Pruning Boosts Growth, Yield, and Fruit Quality of Old Valencia Orange Trees: A Field Study

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Article

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Abstract: Pruning is an important part in controlling the branching, good fruit size, and prodctivity of fruit trees. and consequently, 'Valencia' orange trees were grown many years ago, the trees were suffering from a decline in productivity in the newly reclaimed lands after certain years of plantation. This study elucidated the effect of pruning severity on growth, yield and fruit quality of 'Valencia' orange trees. Four levels of pruning were applied on 35 years old 'Valencia' orange trees as follows: T1: Control (un-pruned), T2: Light pruning (25% of main branches were removed); T3: Moderate pruning (50% of main branches were removed) and T4: Heavy pruning: 75% of main branches were removed. The treatments were done in February 15th (for each season). The results indicated that pruning severity increased vegetative growth paraments such as shoot length and leaf area and decreased canopy volume of Valencia orange trees in comparison to control. Maximum yield was gained from 75% followed by 50% and 25% pruning severity treatment. The pruning treatments improve in fruit weight, size, firmness, juice content, TSS%, TSS/acid ratio and vitamin C content. In addition, pruning produced an increasing in fruit yield per tree as well as yield increasing %. Hence, it might be concluded that pruning at different severity applied in February can be used effectively on 'Valencia' orange trees to improve vegetative growth, fruit physical and chemical properties. Besides, increasing fruit yield by nearly 20% in comparison to control.

Keywords: *Citrus sinensis* L.; decline in productivity; correct pruning; tree canopy; yield; Vitamin C

1. Introduction

Citrus is the most widely grown fruit crop in Egypt [1], and it ranks first among economically important fruit crops worldwide[2]. 'Valencia' orange is considered to be one of the most important oranges in the world and are said to be of Spanish origin [3]. The trees are medium in size, reaching 3 meters in height, and the fruits are medium to large, globes seedless or with seed traces, hard to peel, and have a sweet flavor [4]**.** The overall harvested area is 135962.5 ha, with total production of fresh orange fruits in Egypt is around 3,438,030 tons, with 1,600,000 tons exported [5]**.** 'Valencia' orange [(*Citrus sinensis* L.) (Osbeck)] is considered the most important cultivar for exporting purposes in Egyptian citrus industry [6].'Valencia' orange trees were grown many years ago, and consequently, the trees suffer from a decline in productivity in the newly reclaimed lands after certain years of plantation[7]. As the matter of fact, because of the ageing, the light dose not penetrate into the tree canopies[8], thus the inflorescence and fruits setting around the surface of the tree [9]. Hence, to maintain high production of optimum-sized, good-quality fruit, canopy management is an effective strategy [10]**.** One of the reasons for poor output in many fruit crops could be improper spacing. Planting density is designed in such a way that different managerial or biological characteristics correlate with one another and more trees can be planted in a compact area to boost economic results

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[11,12]. Accordingly, only limited research has been done on pruning severity of 'Valencia' orange grown under high density. Severe pruning is used as a last option to restore the plant to its previous state [13]. To revive the plants, skeletonization (heavily trimming the plant's framework with thick branches) is used [14]. It is attempted after top working, frame working, and pruning [15]. In any case, top working and pruning may be used to prevent citrus orchard decline if the extent of decline, age of the tree, soil and climatic conditions, and other factors are favorable [16].

Citrus tree pruning has long been known to improve fruit size and quality, avoid excessive fruiting, promote vegetative growth, improve light penetration into the tree canopy, and lengthen the tree's life span[10,17,18]. Pruning procedures in citriculture are critical for maintaining plant health and achieving an optimal balance of vegetative and reproductive activity[19]. Pruning at sever level increased shoot length, leaf area and decreased plant height of 'Nagpur' mandarin trees [20]. Pruning of 'Keitt' mango (removing 15, 30, and 45 percent of the tree canopy) improved vegetative growth when compared to unpruned trees. All pruning treatments resulted in a significant increase in leaf area and fruit yield/tree and fruit drop was minimized as a result of the severe pruning [21]. To avoid the following issues, a proper pruning schedule is required to keep the 'Valencia' tree[22] at a suitable size: a) In an orange orchard, the height and canopy shape of mature trees will not be uniform[23] b) The branches will cluster, and internal branches may perish due to a lack of sunshine[24]. The tree will only grow fruit on the canopy's surface, and it will become less prolific over time[25]. Fruit quality is generally poor, and trees do not always give fruit each year[26]. According to the above, the purpose of this study was to determine the impact of pruning severity on the productivity and fruit quality of 'Valencia' orange trees in order to achieve proper pruning management and increase output while maintaining good fruit quality. In addation, another the aim of this research is to opening the tree, which leads to an increase in the bright area to form new vegetative branches that bear the fruits of the following season and reduce the intertwined non-fruitful twigs and thus increase the yield.

2. Materials and Methods

2.1. Experimental Site

This research was conducted throughout the course of two subsequent seasons of 2019/2020 and 2020/2021 on 35-year-old 'Valencia' orange trees [(***Citrus sinensis* L.) (Osbeck**)] grown in sandy soil in a private orchard at Wadi Elmollak, Ismailia Governorate, Egypt (30°35'N, 32°14'E). The Climate graph of Ismailia Governorate, Egypt are presented in Figure 1. The region's climate is Mediterranean with an annual average temperature of 21.3 °C and an annual rainfall of 26 mm. The trees were budded on Volkamer lemon (***Citrus volkameriana* Ten. & Pasq.**) rootstock which is compatible for 'Valencia' orange trees. Trees were planted at 3 × 5 meters apart (666 trees/ha), and surface methods of drip irrigation was used in the research with 8 adjustable discharge emitters/trees (8 litter/h) through 2 irrigation lines. The soil of the studied area is sandy (94.72 % sand). This study aimed to determine the impact of pruning severity on the productivity and fruit quality of Valencia orange trees.

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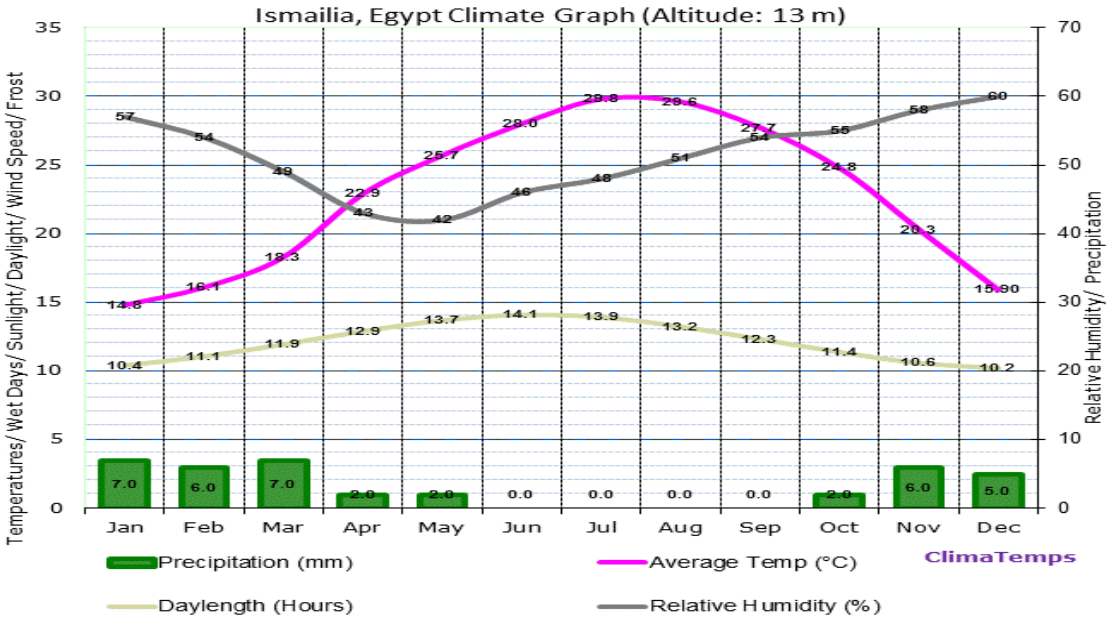

Figure 1. The Climate Graph of Ismailia Governorate, Egypt (http://www.cairo.climatemps.com).

2.2. Plant Material and Experimental Design

On the 'Valencia' orange cultivar, four levels of pruning were used Figure 2; each treatment had four replicates, each with three trees. The following treatments were performed on February 15th for each season:

T1 : Control (un-pruned)

T2:Light pruning: 25% of the major branches (9–12 cm in diameter) were cut off

T3:Moderate Pruning: Main branches (9–12 cm in diameter) were cut in 50% of the total

T4:Heavy pruning: Main branches with a diameter of 9 to 12 cm were cut in 75% of cases.

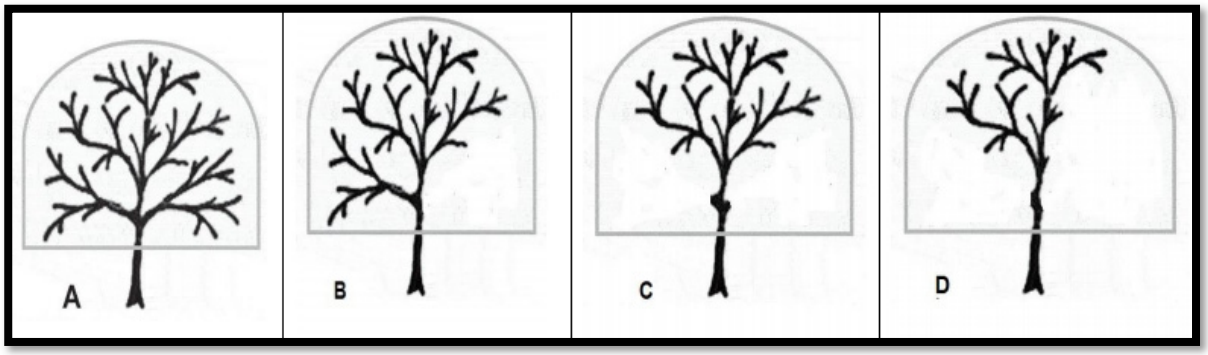

Figure 2. Tree forms used for pruning severity treatments. A) Control; B) Light; C) Moderate and D) Heavy. The diagram sample of the tree (A) according to Cronje et al. [18].

2.3. Measurements

Pruning treatments in this study were done in two different groups of Valencia orange trees in each season, and we have rerecorded the parameters of pruning treatments in the two seasons from those different groups of trees as follow:

2.4. Vegetative Growth: The Following Parameters Were Undertaken

2.4.1. Average Shoots Length (cm). To Measure Shoot Length (cm) at the End of Spring Cycle, Twenty Shoots per Tree Were Devoted Four Times on Three Different Trees

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2.4.2. Leaf Area (cm^2)

At the end of growth season sample of 20 mature leaves were devoted (the fifth distal leaf on the shoot). Moreover, the measure of length and width were recorded), then leaf area (cm^2) was calculated according to the following equation of [27]. Leaf area = 0.49 (Length x Width) + 19.09 = - cm^2

2.4.3. The Volume of Tree Canopy (m^3). Tree Size, Expressed as a Canopy Volume Was Measured and Calculated by the Equation of Zekri [28] as Follows: Tree Canopy Volume (m^3) = 0.52 × Tree Height × (Diameter^2)

2.5. Yield

On February 5th fruit yield harvesting was achieved according to Farag et al. [29] and the yield increasing % when severe pruning impact was compared to the control.. Therefore, percentage was calculated by using [30] equation as follows.

$$\text{Yield increasing (\%)} = \frac{\text{Yield (treatment)} - \text{yield (control)}}{\text{yield (control)}} \times 100$$

2.6. Physical Properties of Fruit

For determine the physical and chemical properties of 'Valencia' orange fruits, at harvest duration ten fruits were chosen as a sample. Then, the sample was replicated 3 times. Fruit weight and volume, fruit firmness (kg/cm^2) was measured in fruit using pressure tester (Digital force-Gauge Model FGV-0.5A to FGV-100A. Shimpo instruments), the volume of fruit juice (mL), peel weight of fruit (g), thickness of fruit peel (cm), and finally pulp weight of fruit were recorded.

2.7. Chemical Properties of Fruit

Total soluble solids percentage and total acidity percentage and vitamin C were determined in the fruit juice as follows: Total soluble solids, TSS (%) digital refractometer was used to determine TSS% of fruit juice. Titratable total acidity (%) was expressed as percent citric acid mg100 mL^{-1} juice [31]. TSS/acid ratio was calculated from the values of total soluble solids divided by values of titratable total acids. Vitamin C (ascorbic acid) expreesed as (mg/100mL juice) was estimated by titrating juice sample with 2,6 dichlorophenol indophenol dye according to **A.O.A.C.** [31].

Statistical Analysis

The analysis of variance (ANOVA) was conducted using Stern [28] one-way ANOVA Co-stat software and a complete randomized block design, and the means were compared using Duncan's multiple range testing at the 5% level [29].

3. Results and Discussion

3.1. Effect of Pruning Severity on Vegetative Growth

3.1.1. Shoot Length

The length of shoots 'Valencia' orange trees was found influenced significantly by renewal pruning severity (Figure 3A). A perusal result showed that when trees were pruned at 75% severity, there was maximum length of growing shoots and it followed by those pruned at 50%, 25% levels of renewal pruning and the unpruned trees (control). The lowest shoot length was recorded with the unpruned treatment (control). The results are consistent with those of Dashora et al., [32] who reported that shoot length was raised by sever levels of rejuvenation pruning of 'Nagpur' mandarin trees. The increase in shoot length caused by pruning severity levels may be due to more resources

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were diverted to a smaller number of branches as a result of pruning and elimination of unhealthy shoots, which operated as a sink rather than a source of nutrients [20]. The role of proper nutrition and metabolite balance in this feature was described by Pandey [33] in mango [13] recorded the maximum length of shoot after rejuvenation pruning. Awasthi and Mitra [34] found that pruned trees had a higher length of shoots than unpruned plants.

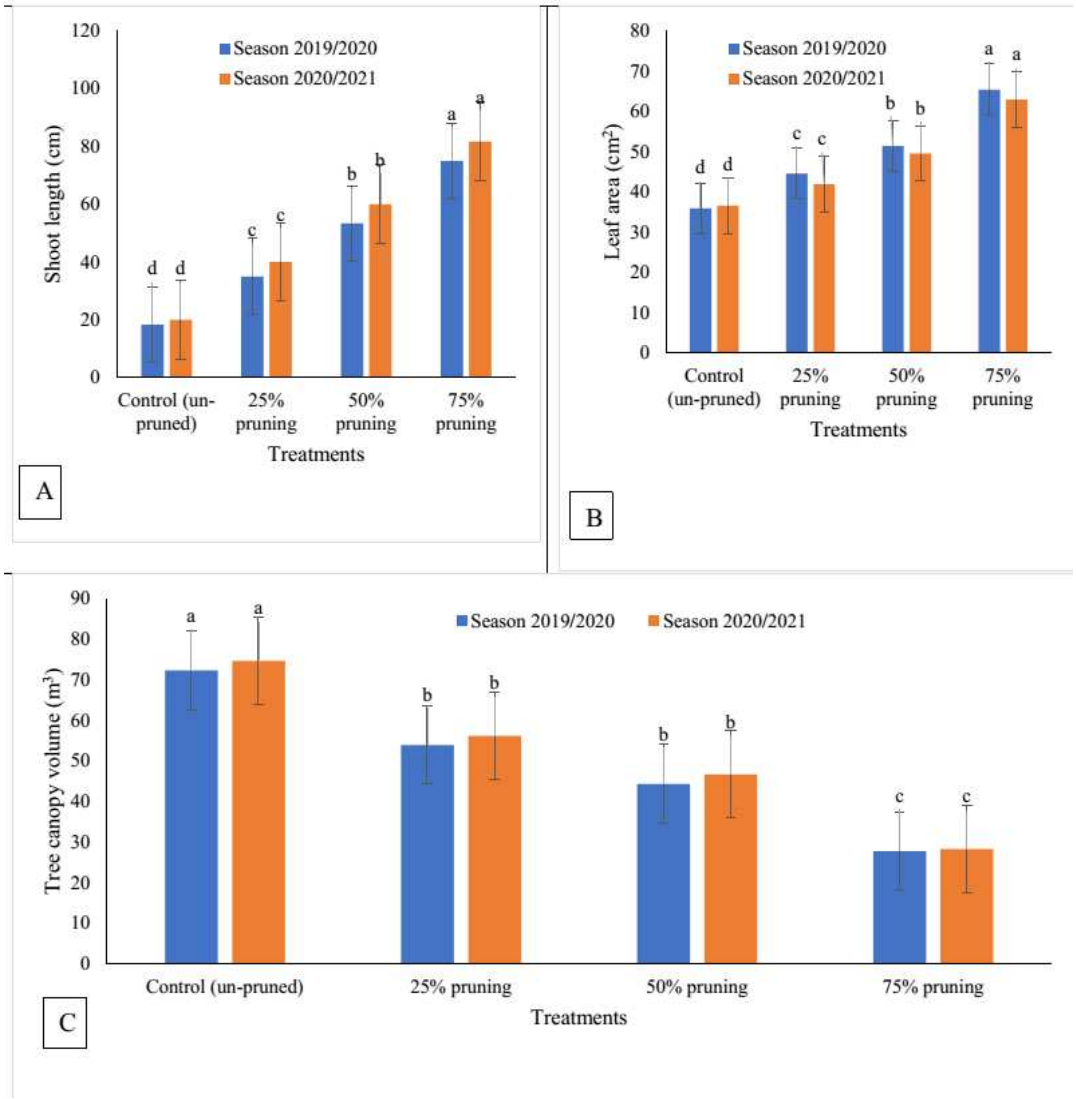

Figure 3. Effect of pruning severity on: A) shoot length (cm), B): leaf area (cm²) and C) tree canopy volume (m³) of 'Valencia' orange trees during 2019/2020 and 2020/2021 seasons. Bars indicate mean values ± SE (n = 9). Different letters above columns indicate significant differences among pruning treatments at *P* = 0.05 according to Bartlett's test.

3.1.2. Leaf Area

Data in (Figure 3B) also indicated that all pruning levels significantly increased the leaf area of 'Valencia' orange trees when compared with that of control (unpruned). Trees pruned at 75% severity had the maximum leaf area, followed by those pruned at 50 percent, 25 percent renewal pruning, and unpruned trees (control). The control treatment produced the smallest leaf area. The same results were observed by Salama et al., [21] who discovered that all pruning treatments boosted the leaf area of the 'Olinda' orange trees. Also, Patil et al., [35] found that sever pruning increased leaf area in acid lime trees. The leaf area increasing parameter might be attributed to the possible that the availability of more photosynthesis and nutrients in severely pruned trees prompted vegetative growth by enhancing cell division and the production of more tissues, which triggered vegetative

growth by enhancing cell division and the formation of more tissues [16] in lemon. Severity of pruning improved vegetative growth in guava trees compared to control plants [36].

3.1.3. Tree Canopy Volume

The effects of varied levels of pruning severity on canopy volume on the 'Valencia' orange tree over the 2019/2020 and 2020/2021 seasons were clearly shown in the results presented in (Figure 3C). The canopy volume of 'Valencia' orange trees that were trimmed by removing 75% of main old branches had the lowest values compared to those that were trimmed by removing 50%, 25%, and control treatment, in the two seasons of the study, there were insignificant differences between 50% and 25% pruning treatments. The same results were observed by Chueca et al., [37] who found that pruning treatment caused a decrease in the percentage of the canopy size in the Navel Foyos orange tree. The variances in the canopy volume of tree vigor may be attributed to the rejuvenation pruning treatment [38]**.** According to Cronje et al., [18] canopy volume improved throughout the experiment period, regardless of treatment in 'Nadorcott' mandarin trees, however, canopy volumes differed significantly between treatments. These results are in consistent with earlier research [38] who reported that the tree spread, tree canopy volume is always higher in unpruned trees than in pruned trees. We can conclude that pruning severity increased the vegetative growth paraments such as (shoot length and leaf area) and decreased canopy size of the 'Valencia' orange tree in comparison to the trees of control.

3.2. Effect of Pruning Severity on Yield/Tree

As can be shown in the Figure 4A results clearly presented that the yield/tree of 'Valencia' orange tree was significantly increased by pruning levels when done in February 15th for each season in comparison to unpruned one (control). Maximum fruit yield/tree was gained from 75% followed by 50% and 25% pruning severity treatment. Whereas, the lowest yield values were recorded with the unpruned trees nearly 64 (kg/tree). The current results are in line with that of **Umar et al.,** [39] who stated that sever pruning of 12-year old 'Kinnow' mandarin trees improved yield compared with light or uprunning. According to Salem et al. [40] who reported that among the pruning treatments the highest increase in fruit retention percentage of 'Balady' mandarin trees was associated with increasing of pruning severity and all of treatments increased fruit retention percentage compared to trees of control**.** In addition, Dashora et al. [20] who found that level of rejuvenation pruning had important positive connection with fruit yield/tree. Similarly, Hamdy [41] discovered that both the investigated 'Murcott' and 'Fremont' mandarin trees significantly increased their yield/tree with modest trimming (50 percent). The fruit yield increasing with 75% sever pruning, 50% moderate pruning and 25% light pruning in comparison with those of control could be attributed to the positive effect removing the old main branches from the trees. In fact, removing an old main branch allows light to penetrate the orange tree, promoting the growth of leafless inflorescence. The results are in accordance with the findings of Salama et al. [21] who stated that pruning (removing 15, 30, and 45 percent of the tree canopy) improved fruit yield/tree and fruit drop of 'Olinda' orange trees was minimized as a result of the severe pruning. The results indicated also that the yield increasing reached nearly 20% fruit yield/tree in compared to unpruned trees in the two studied seasons (Figure 2). This finding is in the same line with Hamdy [41] in 'Murcott' and 'Fremont' mandarin trees. In addition, Chueca et al. [37] found that manual pruning treatment caused an increase in the yield per tree in the 'Navel Foyos' orange tree in comparison to mechanical pruning. According to the above-mentioned literature, young and mature citrus trees respond differently to pruning, and it depends on the manner and intensity of the pruning (i.e., the kind and placement of the branches cut), as well as the changes in light interception that result before and after pruning. Because of this, it's possible that variations in crop load brought on by pruning form, severity, and growing tree age played a role in the treatment differences found in the current study during the trial period. It could be concluded that pruning increased the yield per tree in comparison to control. Maximum fruit yield/tree was gained from 75% followed by 50% and 25% pruning severity

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treatment. Yield increasing reached nearly 20% fruit yield/tree in compared with unpruned trees (Figure 4B).

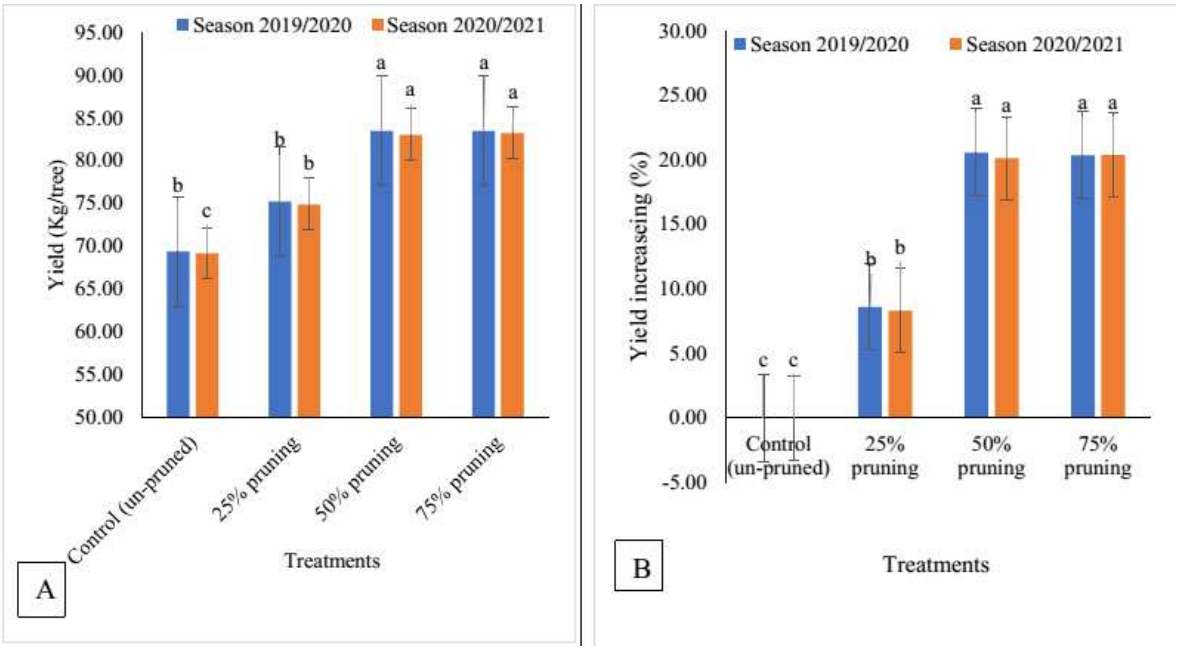

Figure 4. Effect of pruning severity on: A) yield (kg/tree), and B): yield increasing (%) of 'Valencia' orange trees during 2019/2020 and 2020/2021 seasons. Bars indicate mean values ± SE (n = 9). Different letters above columns indicate significant differences among pruning treatments at $P = 0.05$ according to Bartlett's test.

3.3. Physical Characteristics of Fruit

3.3.1. Fruit Weight and Volume

The marketability and profitability of 'Valencia' are heavily influenced by fruit size. In the export market, large fruits have a higher commercial price [42,43]**.** Figures 5B–D and 6A clearly showed that pruning applied on the orange cultivar 'Valencia' in February 15th with levels 25%,50% or 75% ppm increased fruit weight and volume as well as fruit (diameter and height) in comparison to that of control in both seasons studied. Higher level of pruning at 75% resulted in more increase in fruit weight and volume than 25%, 50% severity. Similar trends were found in fruit parameters such as fruit pulp weight, peel thickness and peel weight (Figure 6A–D). The lowest dimensions of orange fruit were obtained by the control trees in the two study seasons compared with other pruning treatments due to their higher number of fruits per tree (Figure 5A). It was shown that the negative association between fruit volume and yield was significantly significant. Additionally, a strong association between fruit volume and tree canopy volume further revealed how pruning affects production and, in turn, fruit volume. The current findings are consistent with those previously made by **Salama et al.,** [21] who reported that pruning (removing 15, 30, and 45 percent of the tree canopy) improved fruit size of 'Olinda' orange trees. In addition, **Cronje et al.,** [18] found that fruit volume of 'Nadorcott' mandarin improved throughout the pruning treatment. The increasing in fruit dimensions (weight and volume) might be attributed to the increase in photosynthates produced by an rise in the number and area of leaves causes a large increase in the weight and size of fruit [44]**. Hamdy's finding** [41] that pruning improved fruit weight, fruit diameter, and fruit length in the 'Murcott' and 'Fremont' mandarin trees were supported by the findings of this study.

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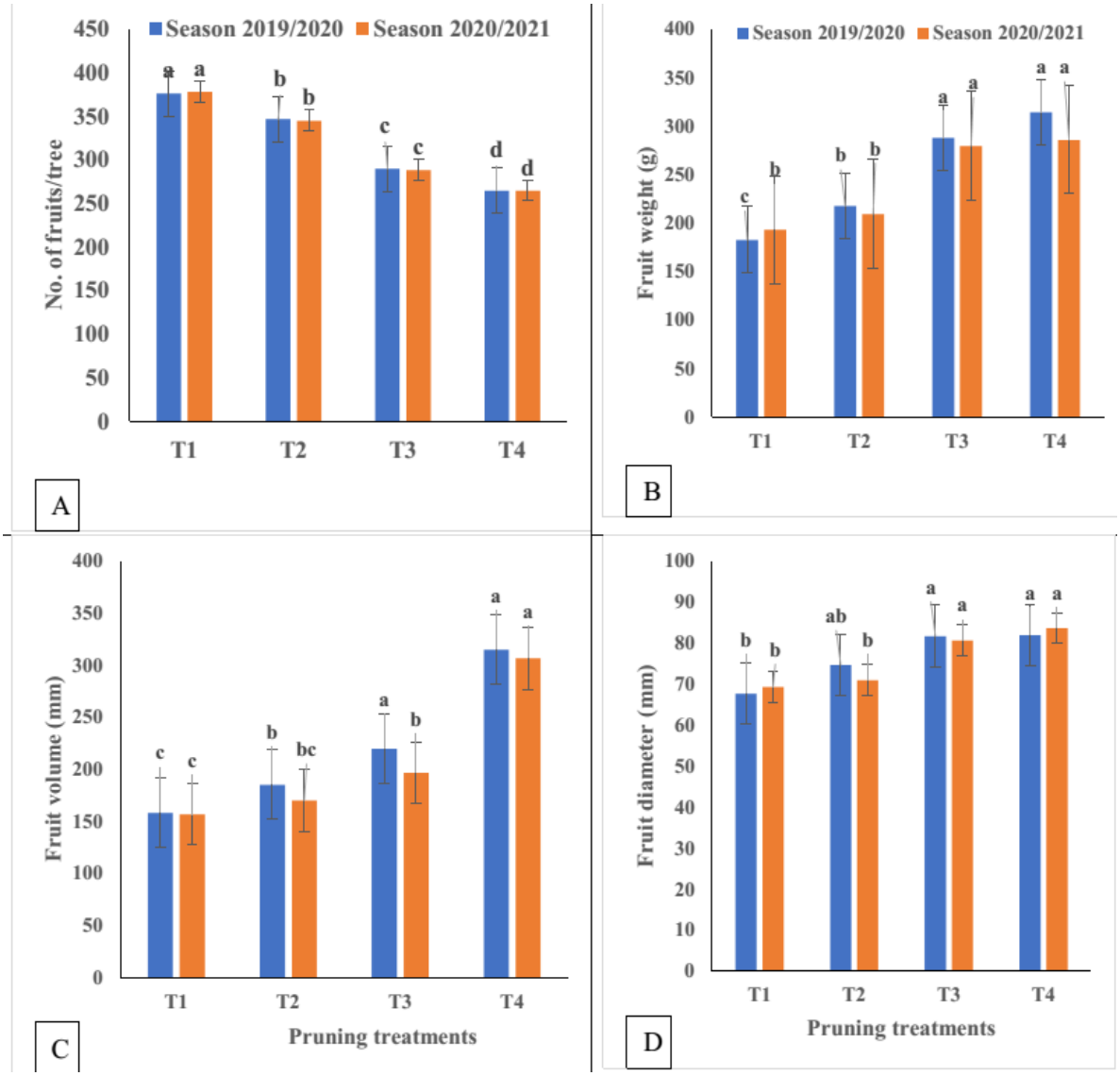

Figure 5. Effect of pruning severity on: A) No. of fruits/tree), B): fruit weight(g), C): fruit volume and D): fruit diameter (mm) of 'Valencia' orange trees during 2019/2020 and 2020/2021 seasons. T1: Control, T2: T2 Light pruning, T3: Moderate pruning and T4: Heavy pruning Bars indicate mean values ± SE (n = 9). Different letters above columns indicate significant differences among pruning treatments at *P* = 0.05 according to Bartlett's test.

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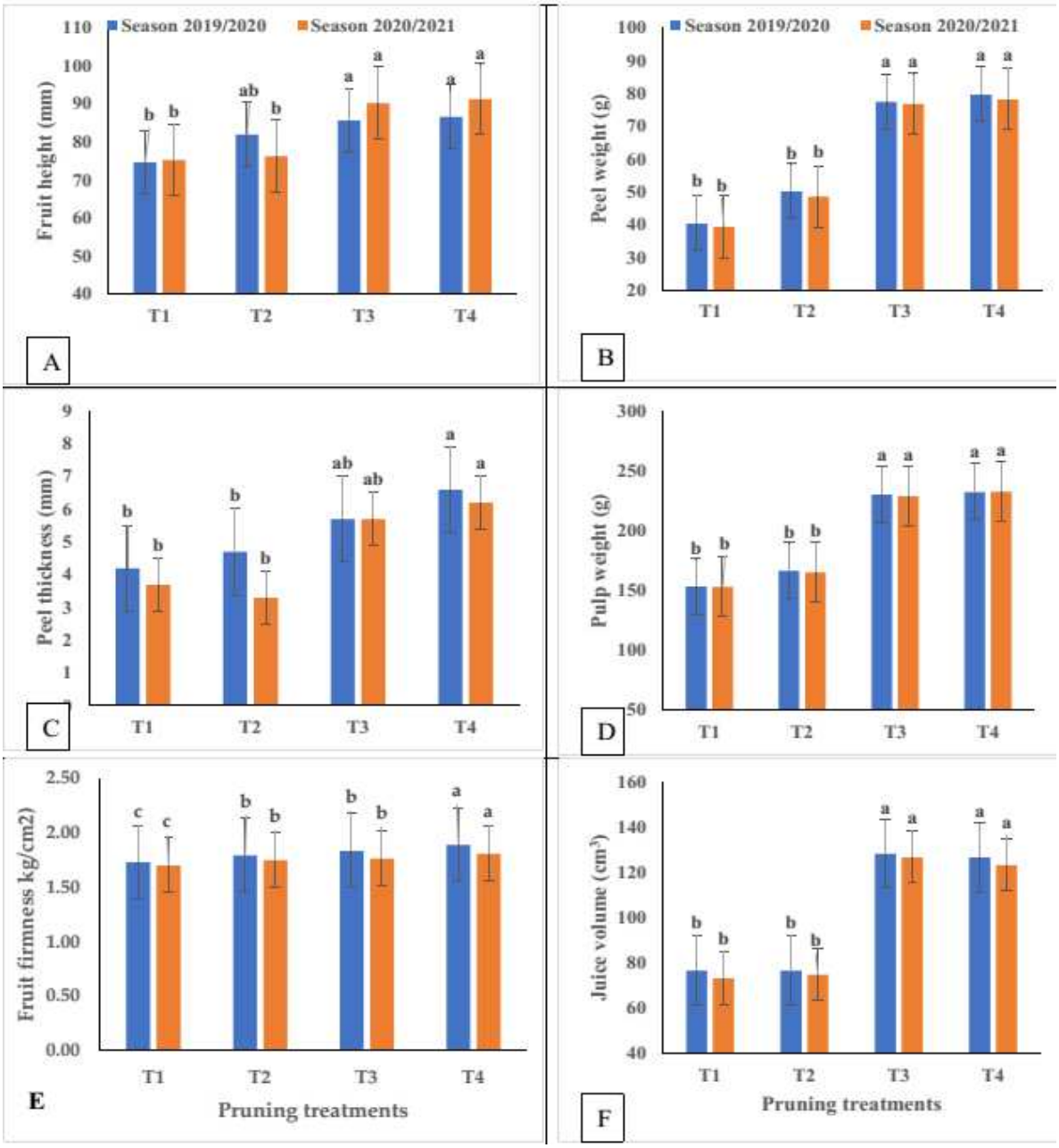

Figure 6. Effect of pruning severity on: A) fruit height (mm), B): peel weight(g), C): peel thickness (mm), D): pulp weight (g), E): fruit firmness (kg/cm²) and F): juice volume (cm³) of 'Valencia' orange trees during 2019/2020 and 2020/2021 seasons. T1: Control, T2: T2 Light pruning, T3: Moderate pruning and T4: Heavy pruning Bars indicate mean values ± SE (n = 9). Different letters above columns indicate significant differences among pruning treatments at $P = 0.05$ according to Bartlett's test.

3.3.2. Fruit Firmness

Results also in Figure 6E indicated that treatments of pruning induced significantly increased the firmness of fruit (kg/cm²) of the 'Valencia' orange tree in comparison to the unpruned one. 75% of pruning level possessed the higher values of the fruit firmness followed by other pruning treatments or control. While, in the two seasons of the study, there were insignificant differences between 50% and 25% pruning severity. The influence of pruning at different levels on fruit quality and yield yielded different outcomes for the researchers. for example, found that pruning increased fruit firmness, of 'Murcott' mandarin fruit which is like our findings in the 'Valencia' orange [41].

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3.3.3. Juice Content of Fruit

The pruning application had a considerable impact on the fruit's juice volume Figure 6F. When compared to those of control (unpruned) that had the least juice volume, 75 percent of pruning level gained the most juice volume. The current findings backed up those of Yildirim et al., [45] who discovered that pruning application had a considerable positive impact on the content of juice Star Ruby grapefruit fruit. Pruning 'Fermont' and 'Murcott' mandarin cultivars considerably enhanced fruit juice content. according to, Hamdy [41] who claimed that fruit juice volume was greatly boosted by trimming 'Fermont' and 'Murcott' mandarin cultivars. Type of pruning was affect in fruit juice content [46]. It's possible that the higher juice content in fruits collected from plants following pruning treatments is related to increased sunlight penetration and nutrition availability to the trees [47].

3.4. Chemical Characteristics of Fruit

3.4.1. TSS %, TSS/Acid Ratio and Total Acidity

The results in Figure 5 showed that pruning treatments at Feb. 5th significantly increased TSS % and TSS/acid ratio of 'Valencia' fruit juice. 50% (moderate pruning) gained the maximum TSS % and TSS/acid ratio compared with those of other treatments or control (unpruned). In this regard, insignificant difference was found between 75% severity pruning or the control treatments. The current findings are consistent with those previously made by [48,49] who reported that all pruning methods eventually increased soluble solids content: acidity ratio compared to the unpruned control. In addition, **Umar et al.** [50] found that pruning treatments significantly increased TSS% and ripening index (TSS: acid ratio) in fruits of 'Kinnow' mandarin trees. Higher TSS percentage in fruits could be attributed to higher carbohydrate buildup and enough supply [47,50,51]. Data also showed that 75% heavy pruning and control trees produce acidic fruits with the maximum total acidity values followed by those 25% light pruning or 50% moderate pruning. The results agreed with **Javaid et al.** [52] who discovered that the Kinnow mandarin variety's overall acidity was reduced by trimming and **Martin-Gorriz et al.** [53] on 'Fortune' mandarin. In addition, **Hamdy** [41] on 'Fermont' and 'Murcott' mandarin trees.

3.4.2. Vitamin C

The results in Figure 5 also showed that the light pruning treatments had a substantial impact on Vitamin C concentration when compared to the control group. The current findings corroborate those of Salama et al. [21] who discovered that trimming 'Olinda' orange trees boosted fruit ascorbic acid concentration. Similarly, Baghdady [54] in comparison to moderate 50 percent light 25 percent pruning and control trees, excessive pruning (75 percent of 2-year-old branches were eliminated) resulted in the highest level of vitamin C in 'Balady' mandarin. The increase in ascorbic acid content in the fruits could be attributed with the increase in the level of nutrients availability like potassium. **Ananthi** [55] discovered that potassium may have assisted in reducing the rate of the enzyme system that promoted ascorbic acid oxidation, enabling the plants to collect more ascorbic acid in the fruits.

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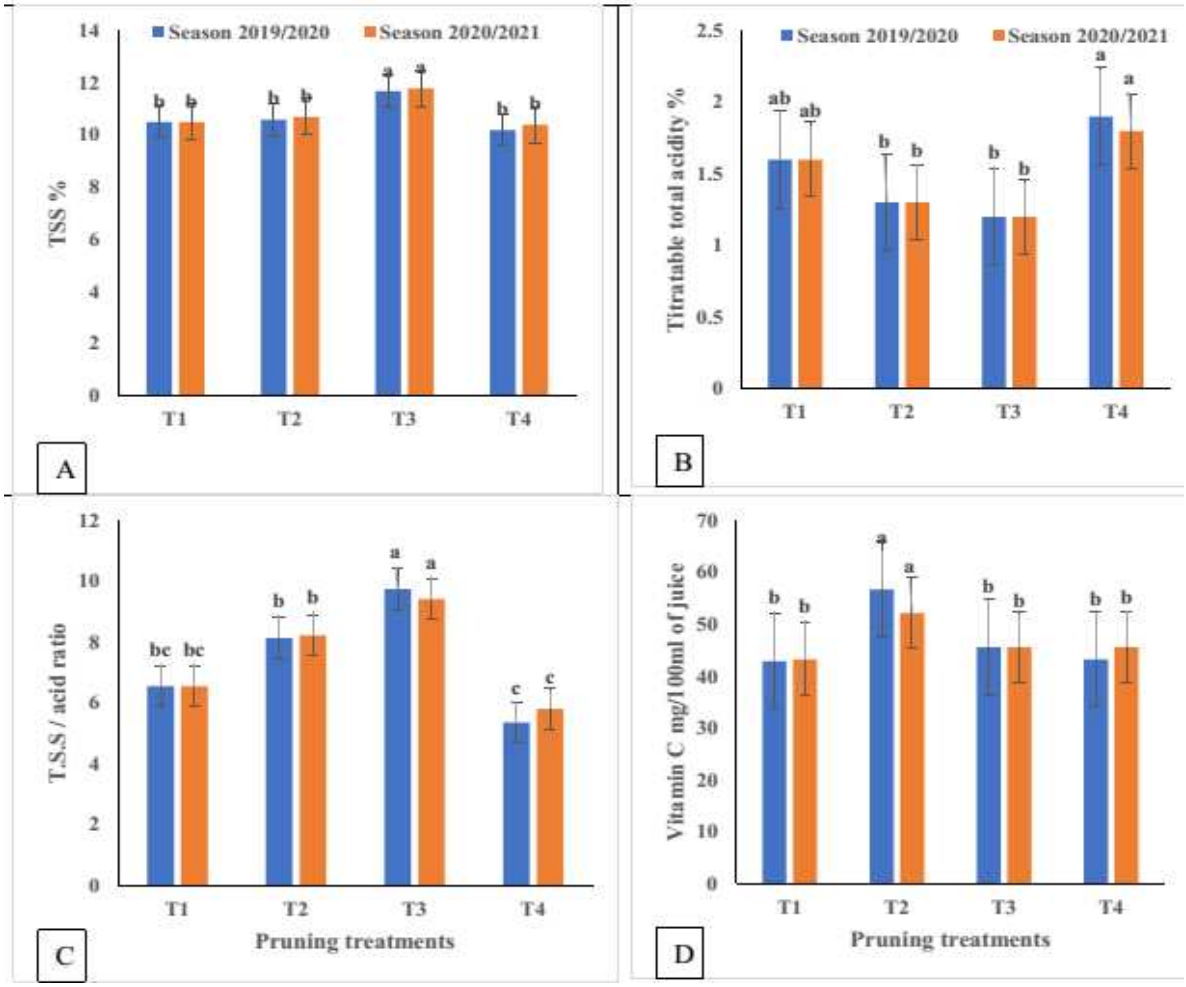

Figure 7. Effect of pruning severity on: A) TSS (%), B): titratable total acidity (%) C): TSS/acid ratio, D): Vitamin C of 'Valencia' orange trees during 2019/2020 and 2020/2021 seasons. T1: Control, T2: T2 Light pruning, T3: Moderate pruning and T4: Heavy pruning Bars indicate mean values ± SE (n = 9). Different letters above columns indicate significant differences among pruning treatments at $P = 0.05$ according to Bartlett's test.

4. Conclusions

In conclusion, the pruning level procedure is a successful technique. 'Valencia' orange trees increased their shoot growth, leaf area, and canopy volume in response to severe pruning treatment. Moreover, pruning produced an increase in fruit yield per tree and yield increasing (%). Maximum fruit yield per tree was increased by 75%. In addition, the pruning treatments caused an improvement in the fruit's physical and chemical properties. Finally, it might be concluded that pruning at different levels of severity applied in February can be used effectively on Valencia orange trees to improve vegetative growth and fruit physical and chemical properties. Besides, it increases fruit yield by nearly 20% in comparison to control.

Author Contributions**:** Conceptualization, A.M.S; H.F.A; I.A.E; A.N. A; A.A.S; A.E.H, and S.M.K; methodology, S.M.K; A.M.A; H.F.A; I.A.E; A.N. A; A.A.S; and A.E.H,; software, A.M.S; H.F.A; I.A.E; A.N. A; A.A.S; A.E.H, and S.M.K; validation, A.M.S; H.F.A; I.A.E; A.N. A; A.A.S; A.E.H, and S.M.K; formal analysis, H.F.A; investigation, S.M.K; resources, H.F.A and A.E.H ; data curation, H.F.A and A.E.H ; writing—original draft preparation, H.F.A and A.E.H writing—review and editing, S.M.K and A.M.A; visualization, A.M.S; H.F.A; I.A.E; A.N.A; A.A.S; A.E.H, and A.M.S; supervision, A.M.A and S.M.K; project administration, A.M.S and S.M.K; funding acquisition, A.M.S All authors have read and agreed to the published version of the manuscript.

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