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Cultivations of *Ficus carica* L. under Different Agricultural Regimes: Some Physiological Aspects

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THE productivity of *Ficus carica* (fig) grown in Mediterranean conditions is one of the most important issues. Consequently, the aim of this study was to evaluate the effect of different agricultural regimes on fig cultivations and productivity. Nine orchards were selected then grouped into four ranks according to the applied agricultural regimes. The following parameters were measured: Soil physical and chemical properties; some physiological properties (RUBISCO, LSu and SSu, protein profile and total soluble sugars) in addition to the productivityof fig fruits. Results obtained revealed that the evaluated parameters differ significantly ($P \leq 0.05$) in relation to the ranks of agricultural regimes. Sand and clay percentages revealed a significant difference ($P \leq 0.05$) in rank IV with respect to other ranks. Ca recorded the highest significant mean differences with values of about 128.7 and 130.4mg for ranks I and II, respectively. Nevertheless, fig agro-economic issue proceeded from the past; it is likely to be continued in the future with some adjustments of the agricultural regimes which cope with the best productivity.

Keywords: *Agricultural practices, Ficus carica*, Productivity, Physiological aspects, Soil nutrients, Rubisco.

Abbreviations: RUBISCO: Ribulose 1,5-bisphosphate carboxylase/oxygenase; LSu and SSu: Large and small subunit.

Introduction

Ficus carica L. (common fig, Moraceae) is produced in the Mediterranean basin with great yield under various soil and climate conditions (FAO, 2011). Cultivation of the Egyptian fig plants spreads from North Egypt till Aswan and intensively grown from Alexandria toward the west to Mersa-Matruh relying on the winter rain-fed irrigation (Taha et al., 1989). Worldwide, Egypt is regarded as the second producing country where the cultivated area of fig reached 28479 hectares, with total production of 165483 tons (Dueñas et al., 2008; FAO, 2011; Ercisli et al., 2012). Among various fig cultivars, Sultani fig (Barshoumy, Fayoumi, Hegazi, Ramadi and Sidi Gaber) is the most domestic grown variety in Egypt. Other less interesting local cultivars are: Abboudi, Adasi-Abiad, Adasi-Ahmer, Asuani, Kahramani and Kommathri (Abo-El-Ez et al., 2013).

An integrated series of safety and quality standards of fig fruit production is a consequence of the high-quality agricultural performance of fig cultivations. The farmland will be considered more productive when agricultural outputs exceed the agricultural inputs (FAO, 2017). Many recognizable studies on fruit crops had been carried out which involved the effect of nutritional elements on the production quality; however less were applied on fig (Marzouk & Kassem, 2011).

The photosynthetic enzyme RUBISCO (EC 4.1.1.39) responsible for capturing CO_2 is usually

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referred to as L8S8 RUBISCO. It is composed of eight chloroplast-encoded large subunits (rbcL, 55kDa) and eight nuclear-encoded small subunits (rbcS,15kDa) (Genkov & Spreitzer, 2009; Valegard et al., 2018). RUBISCO in addition, to be stimulatory for the first determinant step in photosynthesis/photorespiration, it is also the main leaf protein in C_3 plants (Suzuki & Makino, 2012). Therefore, the aim of the present study is to investigate the effect of different agricultural regimes on some physiological characteristics of *F. carica* and how its productivity gets affected.

Materials and Methods

Sampling and analysis of soil

Soil samples were collected as a composite sample from each orchard at about 30-50cm depth from the soil surface. Texture classes were determined according to Bouyoucos (1936). Likewise, EC and pH were estimated for each orchard (Phogat et al., 2015). The soil solutions were subjected to inductively coupled plasma-optical emission spectroscopy (ICP-OES; Agilent 5100 VDV, USA) to estimate different metals content such as;Ca^{2+}, K^+, Na^+, Mg^{2+}, P^3, N^{3-} and HCO_3^-.

Sampling and analysis of plant materials

The study was carried out along the western coastal desert of Egypt at about 30-120km from Alexandria on 9 of the most commercially important fig orchards. Four homogenized fig trees were selected from each orchard then a composite sample of leaves and fruits was collected.

RUBISCO concentration (LSu and SSu) was assessed in fig fresh leaves following Leitao et al. (2003). SDS polyacrylamide gel electrophoresis (SDS-PAGE) was performed to distinguish and fragment total soluble protein in *F. carica* leaves for 9 different orchards according to Laemmli (1970). The content of total sugars was estimated in fruits according to AOAC (2005). Productivity was calculated as yield per tree (number and weight of fresh fruits) of the main-crop (July-August-September).

Statistical analysis

Results obtained were expressed as mean values ± standard deviation (SD). Significance of difference between mean values was determined at $P \leq 0.05$ using one-way analysis of variance (ANOVA) with SPSS Statistical Analysis Software following the methods of Sokal & Rohlf (2013). Pairwise comparison between each two ranks was done using Post Huc Test (Tukey).

Results

Nine *F. carica* orchards were grouped into four ranks according to the applied agricultural regimes. Ranks were graduated from the lowest; non-mechanical (Rank I) till reaching a highly mechanical agricultural regime (Rank IV) (Table 1).

TABLE 1. Ranks description of different agricultural regimes applied in *Ficus carica* orchards

Rank	Description
I Non mechanical	Shallow ploughing, manure fertilizer application, light pruning, rainfed.
II Low mechanical	Shallow ploughing, manure fertilizer application, medium pruning, nitrogen fertilizer, rainfed.
III Mostly mechanical	Ploughing using mechanical traction, manure fertilizer application, medium pruning, nitrogen fertilizer, pesticides, subsidiary irrigation, rainfed.
IV Highly mechanical	Ploughing using mechanical traction, manure fertilizer, heavy pruning, nitrogen fertilizer, pesticides, subsidiary irrigation, foliar fertilization, rainfed.

Physical and chemical properties of soil

Sand and clay percentages revealed a significant ($P \leq 0.05$) difference in rank IV with respect to other ranks. Inversely, silt, EC and pH recorded insignificant differences between the four ranks. Regarding chemical characteristics, only Ca attained the highest significant mean differences with values of about 128.7 and 130.4mg for ranks I and II, respectively. Otherwise, all other elements exhibited insignificant mean differences among the four ranks of the applied agricultural regimes (Table 2).

RUBISCO (LSu and SSu) and protein content in fig leaves

Interestingly, the large subunit of RUBISCO didn't show a significant difference between any of the four ranks. RUBISCO small subunit in ranks I and III attained significant difference (P≤ 0.05) (20 and 24µg, respectively) with respect to ranks II and IV (41.27 and 37.5µg, respectively). The percentage of polymorphism and the total number of bands recorded insignificant variance among the four ranks (Table 3).

The employed SDS Polyacrylamide gel electrophoresis (SDS-PAGE) technique was found to attain an insignificant difference between protein patterns and percentage of polymorphism of fig leaves between ranks of the selected orchards. Two main units of RUBISCO were detected for *F. carica*. Large subunit with 55kDa and an addition RUBISCO small subunit with 15kDa; each of the two subunits was expressed with varying expression levels in all the selected orchards (Fig. 1).

TABLE 2. Variation in physical and chemical properties of soil underneath *Ficus carica* trees in the selected orchards for different ranks

Parameter	Rank I (n=3)	Rank II (n=3)	Rank III (n=2)	Rank IV (n=2)	F	P
Physical						
Sand %	**92.50^{a}±1.74**	**91.21^{a}±2.53**	**89.52^{a}±1.88**	**81.50^{b}±2.12**	**12.166***	**0.006***
Silt %	1.11^{a}±1.02	2.44^{a}±1.39	2.0^{a}±0.95	3.20^{a}±0.42	1.636	0.278
Clay %	**6.39^{b}±1.23**	**6.35^{b}±1.15**	**8.48^{b}±0.95**	**14.80^{a}±0.28**	**31.981***	**<0.001***
EC(µs/cm)	0.26^{a}±0.14	0.20^{a}±0.04	0.19^{a}±0.01	0.22^{a}±0.05	0.437	0.735
pH	8.47^{a}±0.21	8.53^{a}±0.21	8.15^{a}±0.07	8.0^{a}±1.41	0.425	0.742
Chemical						
Ca (mg)	**128.7^{a}±13.61**	**130.4^{a}±23.82**	**79.49^{ab}±10.70**	**71.90^{b}±4.69**	**8.559***	**0.014***
K (mg)	9.42^{a}±1.66	9.31^{a}±0.31	10.38^{a}±0.0	8.98^{a}±0.56	0.739	0.566
Mg (mg)	9.44^{a}±4.73	10.89^{a}±5.42	14.70^{a}±1.55	11.30^{a}±2.43	0.611	0.632
P (ppm)	340.2^{a}±22.94	410.8^{a}±266.1	370.8^{a}±139.6	288.6^{a}±1.99	0.238	0.867
Na (mg)	11.05^{a}±5.02	8.72^{a}±5.82	5.68^{a}±0.09	5.60^{a}±0.32	0.870	0.507
N(%)	0.01^{a}±0.01	0.01^{a}±0.01	0.01^{a}±0.0	0.0^{a}±0.0	1.225	0.379
HCO_3 (meq/100g soil)	0.15^{a}±0.08	0.16^{a}±0.02	0.17^{a}±0.12	0.12^{a}±0.0	0.233	0.870

- Means with common letters between ranks are not significant.
- Data was expressed by using (Mean ± SD.).
- F: F for ANOVA test, Pairwise comparison bet. Each 2 groups was done using Post Hoc Test (Tukey).
- P: P value for comparing between the different ranks.
- *: Statistically significant at P≤ 0.05.

TABLE 3. Variation in RUBISCO (large and small subunit), total number of protein bands and polymorphism (%) in the selected orchards for different ranks

Parameter	Rank I (n=3)	Rank II (n=3)	Rank III (n=2)	Rank IV (n=2)	F	P
RUBISCO conc.						
LSU (ug)	38.57^{a}±11.32	31.43^{a}±6.57	25.70^{a}±0.0	42.90^{a}±0.71	2.176	0.192
SSU (ug)	**20.0^{b}±4.33**	**41.27^{a}±3.75**	**24.40^{b}±2.69**	**37.50^{a}±2.26**	**21.811***	**0.001***
Polymorphism						
Total no. of bands	15.67^{a}±3.79	15.0^{a}±1.73	13.50^{a}±2.12	14.0^{a}±1.41	0.337	0.800
% polymorphism	40.23^{a}±13.06	37.93^{a}±5.98	32.76^{a}±7.31	34.48^{a}±0.92	0.353	0.789

- Means with common letters between ranks are not significant.
- Data was expressed by using (Mean ± SD.).
- F: F for ANOVA test, Pairwise comparison between each 2 groups was done using Post Hoc Test (Tukey).
- P: P value for comparing between the different ranks.
- *: Statistically significant at P≤ 0.05.

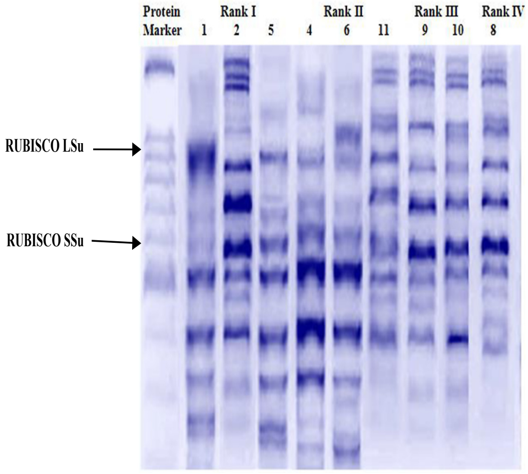

Fig. 1. Protein fingerprinting patterns of *Ficus carica* orchards [The first column is the protein marker followed by the selected orchards grouped into four ranks]

Total soluble sugars and productivity

Total sugars in fruits attained statistically significant differences at P≤ 0.05. Rank IV scored the lowest mean (61.5mg/g) while rank I scored the highest total sugars in all ranks (174.3mg/g). Interestingly, the productivity of fig trees showed significant differences at P≤ 0.05 between four ranks of applied agricultural regimes. The highest productivity was attained at rank IV with a mean value= 19560g fruit/ tree, whereas the lowest productivity was recorded at rank I with a mean value of 3020g/ tree. The number of fruits/tree followed the same approach as productivity with different values/rank. Nevertheless, fig fruits attained almost the same fresh weight which renders the analysis of variance between ranks' means insignificant (Table 4).

Discussion

In the current study, rank IV (the highest productivity) had relatively the lowest sand %, highest clay % and lowest Ca^{++} content in the soil. While the rank I recorded the lowest productivity had the opposite trend for sand and clay %, as well as Ca^{++} content, respectively. The cultivation of *F. carica*is is highly effective in a mixed sandy and clay soil with higher sand proportion rather than being grown entirely in sandy soil (Fischer et al., 2015). This is congruent with results obtained from orchards of ranks III and IV which gave the highest productivity and attained relatively the lowest sand % and the highest clay % with respect to all the other orchards. Physiologically, calcium is a vital nutrient due to its role as a secondary messenger which modulates signal transduction (Bonomelli et al., 2019). It is well known that the development of fruit quality is controlled by Ca treatments in addition to the role of Ca in retarding fruit softening (Kumar, 2007). Nguyen et al. (2017) declared that ratios of Ca, Mg, and K together with their concentrations in the soil are the limiting factors for their proper soil uptake. In the present study, Ca recorded the highest significant mean differences for ranks I and II with respect to the other ranks. On the other hand, Mg and K recorded insignificant differences among all ranks of the selected fig orchards. This renders high Ca/Mg and Ca/K ratios which attained 13.6 and 13.7 for rank I, respectively. The corresponding ratios at rank IV were 6.4 and 8, respectively.

TABLE 4. Variation in total soluble sugarsand productivity in fruits of *Ficus carica* in the selected orchards for different ranks

Parameter	Rank I (n=3)	Rank II (n=3)	Rank III (n=2)	Rank IV (n=2)	F	P
Total sugars (mg/g)	**174.3^{a}±3.51**	**122.9^{ab}±29.92**	**131.2^{ab}±57.98**	**61.50^{b}±2.12**	**5.931^{*}**	**0.032^{*}**
Productivity						
Productivity (g/tree)	**3020.0^{d}±34.64**	**6063.3^{c}±59.48**	**13120.5^{b}±112.4**	**19560.0^{a}±21.21**	**34518.3^{*}**	**$<0.001^{*}$**
No. of fruits/Tree	**150.0^{d}±30.0**	**279.3^{c}±41.10**	**583.5^{b}±23.33**	**978.0^{a}±9.90**	**326.3^{*}**	**$<0.001^{*}$**
Fresh weight (g)	20.67^{a}±4.04	22.0^{a}±3.0	22.50^{a}±0.71	20.0^{a}±2.83	0.302	0.823

- Means with common letters between ranks are not significant.
- Data was expressed by using (Mean ± SD.).
- F: F for ANOVA test, Pairwise comparison between each 2 groups was done using Post Hoc Test (Tukey).
- P: P value for comparing between the different ranks.
- *: Statistically significant at P≤ 0.05.

CO_2 fixation, the first determinant step of photosynthesis is stimulated by chloroplast enzyme RUBISCO. While, the chloroplast LSu forms the active site; the nuclear SSu has a stimulatory role for the enzyme activity (Genkov & Spreitzer, 2009; Khalifa et al., 2017). In the current study, RUBISCO SSu attained its lowest significant differences at ranks I and III whereas the corresponding highest differences were attained at ranks II and IV. On the other hand, RUBISCO LSu though increased as protein content but still didn't record significant differences among any of the four ranks. This may be explained that rbcS contributed in the transcription and then the translation of rbcL but not to the extent to be significantly different among the applied ranks (Suzuki & Makino, 2012). The insignificant difference between protein patterns and the percentage of polymorphism of fig leaves among ranks of the selected orchards together with the insignificance of RUBICO LSu may be due to the harmful consequences of excess irradiation together with increased temperature prevailing in arid regions climate (Mlinarić et al., 2016).

Sucrose was the major sugar in apple leaves, but minor in fruits indicating a preferential utilization of sucrose for fruit growth and maturation (Ali, 2018; Li et al., 2018). In fig fruits, there is an accumulation of glucose and fructose, in contrast to other tree species owing to the hydrolysis of sucrose (Vemmos et al., 2013). This may illustrate the inverse relation between the total soluble sugars and fig productivity recorded in the present study where sucrose may be utilized in fruit growth and maturation so that by increasing the number of fruits/rank (rank IV) more sucrose is hydrolyzed to glucose and fructose.

The studied plant is well adapted to high temperature and low water regime and has been cultivated with very little improved cultural practices. Nowadays, fig cultivation is progressively practiced under irrigation along with different agro-techniques that increase fruit quality and yield (Melgarejo et al., 2006; Abd-El-Rhman et al., 2017). In the present study, productivity showed significant differences among the four applied agricultural regimes. Ranks I and II (characterized by rain-fed conditions) attained the lowest productivity values. Whereas, using subsidiary irrigation increases productivity in ranks III and IV. Actually, it seems that limited water supply, irrational use of fertilizers and exposure to pests and diseases bring about weak fig trees cultivations and diminished crop yield (Lavee et al., 1990). Andria et al. (1992) after using variable rates of irrigation found that non-irrigated fig trees output less harvest and shorter shoot length than the irrigated ones. Al-Desouki et al. (2009) in their study along the western coastal desert of Egypt reported that increasing the vegetative growth of fig plantations come after the concurrent use of subsidiary irrigation with winter rain-fed. In addition, Abd-El-Rhman et al. (2017) notified that irrigation levels and vegetative growth/productivity achieved a fine positive correlation when different subsidiary water supplies were tested. Furthermore, many studies reported that fig growth and productivity were diminished under intense drought conditions (Tapia et al., 2003; Allam et al., 2007; Al-Desouki et al., 2009). Applying different pruning levels in Sultani figs' orchards in the present study seemed effective so that this was reflected on the gradual increase in productivity in ranks II and III until maximum productivity was achieved at rank IV. This increase represented about 1.01, 3.35 & 5.48 times, respectively with respect to light pruning in rank I. Likewise, the degree of ploughing significantly involved in increasing productivity. Nowadays, attaining sustainable and eco-friendly agricultural systems is a crucial goal. The longevity of faulty agricultural practices (ex.: the overuse of soil fertilizers) has led to the reduction of vast areas of cultivated lands and multiple nutrient deficiencies (Kumar, 2007).

Conclusion

The highest productivity of fig fruits in the current study was characterized by more sand and less clay together with high calcium content (Ca-loving plant), low RUBISCO SSu concentration and TSS content; in addition to soil supplementation with manure, nitrogen fertilizers accompanied with foliar fertilization. Finally, this study will allow the fruit grower to select a range of the most appropriate agricultural regimes applied in their orchards coping with the best fig productivity that matches with the market needs.

Conflict of interests: The authors declare no conflict of interest.

Authors contribution: Dr. Rehab El-Dakak: Conceptualization, methodology, data curation, writing - original draft. Prof. Salama El-Darier: Conceptualization, validation, review and edit.

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زراعات التين الشائع تحت أنظمة زراعية مختلفة: بعض الجوانب الفسيولوجية

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تعتبر إنتاجية نبات التين الشائع *Ficus carica* و الذى تتم زراعته في ظروف مناخ البحر الأبيض المتوسط واحدة من أهم القضايا الأن. لذلك كان الهدف من الدراسة الحالية هو تقييم تأثير الأنظمة الزراعية المختلفة على زراعة التين وكيفية تأثير ذلك على إنتاجية النبات. وقد تم اختيار تسعة بساتين قسمت الى اربع رتب حسب النظم الزراعية المطبقة. وقد تم قياس المتغيرات التالية: الخصائص الفيزيائية والكيميائية للتربة، بعض الخصائص الفسيولوجية (انزيم الروبيسكو (LSu و SSu)، خصائص البروتين والسكريات الكلية الذائبة) بالإضافة إلى تقييم إنتاجية الثمار. وقد أظهرت النتائج التي تم الحصول عليها أن المتغيرات التى تم تقديرها تختلف معنويا ($P \leq 0.05$) بالنسبة لرتب النظم الزراعية المستخدمة. وأوضحت نسب الرمل والطمى فرقا معنويا ($P \leq 0.05$) في الرتبة الرابعة مقارنة بالرتب الأخرى. و قد حقق عنصر الكالسيوم أعلى اختلافا معنويا بمقدار حوالي 128.7 و 130.4 مجم للرتبة الأولى والثانية على التوالي. و رغم بروز الأهمية الاقتصادية والزراعية لنبات التين منذ وقت طويل، فمن المرجح أن يستمر هذا الاهتمام أيضا فى المستقبل مع اجراء بعض التعديلات للنظم الزراعية التى تحقق أفضل انتاجية للنبات.