other levels; hence, it presented 26.90 and 26.93 cm for cluster length and 16.00 and 16.17 cm for cluster width in both seasons, respectively. As for level of 5 nodes cm^{-2} TCSA, it presented lower cluster length and width than the other levels; therefore, it presented 21.33 and 21.83 cm for cluster length and 12.83 and 13.00 cm for cluster width in both seasons, respectively (Table 6).

Table 6: Effect of different node load cm^{-2} trunk cross-sectional area (node cm^{-2} TCSA) on cluster length and width of flame seedless grapevines during 2009 and 2010 seasons

	Average cluster length (cm)		Average cluster width (cm)	
Treatment	2009	2010	2009	2010
2 nodes cm^{-2} TCSA	26.90	26.93	16.00	16.17
3 nodes cm^{-2} TCSA	26.00	26.33	15.50	15.67
4 nodes cm^{-2} TCSA	25.17	25.83	15.33	15.40
5 nodes cm^{-2} TCSA	21.33	21.83	12.83	13.00
N-LSD at 5%	0.53	0.54	1.16	0.67

Berry weight and diameter: Different node load levels cm^{-2} TCSA affected significantly the berry weight and diameter of Flame seedless grapes. The highest values of berry weight and diameter were obtained from vines pruned to a level of 2 nodes cm^{-2} TCSA followed by a slight decrease at the vines pruned to levels of 3 and 4 nodes cm^{-2} TCSA, respectively. On the other hand, vines pruned to a level of 5 nodes cm^{-2} TCSA induced lower values in this respect during both seasons of this experiment (Table 7).

Table 7: Effect of different node load cm^{-2} trunk cross-sectional area (node cm^{-2} TCSA) on berry weight and diameter of flame seedless clnsters during 2009 and 2010 seasons

	Average berry weight (g)		Average berry diameter (mm)	
Treatment	2009	2010	2009	2010
2 nodes cm^{-2} TCSA	4.10	4.25	19.00	19.37
3 nodes cm^{-2} TCSA	3.59	3.60	18.12	18.13
4 nodes cm^{-2} TCSA	3.21	3.41	17.12	17.82
5 nodes cm^{-2} TCSA	2.53	2.60	15.32	15.73
N-LSD at 5%	0.45	0.16	0.59	0.37

Soluble solids content (SSC%), titratable acidity and SSC/acid ratio: The obtained data on SSC% obvious that vines pruned to level of 2 nodes cm^{-2} TCSA increased the value of SSC significantly than the other treatments followed by a slight decrease in the case of vines pruned to a level of 3 nodes cm^{-2} TCSA during both seasons of the experiment. The data also revealed that vines pruned to a level of 4 nodes cm^{-2} TCSA diminished the value of SSC% significantly followed by the vines pruned to a level of 5 nodes cm^{-2} TCSA which presented the lowest value in this respect. Regarding to the effect of different treatments on titratable acidity, data indicated that titratable acidity gave an opposite trend to that noticed with soluble solids content. Accordingly, leaving 2 nodes cm^{-2} TCSA of grapevines showed a lower titratable acidity in berry juice in comparison with the other node load levels cm^{-2} TCSA; in contrast, leaving 5 nodes cm^{-2} TCSA occurred in a higher titratable acidity in berry juice compared to the other node levels cm^{-2} TCSA during both seasons. Finally, the values of SSC/acid ratio gave a similar trend to that noticed with the percentages of soluble solids content; therefore, leaving 2 nodes cm^{-2} TCSA gave a higher SSC/acid ratio than 3 or 4 nodes cm^{-2} TCSA of Flame seedless grapevines. Whereas, vines pruned to level of 5 nodes cm^{-2} TCSA showed a lower value of SSC/acid ratio than the other pruning severity during both seasons of the experiment (Table 8).

Table 8: Effect of different node load cm^{-2} trunk cross-sectional area (node cm^{-2} TCSA) on solid titratable acidity and solid/acid ratio of berry Juice of Flame seedless clusters during 2009 and 2010 seasons

	Soluble solids concentration (SSC%)		Titratable acidity (%)		SSC/acid ratio	
Treatment	2009	2010	2009	2010	2009	2010
2 nodes cm^{-2} TCSA	16.64	16.89	0.51	0.53	32.61	31.77
3 nodes cm^{-2} TCSA	16.33	16.57	0.57	0.57	28.65	28.87
4 nodes cm^{-2} TCSA	15.77	15.27	0.64	0.67	24.65	22.67
5 nodes cm^{-2} TCSA	14.06	14.15	0.94	0.99	15.04	14.60
N-LSD at 5%	0.75	0.16	0.03	0.01	1.73	0.64

Anthocyanin content in berry skin: Different node load levels cm^{-2} TCSA affected significantly anthocyanin content in berry skin; indeed, vines pruned to the level of 2 nodes cm^{-2} TCSA showed the highest significant effect in this parameter followed by the levels of 3 and 4 nodes cm^{-2} TCSA; on the contrary, the level of 5 nodes cm^{-2} TCSA presented a sharply decreased about this parameter during the both seasons of the experiment (Table 9).

Total carbohydrates in the canes: Total carbohydrates content in the cane at dormant period was significantly decreased by increasing node load cm^{-2} TCSA of vines. In this connection, vines which were pruned to the level of 2 nodes cm^{-2} TCSA appeared to assimilate and store higher carbohydrates content than the other ones pruned to the level of 5 nodes cm^{-2} TCSA which was recorded lower carbohydrates content during the two seasons of the investigation. Furthermore, vines pruned to the levels of 3 and 4 nodes cm^{-2} TCSA stored the minimum level of carbohydrates, but vines pruned to the level of 3 nodes cm^{-2} TCSA stored higher carbohydrates content than the level of 4 nodes cm^{-2} TCSA during the two seasons of the experiment (Table 9).

Table 9: Effect of different node load cm^{-2} trunk cross-sectional area (node cm^{-2} TCSA) on anthocyanin content in berry skin and total carbohydrates in the canes of Flame seedless grapevines during 2009 and 2010 seasons

	Anthocyanin (mg/100 g fresh weight)		Total carbohydrates (g/100 g dry weight)	
Treatment	2009	2010	2009	2010
2 nodes cm^{-2} TCSA	85.65	85.76	23.99	24.08
3 nodes cm^{-2} TCSA	83.37	84.41	22.08	22.15
4 nodes cm^{-2} TCSA	79.88	79.92	20.77	20.85
5 nodes cm^{-2} TCSA	45.47	45.46	19.96	20.04
N-LSD at 5%	1.75	1.19	0.06	0.056

DISCUSSION

Node load cm^{-2} TCSA had a very good effect on Flame seedless grapevine performance and fruit quality in this experiment.

A significant decrease in bud burst, bud fertility and fruitfulness percentages occurred with an increase in node load cm^{-2} TCSA of Flame seedless grapevines from 2-5 nodes/TCSA cm^{2}. These results confirm those of Archer and Fouche (1987), Rizk *et al.* (2006) and Fawzi *et al.* (2010) for other grape cultivars. Concerning the data of bud burst percentage, such decrease in the percentage might be due to an effect caused by increasing node load cm^{-2} TCSA; as a result, increasing the number of nodes per vine lead to an increase in dormant nodes and that coincides with results obtained by Chritensen *et al.* (1994), Reynolds *et al.* (1994) and Omar and Abdel-Kawi (2000) who found that increasing bud load induced lower percentage of bud burst.

Bud fertility and fruitfulness percentages generally decreased as the node load cm^{-2} TCSA of Flame seedless grapevines and the bud burst percentage increased. That is may be due to the positive relationship between bud burst percentage and shoot number per vine which lead to an unfavorable microclimate condition caused by a higher canopy density at a higher bud load (Archer and Fouche, 1987). The bud fertility and fruitfulness percentages in the different treatments were in the range of 74.59-50.40% and 80.95-51.16% for bud fertility percentage and 93.08-53.20% and 96.69-54.80% for fruitfulness percentage at the two seasons, respectively (Table 1). These values of bud fertility and fruitfulness are close to those reported for some grapes cultivars (Morris and Cawthon, 1980; Salem *et al.*, 1997; El-Kady *et al.*, 2010). However, the current results are in agreement with those reported by Fawzi *et al.* (2010) who found that grapevines which have high growth get low fruitfulness, whereas the moderated vigor ones are usually more fruitful. In addition, getting light into the canopy helps form fruitful buds for the following year which rarely happened with the high node load cm^{-2} TCSA; therefore, the greater leaf densities which obtained at a higher bud load decreased photosynthetic efficiency of grapevine. Highly shaded leaves can actually result in a net carbon loss, as the rate of respiration can be greater than the carbon fixed through photosynthesis (Jackson, 2000). In addition, shoots developing on exposed canes are generally more fruitful and exhibit better vegetative growth than shoots on shaded canes (Kliewer, 1981).

Internode length and thickness correlated with different node load levels cm^{-2} TCSA negatively (Table 1) that is may be due to decreasing node load levels cm^{-2} TCSA of vines are apt to produce excessively vigorous shoots because all of the stored energy in the trunks and roots is available to relatively few growing points. Hence, the increasing of node load levels cm^{-2} TCSA significantly decreased the values in this respect. This negative relationship was also found by Coban and Kara (2002) who mentioned that increasing bud load has a negative effect on vegetative growth in Round seedless cultivar. Also, Shoeib (2004) reported that increasing vine load levels from 72-108 buds per vine caused a significant reduction in shoot length of Thompson seedless grapevines. Furthermore, the obtained data was in the same line with Hegazi (1985) and El-Kady *et al.* (2010) who found that cane thickness was decreased with increasing the number of nodes per vine.

Average of leaf area during the both seasons of this experiment was adversely affected by node load levels cm^{-2} TCSA (Table 2). A similar response of pruning severity levels was referred by Abdel-Wahab (1997) who found that the leaf area was affected by cane length; consequently, leaf area was increased by decreasing the number of nodes per cane of King Ruby grapes.

The trend in the mineral nutrient concentration of the leaf petioles under different treatments is quite distinct (Table 3). The maximum Nitrogen, phosphorus and potassium were in leaf petioles of the lowest node load level cm^{-2} TCSA, indicating that the light node load enables the vines to accumulate these nutrient elements in greater quantities in the leaf petioles. Conversely, the vines with a high node load level and maximum number of clusters (Table 4) had much lower concentration of these elements (Balasurbrahmanyam *et al.*, 1978), especially phosphorus which shows the significant role of this element in the physiology of blooming, since this parameter was estimated at full bloom stage in leaf petioles. In this respect, Shoeib (2004) cleared that there was a gradual and significant reduction in percentage of N in leaf petioles of Thompson seedless grape with increasing vine load levels from 72-108 buds/vine. Furthermore, DeJong and Doyle (1985) reported that nitrogen correlate positively with photosynthetic capacity, presumably because of a greater incorporation of nitrogen into leaf cellular proteins such as ribulose bisphosphate carboxylase under high light. Since the photosynthetic capacity of grape leaves is influenced by light environment (Kriedemann, 1968), my results may indicate that N is allocated preferentially to the more exposed leaves which appeared at the lowest node lode level cm^{-2} TCSA of Flame Seedless grapevines which will optimize whole-vine photosynthesis.

The number of clusters per vine generally increased with the increment of node load levels cm^{-2} TCSA; conversely, average cluster weight was reduced (Table 4). Several studies have reported positive relationships between number of clusters and node load levels per vine and negative relationships between average cluster weight and node load levels per vine in different grape cultivars (Miller and Howell, 1997; Omar and Abdel-Kawi, 2000; Ali *et al.*, 2000). However, El-Kady *et al.* (2010) found that the number of clusters was increased by increasing the number of nodes per vine; therefore, cluster weight was reduced by increasing the bud load. Also, Mahfouz (2007) mentioned that average cluster weight was almost higher from vines which leaving 60 eyes than those obtained from leaving 80 eyes/vine in Red Roumi grape.

The estimated yield per vine or feddan showed increases from level of 2 nodes through to the 4 nodes cm^{-2} TCSA and thereafter, declined at level of 5 nodes cm^{-2} TCSA (Table 5). This is possibly due the severe reduction of average cluster weight referred to the increment of clusters number per vine at level of 5 nodes cm^{-2} TCSA (Table 4). In this respect, Soliman (2004) mentioned that both yield per vine and per feddan was increased by increasing bud load per vine. Since, leaving 8 canes with 14 eyes resulted in higher yield per vine and per feddan than leaving 10 or 12 eyes/cane. Also, Keller *et al.* (2004) found that grape yield is generally correlated positively with the number of nodes retained at pruning and number of clusters per shoot. So, leaving 130 nodes/vine yielded considerably less than 260 nodes/vine.

A negative relationship between Cluster length and/or width and node load levels cm^{-2} TCSA was obtained for all treatments (Table 6), for lower node levels cm^{-2} TCSA resulted in well-exposed shoots which leads to the well-exposed clusters of spray solutions; specially, gibberellic acid (GA3) solution which makes the clusters elongate so they are not as crowded and the grapes will grow larger (Korkutal *et al*., 2008). Conversely, the higher node levels cm^{-2} TCSA resulted in shaded shoots and clusters which showed an opposite effect in this respect. Moreover, Relationships between shoot vegetative characteristics and fruit productivity may thus reflect differences in light exposure and the ability of leaves to supply assimilates to developing clusters as suggested in 'Cabernet Sauvignon' Grapevines (Bowen and Kliewer, 1990).

A general tendency for berry weight and diameter to decrease with increasing node levels cm^{-2} TCSA was evident (Table 7). From the results it seems that differences in berry weight and diameter between different treatments could partly be explained by reductions in berry development on shoots exposed to low light (Kliewer and Antcliff, 1970; May and Antcliff, 1963; Morgan *et al*., 1985). And that was obviously happened with the vines pruned to the highest node levels cm^{-2} TCSA. However, the data resulted in this respect are in harmony with El-Kady *et al.* (2010) who found that berry weight and size were significantly increased when vines pruned to 40 eye/vine than leaving 60 eye/vine in Flame Seedless grapevines.

It is clear that an increase in the node load levels cm^{-2} TCSA reduced the average leaf area available to ripen the grapes (Table 2) and this is partly explains the decrease in Soluble Solids Content (SSC%) and increase in titratable acidity which occurred with an increase in the node load levels cm^{-2} TCSA (Table 8) (Archer and Fouche, 1987). Furthermore, Howell and Strieglar (1998) found a significant increase in soluble solids content with pruning vines to short compared with long cane pruning; likewise, Fawzi *et al.* (2010) reported that soluble solids content was reduced by increasing the number of nodes per cane of Crimson Seedless grapes. Conversely, Morris *et al.* (1985) found that pruning severity (70+10) nodes gave a higher titratable acidity in berry juice of Concord grapes than (30+10) nodes; in addition, Rizk *et al.* (2006) mentioned that when the number of nodes per vines increased titratable acidity in berry juice was increased. The reduction in SSC/acid ratio attributed to the increment of the node load levels cm^{-2} TCSA (Table 8) may be due to the negative relationship between soluble solids content percentages and node load levels cm^{-2} TCSA versus positive correlation between titratable acidity percentages and node load levels cm^{-2} TCSA and these results go in line with El-Kady *et al.* (2010) who mentioned that leaving 40 eye/vine showed a higher values of SSC/acid ratio than leaving 60 eye/vine in Flame Seedless grapevines; similarly, Samra (2001) found that values of SSC/acid ratio were reduced by increasing the number of nodes per cane.

A negative relationship was found between different node load levels cm^{-2} TCSA and anthocyanin content in berry skin (Table 9); hence, leaving 2 nodes cm^{-2} TCSA gave the highest values for this parameter, but leaving 5 nodes cm^{-2} TCSA gave the lowest values in this respect; therefore, when the fruit load on the grapevine increases, the skin color of the berries changes slowly. This is caused by a low integration of sugar (Jackson, 1986); an appropriate fruit load is important for maintaining high fruit quality. Furthermore, shading of clusters which was clearly observed at vines with high node levels cm^{-2} TCSA reduced anthocyanin concentration, especially in red cultivars (Spayd *et al*., 2002); likewise, Downey *et al.* (2004) reported that low light generally reduced anthocyanins and other flavonoids while increased light results in increased flavonoid content. Moreover, Keller *et al.* (2004) reported that fruits of 130 nodes/vine accumulated sugar and color more rapidly than fruits on 260 nodes/vine treatment; also, Mahfouz (2007) mentioned that the values of anthocyanin in berry skin of Red Roumi grape was almost higher under leaving 60 eyes/vine than those obtained from leaving 80 eyes/vine.

Differences in the carbohydrate reserves in the canes in various node load levels cm^{-2} TCSA treatments were relatively small; a decrease in carbohydrate accumulation with the increase in node load was discernible (Table 9). The results obtained in the present investigation were in general agreement with those of Weaver *et al.* (1957) and Weaver and Mccune (1960); while the investigations carried out by the authors cited above did not include as many different node load levels as in the investigation presented here, the tendency in all cases was for vines with a heavy node load to store comparatively smaller amounts of carbohydrates in canes than vines with a light node load that was within the capacity of the vines. This is because vines expend carbohydrates on the ripening of cluster (Balasurbrahmanyam *et al.*, 1978).

In conclusion, the grape quality was quite high for the levels of 2, 3 and 4 nodes cm^{-2} TCSA of Flame Seedless grapevines therefore the decision upon node load and pruning system is strictly dependent on a vine grower's (vineyardists) strategy of grape quantity/quality ratio at harvest. Satisfactory yield and SSC/acid ratio of cultivar Flame Seedless could be obtained with the level of 3 nodes cm^{-2} TCSA or even slightly lower node load at Double t-type.

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