SVU-IJAS SVU-International Journal of Agricultural Sciences
Volume 3 Issue (4) pp.: 233-249, 2021
Print ISSN 2636-3801 | Online ISSN 2636-381X
Doi: 10.21608/svuijas.2021.107191.1157

RESEARCH ARTICLE

Effect of relationship between planting distance and load of buds on bud behavior, vegetative growth, yield, canopy microclimate and fruit quality of Flame seedless grapevines

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Abstract

This experiment was carry out for two successive seasons on Flame seedless grapevines (2019 & 2020) in vineyard of EL-Baramon experimental farm, Horticultural Research Institute, Mansoura, Egypt. The target of this present study was identify the optimum planting distance and number of buds which must be left per square meter to gain the best results with respect to bud behavior, characteristics of vegetative growth , yield**,** canopy microclimate and quality of berries. The vines were planted under three different levels of planting distances (1.5 x 3m & 2 x 3m and 2.5 x 3m) and were loaded at three different levels of buds load (8 &10 and12 buds/ m^2). Results showed that all studied characteristics were significantly affected with planting distance and load of buds. Increasing planting distance from (1.5m×3m) to (2.5m×3m) was accompanied with an improve in vegetative growth parameters, nutritional status, yield/vine, microclimatic data and chemical properties in berries, while decreased bud burst%, cluster and berry weight yield/ feddan. Also, increase load of buds /vine from (8 buds/ m^2) to (12 buds/ m^2) was accompanied by an increase in yield/vines and feddan, while negatively effected on bud burst%, vegetative growth parameters, microclimatic data, chemical properties in berries and total carbohydrates in cans.It could be suggested that planting Flame seedless grapevines at planting distance (2.5mx3m) or (2mx3m) with retained (8buds/m^2) were considered the most optimum treatment for improving vines nutritional status, vegetative growth characteristics, microclimatic data and quality of berries.

Keywords: Buds load; Canopy microclimate; Berry quality; Flame seedless; Grape

1. Introduction

Grape (*vitis vinifera L.*) is considered as one of the major important fruits for domestic consumption and export due to it's a superb flavour, lovely taste and high nutritional content. It is high in minerals such as calcium, phosphorus and iron, as well as vitamins like B1 and B2. Its juice is a slight laxative and make as a stimulant to kidneys Kumar (2017). Flame seedless grapevines is count one of the major important cultivars and early in Egypt.

Cultivation density or the number of vines per feddan and their arrangement between and within rows is the only vineyard yield component that is determined at planting and remains unchanged for the life period of most vineyards. It effect on other yield components, such as the number of buds, shoots and clusters per vine, also influence the number of berries per cluster, and berry weight and quality (Keller *et al.*, 2004; Reynolds and Vanden, 2009; Keller and Mills, 2021). Therefore, the choice of planting distance is considered a key decision and important for grape growers to make before vineyard establishment Keller and Mills (2021)

Wolpert (2001) found that vegetative growth and yield per vine were depended on load of buds and vines spacing, also berries ripeness depended on load of buds, which soluble solids content were higher at load 6 buds per square meter, but decreased below 23 °Brix at higher buds load. Increase of

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Received: November 21, 2021; Accepted: December 25, 2021; Published online: December 26, 2021.

vines distance (3meter between rows and 1–1,5 meter between plants) resulted in vines that are more vigorous and high production also, the large square of spacing allows increased in shoot length (Mayborodin, 2016). It was shown that there is a positive relationship between exposed leaf area and the concentration of sugars, anthocyanins, and phenolic compounds found in grape berries (Jackson, 2008; Reynolds and Vanden, 2009). According to Justine *et al.* (2013) who reported that yield per meter of ‘Noiret’ wine grape increased as a result of increasing vines spacing from 1.2 to 2.4 m. Winter pruning (buds load) is considered one of the most essential horticultural operations in the management of grapevines to maintain productivity. It is a practice aimed to increasing grape yield and improving cluster quality. (Khamis *et al.*, 2017; Abo-ELwafa, 2018; Bassiony, 2020). The vines should be carry moderate number of buds to keep the good vigor throughout its life period Khamis *et al.* (2017).

Many of the previous investigation interested in working on buds load and adjusting the length of fruiting spurs in winter pruning with neglecting the planting distance between the vines. Therefore, the aim of this present study identify the optimum planting distance and number of buds which must be left per meter square under support with Spanish baron system and effect that on the bud behavior, characteristics of vegetative growth and yield, and canopy microclimate and quality of berries of Flame seedless cultivar.

2. Materials and methods

This experiment was conducted during two successive seasons (2019 & 2020) in vineyard of El- Baramon experimental farm, Horticultural Research Institute, Mansoura, Egypt. Eighty one grapevines, 5-years-old of Flame seedless grapevines cultivar grafted on freedom rootstock were selected for this investigation. The vines were regularly in vigor as possible and grown in a clay soil with surface irrigation system. The vines were planted under three different levels of planting distances (1.5 x 3m& 2 x 3m and 2.5 x 3m) and were loaded under three different levels of buds load (8& 10 and12 buds/ m^2) under trained with quadrilateral cordon trellis system with supported by Spanish baron system, all vines received the same cultural management recommended by ministry of agriculture, such as fertilization, irrigation, diseases and pests resistant. The experiment was comprised of nine treatments arranged in a randomized completely block design, each treatment was replicated 3 times and each replicate included 3 vines.

2.1. The experiment included the following treatments

1- Planting distance (1.5 m x 3 m) + 8 buds/m^2 (36 buds/vine)
2- Planting distance (1.5 m x 3 m) + 10 buds /m^2 (45 buds/vine)
3- Planting distance (1.5 m x 3 m) +12 buds /m^2 (54 buds/vine)
4- Planting distance (2 m x 3 m) + 8 buds / m^2 (48 buds/vine)
5- Planting distance (2 m x 3 m) + 10 buds / m^2 (60 buds/vine)
6- Planting distance (2 m x 3 m) + 12 buds / m^2 (72 buds/vine)
7- Planting distance (2.5 m x 3 m) + 8 buds / m^2 (60 buds/vine)
8- Planting distance (2.5 m x 3 m) + 10 buds / m^2 (75 buds/vine)
9- Planting distance (2.5 m x 3 m) + 12 buds / m^2 (90 buds/vine)

2.2. The following characteristics were determined

2.2.1. Bud behavior

Bursted buds number was counted one month after bud burst and the percentage of bud burst %, coefficient of bud fertility and fruiting coefficient were calculated according to **Bessis (1960)** as the following:

- Bud burst % = $\frac{\text{No of bursted buds per vine}}{\text{No of total buds left at winter pruning}}$ x100
- Coefficient of bud fertility = $\frac{\text{No of clusters per vine}}{\text{No of total buds left at winter pruning}}$
- Fruiting coefficient = $\frac{\text{No of clusters per vine}}{\text{No of bursted buds per vine}}$

2.2.2. Vegetative growth parameters (shoot length and leaf surface area) and Total chlorophyll content in the leaves

The vegetative growth parameters were evaluated from non-fruiting shoots at full bloom. The evaluated parameters included average shoot length (cm), leaf surface area (cm^2) according to Montero *et al.* (2000) and total chlorophyll content in the leaves (mg/g F.w.) according to the method were described by Mackinny (1941).

2.2.3. N, P and K content in leaf petioles

At full bloom, samples of 20 leaf petioles per each replicate were taken from leaves opposite to cluster were used for the determination of N, P and K content as mentioned by **Cottenie *et al.* (1982).**

2.2.4. Yield and its components

A representative sample of 6 clusters /vine was taken at harvest for the following measurement average cluster weight (g), yield/vine (Kg), yield/ feddan (ton), average of 100 berry weight (g) and volume (cm^3).

2.2.5. Microclimatic data

Microclimate data of the vines canopy (light intensity and air temperature) were estimated by Scheduler plant stress monitor Model R/O Consuitant made by Standard oil company, U.S.A. These parameters were recorded weekly at the clusters zone during the growing period from veraison stage to the harvest to determine the average of light intensity (watt/m^2) and air temperature (ºC) for vines canopy according to Ghada (2015).

2.2.6. Chemical properties of berries

A representative sample of 6 clusters/ vine was taken to determine. Soluble solids content (SSC 0Brix) by using hand refractometer.Total acidity percentage (g tartaric acid/100 ml juice) according to A.O.A.C. (1980).Total sugars (%) were estimated on the method described by Sadasivam and Manickam (1996)Total anthocyanin of the berry skin (mg/100g fresh weight) was calculated according to Husia *et al.* (1965).

2.2.7. At dormant season's parameters

Coefficient of wood ripening was calculated according to Rizk and Rizk (1994). Total carbohydrates in canes (gm/100gm d.w) were estimated according to Hodge and Hofreiter (1962) and pruning wood weight was recorded as (Kg/vine).

2.3. Statistical Analysis

The factorial randomized complete block design was adopted for this experiment. The statistical analysis of the present data was carried out according to Snedecor and Cochran (1980). Averages were compared using the new L.S.D. values at 5% level (Steel and Torrie, 1980).

3. Results and discussion

3.1. Bud behavior

Data in Table (1) clearly displayed that planting Flame seedless grapevines at distance (1.5m×3m) gave the highest significant values of bud burst percentage (89.20 and 93.50%), coefficient of bud fertility (0.60 and 0.64), and fruiting coefficient (0.68 and 0.69) in both seasons, respectively, as compared with the vines which were planted at distance (2m×3m) and (2.5m×3m). On the other hand, planting the vines at distance (2.5m×3m), recorded the lowest significant values of bud burst percentage (83.10 and 88.00 %), coefficient of bud fertility (0.51 and 0.55) and fruiting coefficient (0.62 and 0.62) during the two seasons, respectively.

With respect to the effect of buds number/ m^2, there was a gradual and significant reduction in the percentage of bud burst percentage, coefficient of bud fertility and fruiting coefficient as a result of increasing buds load from 8 buds/m^2 to 10 buds / m^2 or 12 buds/m^2, the vines which were loaded at level (8 buds/ m^2) gave the highest significant values of bud burst percentage (89.50 a and 94.90%), coefficient of bud fertility (0.61 and 0.65) and fruiting coefficient (0.68 and 0.68) as compared with the vines which were loaded at level (10 and 12 buds/ m^2) in both seasons respectively, on the other hand, the vines which were loaded at level (12 buds/ m^2) recorded the lowest significant values for bud burst percentage (83.50 and 87.10 %), coefficient of bud fertility (0.51 and 0.55) and fruiting coefficient (0.62 and 0.63) in both seasons respectively. The data also show non-significant differences between the vines which were loaded at level (10 buds/ m^2) and (12 buds/ m^2) on bud burst in the first season only. In general, increasing bud burst percentage was accompanying on increasing on coefficient of bud fertility and fruiting coefficient. Regarding to the effect of interaction between planting distance and buds number/ m^2, data in the same table indicate that the vines which were planted at distance (1.5m×3m) in combine with (8 buds/m^2) (A1×B1) gave the highest significant values on bud burst percentage (91.70 and 97.20%), coefficient of bud fertility (0.64 and 0.69), and fruiting coefficient (0.70 and 0.70) as compared with other treatments in in both seasons respectively, while the vines which were planted at distance (2.5mx3m) with (12 buds/m^2) (A3×B3) gave the lowest significant values of bud burst percentage (80.0 and 84.40%), coefficient of bud fertility (0.46 and 0.48), and fruiting coefficient (0.57 and 0.57) in both seasons, respectively.

Table 1. Effect of planting distance and load of buds per square meter on the percent of bud burst, coefficient of bud fertility and fruiting coefficient of Flame seedless grapevines during 2019 and 2020 seasons.

Treatments		Characteristics	bud burst%		coefficient of bud fertility		fruiting coefficient	
			2019	2020	2019	2020	2019	2020
planting distance /m (A)		1.5 m X 3m (A1)	89.20	93.50	0.60	0.64	0.68	0.69
		2m X 3m (A2)	86.20	90.70	0.56	0.61	0.65	0.67
		2.5 m X 3m (A3)	83.10	88.00	0.51	0.55	0.62	0.62
New LSD at 5%			2.40	1.60	0.02	0.02	0.02	0.02
No. of buds/ m^2 (B)		8 (B1)	89.50	94.90	0.61	0.65	0.68	0.68
		10 (B2)	85.50	90.20	0.58	0.60	0.65	0.66
		12 (B3)	83.50	87.10	0.51	0.55	0.62	0.63
New LSD at 5%			2.40	1.60	0.02	0.02	0.02	0.02
Interaction (A x B)	A1	B1	91.70	97.20	0.64	0.69	0.70	0.70
		B2	88.90	92.60	0.60	0.63	0.68	0.68
		B3	87.00	90.70	0.57	0.61	0.66	0.67
	A2	B1	90.30	95.80	0.60	0.65	0.67	0.67
		B2	85.00	90.00	0.57	0.62	0.67	0.69
		B3	83.33	86.10	0.51	0.56	0.62	0.65
	A3	B1	86.70	91.70	0.58	0.62	0.67	0.67
		B2	82.70	88	0.51	0.55	0.61	0.62
		B3	80.00	84.40	0.46	0.48	0.57	0.57
New LSD at 5%			4.20	2.80	0.03	0.03	0.03	0.03

The data also show non- significant differences between the vines which were planted at distance (1.5mx3m) with (10 buds/ m^2) (A1×B2) and the vines which were planted at distance (1.5mx3 m) with (12 buds/m^2)) (A1×B3) in this regard except coefficient of bud fertility in the first season only gave significant differences also, non-significant was noticed between the vines which were planted at distance (2mx3m) with (8 buds/m^2) (A2×B1) and the vines which were planted at distance (2.5 m x 3 m) with (8 buds/m^2) (A3×B1) in this concern except bud burst percentage and coefficient of bud fertility in the second season only gave significant differences.These results are in harmony with (Ahmad *et al.,* 2004; Sánchez and Dokoozlian, 2005; Arora and Gill, 2009; Călugăr *et al.,* 2010; El-Kady *et al.,* 2010; Fawzi *et al.,* 2010; Abdel-Mohsen, 2013; Porika *et al.,* 2015; Ali and Moumen, 2016; Abo-ELwafa, 2018). In addition, Bassiony (2020) observed that the highest percentages of bud burst and fertility were recorded when the vines pruned at (20 buds load level) as compared with (30 and 40 buds load level) of Flame seedless grapevine.

3.2. *Vegetative growth parameters (shoot length and leaf surface area, as well as total chlorophyll content in the leaves*

It is clear from the data in Table (2) that vegetative growth parameters such as shoot length and leaf surface area, as well as total chlorophyll in leaves were significantly increased by increasing the planting distance from (1.5m×3m) to (2m×3m) or (2.5m×3m) in both seasons, the vines which were planted at distance (2.5m×3m) had significant effect in this respect as compared with (1.5m×3m) and (2m×3m), which gave the highest significant values on shoot length (165 and 171cm), leaf surface area (147 and 154 cm^2), and total chlorophyll in leaves (7.78 and 8.20 mg\g F.W) in both seasons, respectively, followed by the vines which were planted at distance (2m×3m), while the vines which were planted at distance (1.5m×3m) recorded the lowest significant values in this respect, which gave (147and 158 cm) for shoot length, (133 and 145 cm^2) for leaf area and (7.13 and 7.54 mg\g F.W) for total chlorophyll in leaves during the two seasons, respectively.

With respect to the effect of buds number/m^2, data in the same table show that change the number of buds /m^2 had pronounced and significant effect on shoot length, leaf surface area and total chlorophyll in leaves. Increasing buds load from (8 buds/ m^2) to (10 or 12 buds/m^2) was significantly accompanied with reduction in main shoot length, leaf surface area and total chlorophyll in leaves. The vines which were loaded with (8 buds /m^2) gave the highest significant values in shoot length (165 and 173cm), leaf surface area (149and 159 cm^2), and total chlorophyll in leaves (8.24 and 8.52 mg\g F.W), while the vines which were loaded with (12 buds /m^2) gave the lowest significant values in shoot length (147 and 156 cm), leaf surface area (131and 139 cm^2), and total chlorophyll in leaves (6.68 and 7.22 mg\g F.W) in both seasons, respectively. Increasing buds load from (8 buds/ m^2) to (10 buds/m^2) or (12 buds/ m^2) was accompanied with decreasing shoot length and leaf surface area this may be attributed to the competition between the shoots in the treatments of high bud loads on nutrients content.

Concerning the effect of interaction between planting distance and buds number /m^2, data in the same table confirm that the vines which were planted at distance (2.5m×3m) in combine with (8 buds/m^2) (A3×B1) recorded the highest significant values in shoot length (172 and 180 cm), leaf surface area (158 and 166 cm^2), and total chlorophyll in leaves (8.46 and 8.74 mg\g F.W) followed by the vines which were planted at space (2m×3m) plus (8buds/m^2) (A2×B1),while the vines which were planted at space (1.5mx3m), plus (12 buds/m^2) (A1×B3) recorded the lowest significant shoot length (138 and 147cm), leaf area (126 and 132 cm^2), and total chlorophyll in leaves (6.37 and 6.87 mg\g F.W) respectively, in the both seasons of study. Also, data indicated significant differences between most of treatments on studied characteristics during the two seasons.

The positive effect of light or moderate buds load/ vine on improving vegetative growth parameters may be due to reduce the competition among the shoots, promote bursting of laterals buds, growth and leaf elongation. Bassiony (2020).

These findings are in agreement with those obtained by (Nikov and Pondov, 1981; Wolpert, 2001; Awad, 2003; Ali and Moumen, 2016; Khamis *et al.*, 2017; Abo-ELwafa, 2018; Bassiony, 2020).

Table 2. Effect of planting distance and load of buds per square meter on shoot length, leaf surface area and total chlorophyll in leaves of Flame seedless grapevines during 2019 and 2020 seasons

Treatments		Characteristics	Shoot length (cm)		Leaf surface area (cm^2)		Total chlorophyll (mg\g F.W)	
			2019	2020	2019	2020	2019	2020
planting distance /m (A)		1.5 m X 3m (A1)	147	158	133	145	7.13	7.54
		2m X 3m (A2)	154	163	138	147	7.56	7.96
		2.5 m X 3m (A3)	165	171	147	154	7.78	8.20
New LSD at 5%			2.0	3.0	2.0	2.0	0.11	0.08
No. of buds/ m^2 (B)		8 (B1)	165	173	149	159	8.24	8.52
		10 (B2)	155	163	138	147	7.54	7.96
		12 (B3)	147	156	131	139	6.68	7.22
New LSD at 5%			2.0	3.0	2.0	2.0	0.11	0.08
Interaction (A x B)	A1	B1	156	166	140	154	7.86	8.16
		B2	148	160	134	148	7.14	7.6
		B3	138	147	126	132	6.37	6.87
	A2	B1	166	172	148	158	8.40	8.68
		B2	152	160	136	143	7.59	7.86
		B3	145	156	130	140	6.67	7.32
	A3	B1	172	180	158	166	8.46	8.74
		B2	164	169	144	150	7.89	8.42
		B3	158	165	138	145	6.98	7.46
New LSD at 5%			4.0	5.0	3.0	4.0	0.19	0.15

3.3. N, P and K content in leaf petioles

Data obtained from Table (3) show that planting Flame seedless grapevines at distance (2.5m×3m) gave the highest significant values of total N, P and K content in leaf petioles, which recorded (2.30 and 2.26%) for N, (0.25 and 0.25 %) for P and (1.62 and 1.57 %) for K in both seasons respectively, followed by the vines which were planted at distance (2 m×3m) and non-significant differences between of them except total P which gave a significant differences in the second season only. Also, non-significant differences were observed among the three various planting distance (1.5m×3 m), (2m×3 m) and (2.5m×3 m) on P content in the first season. On the other hand, the vines which were planted at distance (1.5m×3 m), recorded the lowest significant values in this respect which recorded (2.18 and 2.07 %) for N, (0.24 and 0.23 %) for P and (1.57 and 1.50) for K in both seasons, respectively,

With respect to the effect of buds number/m^2 on N, P and K content in leaf petioles, data presented in the same table revealed statistically significant differences due to various levels, the vines which were loaded at level (8 buds/m^2) gave the highest significant values in total N, P and K content in leaf petioles, which recorded (2.76 and 2.67%) for N, (0.31 and 0.29 %) for P and (1.81 and 1.77 %) for K, followed by the vines which were loaded at (10 buds/m^2) in both seasons, respectively. On other contrary, the vines which were loaded with (12buds/m^2) recorded the lowest significant values, which gave (1.79 and 1.77 %) for N, (0.20 and 0.20) for P and (1.39 and 1.34) for K in both seasons, respectively. Generally, gradual increasing of buds load from (8 buds/m^2) to (10 buds/m^2 or 12 buds /m^2) led to a significant and gradual decreasing on total N, P and K content in leaf petioles in both seasons.

As regarding to the interaction between planting distance and of buds number /m^2, data in the same table proved that the highest significant percentage of nitrogen, phosphorous and potassium were obtained when the vines were planted at distance (2.5mx3m) in combine with (8 buds/m^2) (A3×B1), which gave (2.83 and 2.78%) for N, (0.31 and 0.30 %) for P and (1.84 and 1.82 %) for K in both seasons, respectively, followed by the vines which were planted at distance (2mx3m) with (8 buds/m^2) (A2×B1) then the vines which were planted at distance (1.5mx 3m) plus (8 buds /m^2) (A1×B1) and non-significant differences between (A2×B1) and (A1×B1) except nitrogen in the first season only gave significant effect also, the data showed non-significant differences between the vines which were planted at distance (2mx3m) plus 10 buds/m^2 (A2×B2) and (2.5mx3m) plus (10 buds/ m^2) (A3×B2) except nitrogen in the first season only gave significant effect as well as between the vines which were planted at distance (2mx3m) plus (12 buds/ m^2) (A2×B3) and (2.5mx3m) plus (12 buds / m^2) (A3×B3) On the other hand, the vines which were planted at distance (1.5m×3 m) with (12 buds /m^2) (A1×B3) recorded the lowest significant values in this respect which recorded (1.72and 1.68 %) for N, (0.19 and 0.19 %) for P and (1.36 and 1.30%) for K in both seasons of study respectively.

Table 3. Effect of planting distance and load of buds per square meter on leaf content of N, P and K of Flame seedless grapevines during 2019 and 2020 seasons.

Treatments		Characteristics	N (%)		P (%)		K (%)	
			2019	2020	2019	2020	2019	2020
planting distance /m (A)		1.5 m X 3m (A1)	2.18	2.07	0.24	0.23	1.57	1.50
		2m X 3m (A2)	2.31	2.24	0.25	0.24	1.60	1.55
		2.5 m X 3m (A3)	2.30	2.26	0.25	0.25	1.62	1.57
New LSD at 5%			0.08	0.05	NS	0.01	0.05	0.06
No. of buds / m^2 (B)		8 (B1)	2.76	2.67	0.31	0.29	1.81	1.77
		10 (B2)	2.24	2.12	0.24	0.24	1.59	1.51
		12 (B3)	1.79	1.77	0.20	0.20	1.39	1.34
New LSD at 5%			0.08	0.05	0.02	0.01	0.05	0.06
Interaction (A x B)	A1	B1	2.68	2.58	0.30	0.28	1.80	1.74
		B2	2.14	1.96	0.23	0.22	1.54	1.46
		B3	1.72	1.68	0.19	0.19	1.36	1.30
	A2	B1	2.82	2.66	0.31	0.29	1.78	1.76
		B2	2.38	2.21	0.25	0.24	1.62	1.54
		B3	1.78	1.84	0.20	0.20	1.40	1.34
	A3	B1	2.83	2.78	0.31	0.30	1.84	1.82
		B2	2.21	2.18	0.24	0.24	1.60	1.52
		B3	1.85	1.80	0.21	0.20	1.42	1.38
New LSD at 5%			0.14	0.9	0.04	0.02	0.09	0.10

In general, increasing planting distance from (1.5mx3m) to (2mx3m) or (2.5mx3m) was accompanied with increasing in total N, P and K content in leaf petioles, this may be due to decreasing number of vines in feddan. On the other hand, increasing load of buds /vine from (8 buds/m^2) to (10 buds/m^2) or (12buds/m^2)

lead to increasing number of buds which were left on the vine, consequently increased number of shoots on the vines, so competition takes place between the shoots on nutrients content, this may be explain decreasing in total N, P and K content in leaf petioles in the treatments of high bud loads.

These results are in consistent with those reported by Abo-ELwafa (2018) who revealed that vines which were loaded at (48 buds/vine) gave the highest percent of N, P and K in leaf petioles as compared with vines which were pruned at (72 buds/vine) and (96 buds/vine) in both seasons of study, respectively.

3.4. Yield and its components

Data presented in Table (4&5) reveal that planting Flame seedless grapevines at distance (2.5m×3m) gave the highest significant values for total clusters number and yield/vine, while gave the lowest significant values on cluster weight**,** yield/feddan, 100 berry weight and 100 berry volume, which recorded (37.9 and 40.3) for total number of clusters and (17.98 and 18.28 Kg.) for yield/vine, while recorded (476 and 455 g) for cluster weight, (10.07 and 10.24 ton.) for yield/feddan, (233 and 222 g) for 100 berry weight and (215 and 202cm^3) for 100 berry volume in both seasons, respectively. On the other hand, the vines which were planted at distance (1.5m×3m) gave the lowest significant values on total clusters number (27.0 and 28.7) and yield/ vine (14.13 and 14.74 Kg.), while gave the highest significant values on cluster weight (530 and 521 g)**,** yield/feddan (12.72 and 13.26 ton.), 100 berry weight (257 and 248 g) and 100 berry volume (239 and 227cm^3) during the two seasons, respectively.

With respect to effect of buds number/ m^2 on yield and its components, data in the same tables indicate that the vines which were loaded with (12 buds/m^2) gave the highest significant values on total number of clusters (36.3 and 38.7 cluster),yield/vine (16.69 and 17.18 Kg.) and yield/feddan (11.80 and 12.16 ton.), while gave the lowest significant values on cluster weight (461 and 466 g)**,** 100 berry weight (224 and 218 g), and 100 berry volume (208 and 196 cm^3) during the two seasons, respectively. On the other contrary, the vines which were loaded with (8 buds/m^2) gave the lowest significant values on total number of clusters (28.9 and 30.9 cluster), yield/ vine (15.36 and 15.97 Kg.) and yield/feddan (10.83 and 11.30 ton.), while gave the highest significant values on cluster weight (538 and 524 g)**,** 100 berry weight (261 and 248 g) and 100 berry volume (242 and 227cm^3) during the two seasons, respectively.

As concerned to interaction between planting distance and buds number /m^2 on yield and its components, data in the same tables show that the vines which were planted at distance (2.5m×3m) and were loaded with(12 buds/m^2) (A3×B3) recorded the highest significant values on total clusters number (41 and 43 cluster) and yield/vine (18.35 and 18.74 Kg.), while gave the lowest significant values on cluster weight (448 and 436 g)**,** 100 berry weight (220 and 212 g) and 100 berry volume (200 and 190 cm^3). Also, data show that the vines which were planted at distance (1.5m×3m) and were loaded with (8 buds/m^2) (A1×B1) recorded the highest significant values on cluster weight (580 and 574 g)**,** 100 berry weight (280 and 270 g) and 100 berry volume (258 and 246 cm^3), while gave the lowest significant values on number of clusters (23 and 24.7) and yield/vine (13.32 and 14.14 Kg.) in both seasons respectively.

Also, data show non-significant differences between the vines which were planted at distance (1.5m×3m) plus (10 buds/m^2) (A1×B2) and the vines which were planted at distance (1.5mx3m) plus (12buds/m^2) (A1×B3) on yield/vine and yield/feddan in both seasons. Also, data clearly indicated significant differences between most of treatments on studied characteristics during both seasons.

Table 4. Effect of planting distance and load of buds per square meter on clusters number, clusters weight and yield/ vine of Flame seedless grapevines during 2019 and 2020 seasons.

Treatments		Characteristics	Clusters number		Cluster weight (g.)		Yield /vine (Kg.)	
			2019	2020	2019	2020	2019	2020
planting distance /m (A)		1.5 m X 3m (A1)	27.0	28.7	530	521	14.13	14.74
		2m X 3m (A2)	33.3	36.0	492	470	16.28	16.78
		2.5 m X 3m (A3)	37.9	40.3	476	455	17.98	18.28
New LSD at 5%			0.8	0.9	6.0	8.0	0.33	0.32
No. of buds/ m^2 (B)		8 (B1)	28. 9	30. 9	538	524	15.36	15.97
		10 (B2)	33.0	35.4	499	475 b	16.34	16.64
		12 (B3)	36.3	38.7	461	466	16.69	17.18
New LSD at 5%			0.8	0.9	6.0	8.0	0.33	0.32
Interaction (A x B)	A1	B1	23.0	24.7	580	574	13.32	14.14
		B2	27.0	28.3	535	528	14.42	14.92
		B3	31.0	33.0	474	460	14.66	15.15
	A2	B1	29.0	31.0	528	518	15.26	16.048
		B2	34.0	37.0	486	450	16.51	16.622
		B3	37.0	40.0	462	442	17.06	17.664
	A3	B1	34.7	37.0	505	480	17.50	17.73
		B2	38.0	41.0	476	448	18.08	18.37
		B3	41.0	43.0	448	436	18.35	18.74
New LSD at 5%			1.37	1.49	10.0	14.0	0.58	0.55

Table 5. Effect of planting distance and load of buds per square meter on yield/feddan, 100 berry weights, 100 berry volume of Flame seedless grapevines during 2019 and 2020 seasons.

Treatments		Characteristics	Yield/feddan (ton)		100 Berry weight (g.)		100 Berry volume (cm^3)	
			2019	2020	2019	2020	2019	2020
planting distance / m (A)		1.5 m X 3m (A1)	12.72	13.26	257	248	239	227
		2m X 3m (A2)	11.40	11.74	239	227	221	204
		2.5 m X 3m (A3)	10.07	10.24	233	222	215	202
New LSD at 5%			0.25	0.25	5.0	4.0	5.0	4.0
No. of buds / m^2 (B)		8 (B1)	10.83	11.30	261	248	242	227
		10 (B2)	11.55	11.78	245	229	227	209
		12 (B3)	11.80	12.16	224	218	208	196
New LSD at 5%			0.25	0.25	5.0	4.0	5.0	4.0
Interaction (A x B)	A1	B1	11.99	12.72	280	270	258	246
		B2	12.97	13.43	264	248	246	228
		B3	13.19	13.63	228	226	212	206
	A2	B1	10.68	11.23	256	242	236	220
		B2	11.55	11.64	238	222	220	200
		B3	11.94	12.37	224	216	208	192
	A3	B1	9.80	9.93	248	232	228	214
		B2	10.12	10.28	232	218	216	198
		B3	10.27	10.49	220	212	200	190
New LSD at 5%			0.44	0.42	9.0	7.0	9.0	7.0

Generally, the gradual increasing of planting distance from (1.5m×3m) to (2.5m×3m) or load of buds/vine from (8buds/m^2) to (12buds/m^2) was accompanied with increase in number of buds which were left on vines during winter pruning, which led to an increased in number of busted buds, consequently increased clusters number, yield/vine, but cluster weight, berry weight and berry volume were decreased also, yield/feddan was decreased when planting distance increased from (1.5m×3m) to (2m×3m) or (2.5m×3m) as a result of decreasing number of vines in feddan. These findings are in harmony with those obtained by (Bowed and Kliewer, 1990; Wolpert, 2001; Aly, 2001; El-Sese, 2004; Palanichamy *et al.,* 2004; El-Kady, *et al.*, 2010; Abdel-Mohsen, 2013; Justine *et al.*, 2013; Sahebrao, 2013; Fawzi *et al.,* 2015 ; Hamid *et al.* 2015; Archer and Strauss, 2017; Khamis *et al.,* 2017 Kumar *et al.*, 2017; Abo-ELwafa, 2018; Bassiony, 2020; Keller and Mills, 2021).

3.5. Microclimate data

Data presented in (Table 6) clear show that microclimate data of the vines canopy such as light intensity and air temperature were affected by all planting distance treatments used, the vines which were planted at distance (2.5 m×3m) recorded the highest significant values of light intensity (58.67 and 59.44 watt/m^2) and air temperature (26.67 and 27.11ºC) followed by the vines which were planted at distance (2 m×3m), while the vines which were planted at distance (1.5m×3 m) recorded the lowest significant values in this respect which recorded (53.89 and 54.67 watt/m^2) for light intensity and (24.67 and 25.00ºC) for air temperature in both seasons, respectively.

With regarding to the effect of buds number/m^2, data in the same table show that increased the number of buds /m^2 had pronounced and significant effect on microclimate data of the vines canopy. The gradual increasing in buds load from (8 buds/ m^2) to (10 or 12 buds/m^2) was significantly accompanied with reduction on light intensity and air temperature inside the vines canopy. The vines which were loaded with (8 buds /m^2) recorded the highest significant values of light intensity (57.78 and 58.89 watt/m^2) and air temperature (26.33 and 26.67ºC) in both seasons of study, respectively, followed by the vines which were loaded with (10 buds /m^2), while the vines which were loaded with (12 buds /m^2) recorded the lowest significant values in this respect, which recorded (54.78 and 55.56 watt/m^2) for light intensity and (25.11 and 25.33ºC) for air temperature in both seasons of study, respectively.

Concerning to the effect of interaction between planting distance and buds number/ m^2, data in the same table indicate that the vines which were planted at distance (2.5m×3m) in combine with (8 buds/m^2) (A3×B1) recorded the highest significant values on of light intensity (60.33 and 61.66 watt/m^2) and air temperature (27.33 and 27.66ºC) in both seasons of study, respectively, followed by the vines which were planted at spacing (2.5m×3m) plus (10buds/m^2) (A3×B2), on the other hand, the vines which were planted at spacing (1.5mx3m), and loaded with (12 buds/m^2) (A1×B3) recorded the lowest significant values on of light intensity (52.66 and 53.33 watt/m^2) and air temperature (24.0 and 24.33ºC) in both seasons, respectively,

Generally, there was a relation between planting distance, pruning severity (buds load /vine) and microclimate data inside the vines canopy. Increasing planting distance from 1.5m×3m to 2m×3m or 2.5m×3m, and decreasing buds load /vine from (12buds/m^2) to (10buds/m^2) or (8buds/m^2) led to improving in microclimate data of the vines canopy such as light intensity and air temperature in both seasons**.** Our results are in consistent with the findings of Keller and Mills (2021).

Table 6. Effect of planting distance and load of buds per square meter on light intensity and air temperature of Flame seedless grapevines during 2019 and 2020 seasons.

Treatments		Characteristics	Light intensity (watt/m^2)		Air temperature (ºC)	
			2019	2020	2019	2020
planting distance /m (A)	1.5 m X 3m (A1)		53.89	54.67	24.67	25.00
	2m X 3m (A2)		56.22	57.44	25.78	26.00
	2.5 m X 3m (A3)		58.67	59.44	26.67	27.11
	New LSD at 5%		0.55	0.56	0.45	0.42
No. of buds / m^2 (B)	8 (B1)		57.78	58.89	26.33	26.67
	10 (B2)		56.22	57.11	25.67	26.11
	12 (B3)		54.78	55.56	25.11	25.33
	New LSD at 5%		0.55	0.56	0.45	0.42
Interaction (A x B)	A1	B1	55.33	56.0	25.33	25.66
		B2	53.66	54.66	24.66	25.0
		B3	52.66	53.33	24.0	24.33
	A2	B1	57.66	59.0	26.33	26.66
		B2	56.33	57.33	25.66	26.0
		B3	54.66	56.0	25.33	25.33
	A3	B1	60.33	61.66	27.33	27.66
		B2	58.66	59.33	26.66	27.33
		B3	57.0	57.33	26.0	26.33
	New LSD at 5%		0.95	0.98	0.79	0.73

3.6. *Chemical properties of berries*

Data illustrate in Table (7) indicate that the highest significant values for SSC (18.27 and 18.60 %), total sugars% (16.71 and 16.93 %) total anthocyanins (37.82 and 38.38 mg/100g f.w.) and the lowest significant values for total acidity (0.54 and 0.53 %) were recorded when Flame seedless grapevines were planted at distance (2.5m×3m) followed by the vines which were planted at distance (2m×3m) with non-significant differences between of them in the second season only. On the other hand, the vines which were planted at distance (1.5m×3m) recorded the lowest significant values for SSC (17.47 and 17.93 %), total sugars (15.84 and 16.23 %) and total anthocyanins (36.30 and 36.93 %), while recorded the highest significant values for total acidity% (0.61 and 0.59 %) in both seasons respectively**.**

As for the effect of number of buds/m^2 on chemical properties of berries, data in the same table show that the vines which were loaded at level (8 buds/ m^2) gave not only the highest significant values of SSC (18.47 and 18.80 %), total sugars% (16.86 and 17.11 %) and total anthocyanins (38.26 and 38.77 %) but also the lowest significant values of total acidity (0.52 and 0.51%) in both seasons respectively, followed by the vines which were loaded at level (10 buds/ m^2). On the other side, the vines which were loaded with (12 buds/m^2) gave the lowest significant values on SSC (17.33 and 17.80 %), total sugars% (15.70 and 16.11 %) and total anthocyanins (36.02 and 36.71%), while gave the highest significant values of total acidity (0.63 and 0.60%) in both seasons respectively.

Concerning the effect of interaction between planting distance and buds number /m^2 on chemical properties of berries, data in the same table reveal that the vines which were planted at distance (2.5m×3m) in combine with (8 buds/m^2) (A3×B1) gave the highest significant values for SSC (18.8 and 19.0 %), total sugars% (17.18 and 17.31 %) total anthocyanins (39.0 and 39.20 mg/100g f.w.) and the lowest significant values for total acidity% (0.50 and 0.49 %) followed by the vines which were planted at distance (2m×3m) and were loaded at (8buds/m^2) (A2×B1) and non-significant differences between of them during the two seasons. On the contrary, the vines which were planted at distance (1.5m×3m) and were loaded at (12 buds/m^2) (A1×B3) gave the lowest significant values for SSC (17.0 and 17.4 %), total sugars% (15.30 and 15.64 %) total anthocyanins (35.47 and 35.88 mg/100g f.w) and the highest significant values for total acidity (0.66 and 0.63 %) followed by the vines which were planted at (2m×3m) and were loaded at (12 buds/m^2) (A2×B3) and non-significant differences between of them during the two seasons. Also, data show non-significant differences between the vines which were planted at distance (1.5m×3m) and were loaded at (8 buds/m^2) (A1×B1) and the vines which were planted at distance (2m×3m) and loaded at (10 buds/m^2) (A2×B2), as well as between the vines which were planted at spacing (2.5 m x 3 m) and were loaded at (10 buds / m^2) (A3×B2) and the vines which were planted at distance (2.5 m x 3 m) and were loaded at (10 buds / m^2) (A3×B3) except total anthocyanins in the first season only gave significant effect.

Table 7. Effect of planting distance and load of buds per square meter on the percent of SSC, acidity, total sugar and total anthocyanins of Flame seedless grapes berries during 2019 and 2020 seasons.

		Characteristics	SSC (^{0}Brix)		Acidity (%)		Total sugars (%)		Total anthocyanins (mg/100g f.w)	
Treatments			2019	2020	2019	2020	2019	2020	2019	2020
planting distance /m (A)		1.5mX3m (A1)	17.47	17.93	0.61	0.59	15.84	16.23	36.30	36.93
		2mX3m (A2)	17.87	18.40	0.58	0.55	16.22	16.70	37.09	37.90
		2.5mX3m (A3)	18.27	18.60	0.54	0.53	16.71	16.93	37.82	38.38
New LSD at 5%			0.34	0.32	0.03	0.03	0.37	0.35	0.58	0.61
No. of buds / m^2 (B)		8 (B1)	18.47	18.80	0.52	0.51	16.86	17.11	38.26	38.77
		10 (B2)	17.80	18.33	0.59	0.55	16.22	16.63	36.93b	37.73
		12 (B3)	17.33	17.80	0.63	0.60	15.70	16.11	36.02	36.71
New LSD at 5%			0.34	0.32	0.03	0.03	0.37	0.35	0.58	0.61
Interaction (A x B)	A1	B1	18.0	18.4	0.56	0.55	16.46	16.76	37.18	37.98
		B2	17.4	18	0.62	0.58	15.75	16.28	36.24	36.94
		B3	17.0	17.4	0.66	0.63	15.30	15.64	35.47	35.88
	A2	B1	18.6	19.0	0.51	0.49	16.92	17.26	38.58	39.12
		B2	17.8	18.4	0.59	0.55	16.22	16.68	36.88	37.79
		B3	17.2	17.8	0.64	0.59	15.53	16.14	35.80	36.78
	A3	B1	18.8	19.0	0.50	0.49	17.18	17.31	39.0	39.20
		B2	18.2	18.6	0.55	0.53	16.68	16.92	37.66	38.46
		B3	17.8	18.2	0.58	0.57	16.27	16.56	35.47	37.48
New LSD at 5%			0.59	0.55	0.05	0.05	0.64	0.61	1.0	1.10

In general, there was relation between planting distance, pruning severity (buds load /vine) and chemical properties of berries. The gradual increasing on planting distance from 1.5m×3m (900vine/ Feddan) to 2m×3m (700vine/ Feddan) or 2.5m×3m (560 vine/ Feddan) and gradual decreasing of buds load /vine from (12buds/m^2) to (10buds/m^2) or (8buds/m^2) led to a gradual increased in SSC%, total sugars%, total anthocyanins and decreasing total acidity % in berries in both seasons.

The positive effects of these treatments may be due to pruning severity (low buds load) reduces number of shoots that growth, with increase the distance between the vines, this reflected on enhancing light exposure and air temperature through vine canopy, which reflected on increased the photosynthetic activity and carbohydrate accumulation in of the leaves, consequently improve chemical properties of berries (Dokoozlian and Kliewer, 1996; Ghada, 2015). Furthermore, the level of sugars, ripening processes and anthocyanin content in berries dependent on microclimatic conditions around cluster zone. Clusters well exposed to sunlight contain high percentage of anthocyanin content (Spayd *et al.*, 2002; Pereira *et al.*, 2006; Candar *et al.*, 2019).

Our results are consistent with the findings of (Wolpert, 2001; Mahfouz, 2007; Fawzi *et al.*, 2010; Kohale *et al.*, 2013; Fawzi *et al.*, 2015; Philippe *et al.*, 2016; Khamis *et al.*, 2017; Abo-ELwafa, 2018; Bassiony, 2020).

3.7. At dormant season's parameters

It is evident from the data in Table (8) that wood ripening coefficient, pruning wood weight and total carbohydrates in canes were significantly affected by various planting distance, the vines which were planted at distance (2.5m×3m) recorded the highest significant values of wood ripening coefficient (0.90 and 0.90), pruning wood weight (2.93 and 3.06 Kg/vine) and total carbohydrates (29.55 and 30.35 gm/100gm D.W.) followed by the vines which were planted at spacing (2m×3m), while the vines which were planted at distance (1.5m×3m) recorded the lowest significant values of wood ripening coefficient (0.84 and 0.86), pruning wood weight (2.16 and 2.24 Kg) and total carbohydrates (27.45 and 28.05 gm/100gm D.W) in the two seasons, respectively.

Concerning the effect of number of buds/m^2, data in the same table show that the vines which were loaded at level (8 buds/m^2) was more effective in increasing wood ripening coefficient and total carbohydrates in canes, while the vines which were loaded with (12 buds/m^2) was more effective in increasing pruning wood weight during the two seasons, the vines which were loaded with (8 buds/m^2) gave the highest significant values of wood ripening coefficient (0.92 and 0.92), and total carbohydrates (30.25 and 30.85 gm/100gm D.W) and lowest significant values of pruning wood weight (2.29 and 2.35 Kg/vine). On the other hand, the vines which were loaded with (12buds/m^2) recorded the lowest significant values of wood ripening coefficient (0.83 and 0.83) and total carbohydrates (26.61 and 27.36 gm/100gm D.W.), but it gave the highest significant values of pruning wood weight (2.82 and 2.93 Kg/vine) in both seasons, respectively

Regarding the interaction between planting distance and buds number /m^2 of wood ripening coefficient, pruning wood weight and total carbohydrates in canes, data in the same table reveal that the vines which were planted at distance (2.5mx3m) and loaded at level (8 buds/m^2) (A3×B1) recorded the highest significant values of wood ripening coefficient (0.94 and 0.92), and total carbohydrates (31.62 and 32.22 gm/100gm D.W) followed by the vines which were planted at spacing (2m×3m) and loaded at level at (8 buds/m^2) (A2×B1) and non-significant differences between of them on wood ripening coefficient of the two season. Also, the vines which were planted at distance (2.5mx3m) and loaded with (12 buds/m^2) (A3×B3)recorded the highest significant values of pruning wood weight (3.12 and 3.30 Kg) followed by the vines which were planted at spacing (2.5m×3m) and loaded with (10 buds//m^2) (A3×B2). On contrary, the vines which were planted at distance (1.5m×3m) with (12 buds/ m^2) (A1×B3) recorded the lowest significant values of wood ripening coefficient (0.78 and 0.80), and total carbohydrates (25.82 and 26.34 gm/100gm D.W), while the vines which were planted at distance (1.5m×3m) and loaded with (8 buds/m^2) (A1×B1) recorded the lowest significant values of pruning wood weight (1.85 and 1.92 Kg) in both seasons, respectively.

The positive effect of increasing wood ripening coefficient and total carbohydrates in canes as a result of loaded the vines with (8 buds/m^2) may be due to improve the sunlight that received by the leaves in inside of the vines, leading to enhance the photosynthesis in the leaves, consequently increasing carbohydrates content in the canes and wood ripening coefficient. Also, increased pruning wood weight in the vines which were loaded with (12buds/m^2) may be due to increasing number of buds/vine which was left during winter pruning, consequently increasing number of shoot development, which led to increasing pruning wood weight.

These results are in line with the findings of (Wolpert, 2001; Reynolds *et al.*, 2004; Abo-ELwafa, 2018; Bassiony, 2020).

Table 8. Effect of planting distance and load of buds per square meter on wood ripening coefficient, pruning wood weight and total carbohydrates in canes of Flame seedless grapevines during 2019 and 2020 seasons.

Treatments		Characteristics	Wood ripening coefficient		Pruning wood weight (Kg)		Total carbohydrates (gm/100gm D. W.)	
			2019	2020	2019	2020	2019	2020
planting distance /m (A)	1.5 m X 3m (A1)		0.84	0.86	2.16	2.24	27.45	28.05
	2m X 3m (A2)		0.88	0.89	2.61	2.68	28.31	28.98
	2.5 m X 3m (A3)		0.90	0.90	2.93	3.06	29.55	30.35
New LSD at 5%			0.02	0.02	0. 07	0.05	0.38	0. 39
No. of buds / m^2	8 (B1)		0.92	0.92	2.29	2.35	30.25	30.85
	10 (B2)		0.88	0.89	2.59	2.70	28.45	29.17
	12 (B3)		0.83	0.83	2.82	2.93	26.61	27.36
New LSD at 5%			0.02	0.02	0.07	0.05	0.38	0.39
Interaction (A x B)	A1	B1	0.88	0.90	1.85	1.92	28.98	29.48
		B2	0.86	0.87	2.18	2.26	27.54	28.32
		B3	0.78	0.80	2.46	2.53	25.82	26.34
	A2	B1	0.93	0.94	2.34	2.40	30.15	30.84
		B2	0.87	0.90	2.62	2.70	28.26	28.82
		B3	0.84	0.83	2.88	2.94	26.52	27.28
	A3	B1	0.94	0.92	2.69	2.74	31.62	32.22
		B2	0.91	0.90	2.97	3.13	29.55	30.376
		B3	0.86	0.87	3.12	3.30	27.48	28.46
New LSD at 5%			0.04	0.04	0.12	0.09	0. 67	0.68

4. Conclusion

The choice of planting distance is considered a key decision and important for grape growers to make before vineyard establishment, also pruning (buds load) is considered one of the most important horticultural practices in grapevines production. Also, the correlation of pruning severity (buds load) with the planting distance for any grape cultivars is of utmost importance for obtaining optimum yield and quality. The vine load must be moderate, in order to maintain the uniform vigour throughout its life period. From the results of this study, it could be recommended that planting Flame seedless grapevines at distances (2.5mx3m) or (2mx3m) with retain (8 buds/ m^2) was considered the most optimum treatment to improve vines nutritional status, vegetative growth and yield characteristics, canopy microclimate and quality of berries.

5. References

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