RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

4.1.Response of Washington navel orange trees to different irrigation rates:-

4.1.1. Vegetative growth:

4. 1. 1. 1. Tree canopy volume:-

The tree canopy volume, as shown in Table (2), ranged from 1.42 to 2.63 m^3 in the first season and from 1.65 to 2.93 m^3 in the second season. The tested levels of irrigation significantly affected tree canopy volume in both seasons. The least values (1.42, 1.65 m^3 in the two seasons, respectively) were obtained by the lowermost irrigation level (1850 m^3/fed./yr.). The highest values (2.63, 2.93 m^3) were gained by the uppermost irrigation rates (5550 m^3 / fed./yr.). The intermediate irrigation level (3700 m^3/fed./yr.) gave in between values(1.71,1.78 in the two seasons, respectively).

4. 1. 1. 2. Increase in shoot length and thickness:

The main indices of shoot vigor i.e. increase in shoot length and thickness through the season (as a percent of initial shoot measurements at the beginning of growth) are given in Table (2). Percentage increment of shoot length generally ranged from 193.8 to 223.9% in the first season and from 167.9 to 249.9% in the second season. The irrigation rates significantly affected the increase in shoot length in both seasons. The least increase (193.8, 167.9 % in two seasons) resulted from the lowermost irrigation level (1850 m^3/fed./yr.). However, the intermediate level (3700 m^3/ fed./yr.) generally promoted the increase in shoot length to reach 206.2 , 209.6 %, respectively. The increments due to the uppermost level (5550 m^3/fed./yr.) were significant, since the increments reached 223.9 , 249.9%, respectively.

The increase in shoot thickness in response to the increase of irrigation rate ranged from 35.16 to 47.83 % in the first season and from 33.33 to 70.42 % in the second season. The least values (35.16, 33.33 % in the two seasons) were obtained by the lowermost irrigation rate (1850 m^3/fed./yr.). Meanwhile, intermediate and high levels of irrigation (3700,5550 m^3/fed./yr.) significantly increased shoot thickness (39.09 - 47.83 % in the first season and 62.42 - 70.42 % in the second season).

4.1.1.3. Leaf parameters

4.1.1.3. a. Leaves number per shoot and leaf area:

Table (2) reveals the percentage increment of leaves number per shoot and average leaf area (cm^2) in response to irrigation rate. The percentages of increment of leaf number per shoot, generally, ranged between 64.51 to 146.89 % in the first season and from 63.13 to 206.21% in the second season. Increasing irrigation rate from 1850 to 5550 m^3/fed. /yr. nearly recorded 2-3 fold increase in the number of leaves per shoot (146.89 - 206.21 % in the two seasons, respectively). The uppermost irrigation level added a significant increment comparatively with that of intermediate irrigation level. This trend was true in both tested seasons.

The average leaf area, generally, increased in response to the increase in irrigation rate. The uppermost level (5550 m^3 fed./ yr.) was leading in this respect and recorded 35.4 , 38.4 cm^2

in the first and second seasons, respectively against 32.50 , 32.07 cm^2, respectively for the lowermost irrigation level (1850 m^3 / fed./ yr.).

Generally, the obtained results indicate that increasing irrigation rate up to 5550m^3/fed/year clearly promoted tree canopy volume and shoot growth, as well as leaf surface area. These results are in general agreement with **Deidda *et al*** (1994), and **Castel & Buj** (1995) on Clementine mandarin they mentioned that trees irrigated at the 40% of ETP level had significant less growth than those in the other higher level treatments. Moreover, **Castel** and **Buj** (1994) on grapefruit trees reported that trees receiving moderate levels of irrigation water had the largest canopies and trunk diameters and highest vegetative growth.

4.1.1.3.b.Leaf dry matter contents:

Table (3) shows leaf dry weight percentages in response to irrigation rate. The differences between samples were not greatly obvious. However, the average values indicate progressive increment in leaf dry matter percentage with increasing irrigation rate. But only trees irrigated with the highest rate gave significantly the highest dry matter percentage among the other levels used in this study. The results of the second season gave the same trend of the first one.

4.1.1.3.c. Leaf nutrients content:

As shown in Table (3) the leaf nutrients content (N, K, Mn, Zn & Fe) of Washigton navel orange trees were significantly increased with the increase in irrigation rate. Meanwhile, leaf

Table (2) Effect of different irrigation rates on some vegetative growth characteristics of Washington navel orange trees (seasons of 1997&1998)..

Irrigation rate m^3/ fed./ yr.	Tree canopy volume (m^3)	Percentage increments of:* Shoot length	Shoot thickness	Leaf number	Leaf area (cm^2)	Leaf dry weight (%)
Season 1997						
1850	1.42 **c**	193.86 **b**	35.16 **b**	64.51 c	32.50 **b**	40.93 **b**
3700	1.71 **b**	206.20 **ab**	39.09 **ab**	104.30 **b**	33.27 **b**	41.51 **b**
5550	2.63 **a**	223.93 **a**	47.83 **a**	146.89 **a**	35.40 **a**	42.21 **a**
Season 1998						
1850	1.65 **c**	167.97 **c**	33.33 **b**	63.13 c	32.07 **b**	40.38 **b**
3700	1.78 **b**	209.64 **b**	62.42 **a**	76.46 b	35.53 **a**	40.99 **b**
5550	2.93 **a**	249.94 **a**	70.42 **a**	206.21 **a**	38.40 **a**	43.46 **a**

Table (3) Effect of different irrigation rates on some leaf chemical constituents of Washington navel orange trees (seasons of 1997&1998).

irrigation rate m^3/ fed./ yr.	N (%)	P (%)	K (%)	Fe (ppm)	Zn (ppm)	Mn (ppm)
Season 1997						
1850	2.16 c	0.13 **a**	1.06 c	74 c	42.7 c	38.0 c
3700	2.26 b	0.14 **a**	1.16 b	89 b	47.3 b	44.7 b
5550	2.42 a	0.15 a	1.36 a	112 a	53.3 a	46.3 a
Season 1998						
1850	2.18 **c**	0.13 **a**	1.10 c	77 c	55.3 b	35.0 c
3700	2.33 **b**	0.16 a	1.28 b	92 b	56.3 ab	42.3 b
5550	2.60 **a**	0.15 a	1.42 a	110 a	62.7 a	55 a

phosphorus content did not show any appreciable response to the irrigation rates used in this study, such trend was true in both studied seasons.

It was obvious that increasing irrigation rate promoted the content of all determined nutrients except phosphorus. The obtained results are in general agreement with the related literature. Thus, **Maurer** ***et al*** (1995) on, Redblush grapefruit and **Iobishvili & Mikautadye** (1984) on mandarin found that irrigation increased N and K content in both old and young leaves and the higher application rate gave only slightly higher nutrients level in comparison with lower rate. The control treatment had the lowest leaf nutrients content.

4.1.3. Fruit set and periodic fruit drop:

4.1.3.1 fruit set:

As shown in Table (4), fruit set percentages indicated an obvious response to increasing irrigation rate in both seasons. Differences between the tested irrigation water levels were always statistically significant. However, increasing irrigation rate from 1850 to 5550 m^3/fed./yr. promoted fruit set by around 6% in both seasons, while fruit set in the second season was some what higher in comparison with those of the first one. Fruit set percentages ranged between 37.7 to 43.84% in the first season and from 40.26 to 46.34% in the second season.

4.1.3.2. Periodic fruit drop (%):

Data presented in Table (4) and illustrated in Fig(1) show the effect of different irrigation rates on the periodic fruit drop percentages throughout the three main stages of fruit growth (i.e. at June drop stage, fruit development stage and pre-harvest drop stage).

During the period of June drop, trees received the lowermost irrigation level dropped most of their fruits in this stage (75.3 72.94% in the two seasons, respectively). Meanwhile, trees received intermediate irrigation level dropped 53.4 & 52.85% in the same two seasons, respectively. Simultenously, trees irrigated by the uppermost level of irrigation dropped only 41.5and 41.66% of their fruits in the two seasons, respectively. Therefore, it is quite evident that, in both seasons of study, fruit June drop percentages decreased significantly with the increase in irrigation rate up to the level of 5550 m^3/fed./year.

During fruit development stage, trees received the intermediate irrigation level were leading in the percentages of dropped fruits that amounted to 33.89and 34.93% in the two seasons, respectively, followed by trees received the uppermost level which dropped 25.48and 24.18 % in the same period. However, trees received the lowermost level dropped only 13.79 and 13.21% in the first and second seasons, respectively.

Concerning the pre- harvest drop stage, the highest percentage of fruit drop in this period was reported by trees received the uppermost level (16.76 and 21.12% in the two seasons, respectively), followed by trees irrigated by lowermost level (11.70 and 10.0%, respectively). On the other hand, application of the intermediate level of irrigation water had a moderate percentages of fruit drop that amounted to 6.81and 5.33 % in the same two seasons, respectively.

Generally, increasing irrigation water level significantly increased fruit set percent and regulated fruit drop rates recorded throughout the three stages of fruit growth. However, lowermost level attained the lowest fruit set percentage and those fruits tended to drop early in the growth season. The obtained results concerning fruit set are in a general agreement with **Sanchez** *et al* (1989) on *C. lemon,* **Castel** (1994),on Clementine **Davies** *et. al* (1994)on Valencia. In this respect they mentioned that increasing irrigation rates significantly affected flowering and fruit set. Moreover, **Germana at al** (1994) on orange mentioned that daily irrigation treatments reduced fruit drop.

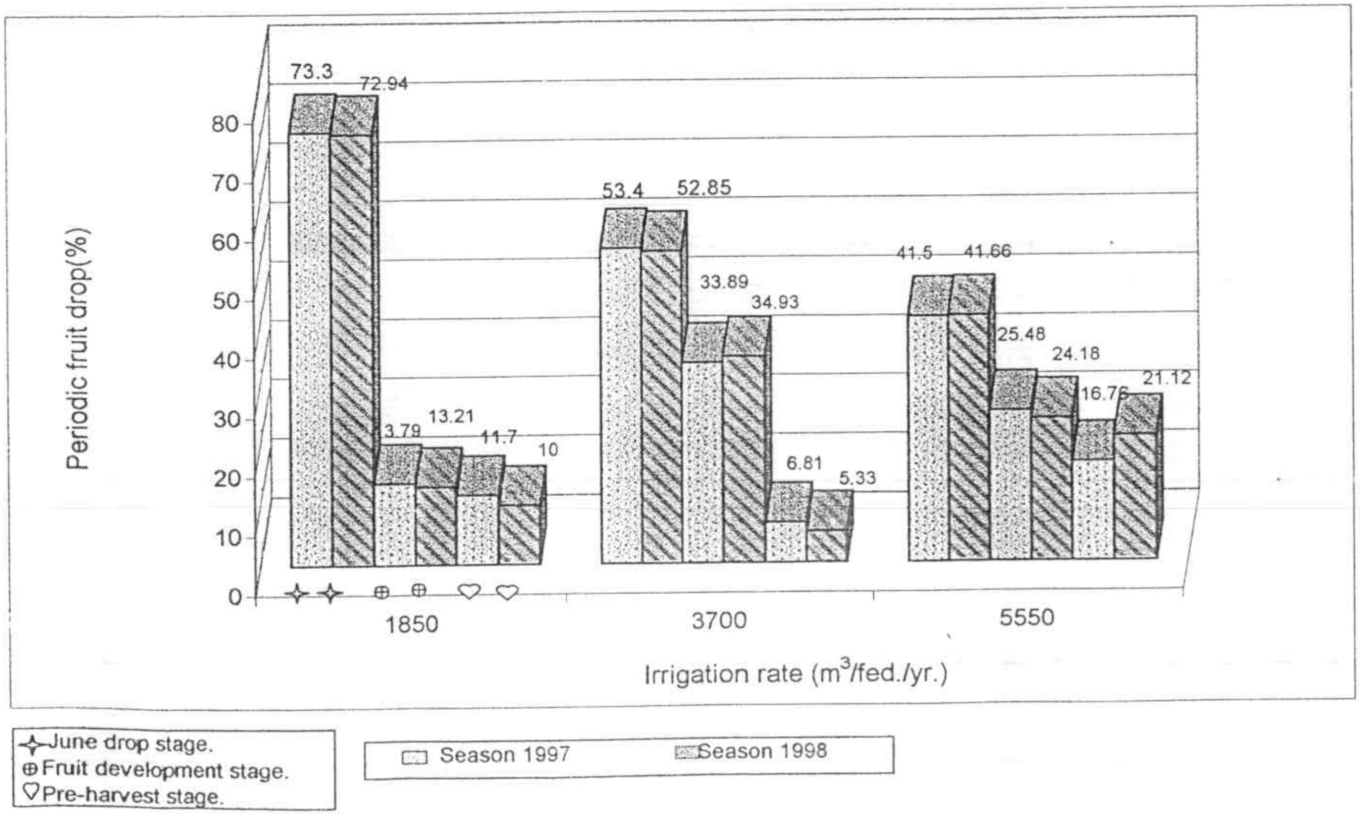
Furthermore, table (4) shows that total fruit drop during the whole season, ranged from 85.20 to 97.91 % in the year 1997 and from 86.96 - 96.08% in 1998.

Concerning the effect of irrigation water levels on total fruit drop, it is clear that the lowermost level (1850 m^3/fed./yr.) induced the highermost total fruit drop percentages (97.91 and 96.08 % in the two seasons respectively). The intermediate level (3700 m^3/fed./ yr.) decreased fruit drop by around 3-4% in both seasons compared with the lowermost irrigation water level. The uppermost irrigation level (5550 m^3 / fed./ yr.) depressed total fruit drop again by around 9% in the first season and 6% in the second season.. The differences in total fruit drop were significant in response to the different irrigation rates used. Present data are ageneral agreement with that mentioned by **Germana at al** (1994),**Huang**(1989) on orange and **Barbera &Carimi**(1988) on lemon.

4.1.4. Yield parameters:

The effect of different levels of irrigation rates on yield of Washington navel orange trees expressed as, number of fruits per

Fig (1): Effect of different irrigation rates on periodic fruit drop of Wshington navel orange trees (Seasons of 1997 & 1998).



tree, yield in kilograms per tree, and yield in tons per feddan is shown in Table (5).and Fig(2)

The number of fruits per tree generally ranged between 92 and 212 in the first season and between 98.33and 228 in the second season. The effect of different irrigation rates was significant in both seasons of study. The lowermost level (1850 m^3/fed./yr.) produced the least number of fruits. The intermediate level (3700 m^3/ fed./yr.) significantly increased the harvested fruits comparatively with that of lowermost level. However, the uppermost level (5550 m^3 /fed./ yr.) added significant increase and recorded the highest number of fruits per tree.

Concerning total yield in Kgs. per tree, the data indicated that it responded significantly to the irrigation rates used in both seasons. The lowermost level (1850 m^3 /fed./yr.) produced only 14.54 and 16.62 kg /tree in the two seasons, respectively. The intermediate level (3700 m^3 /fed./ yr.) increased the yield/tree by around 19-22 kg / tree in the two seasons, respectively compared with the lowermost level. The uppermost level (5550 m^3 /fed./ yr.) added further 11.9 kg to the yield / tree in the first season and 14.45 kg/tree in the second season, as compared with the intermediate level.

Meanwhile, the calculated yield per feddan, responded to different irrigation rates in the same way as discussed for the yield per tree.

Table (4) Effect of different irrigation rates on fruit set, periodic drop and total fruit drop throughout two studied seasons(1997&1998)

Irrigation rate m³/fed,/yr.	Fruit set (%)	Periodic drop (%)			Total fruit drop (%)
		* June drop stage	** Fruit development stage	*** Pre-harvest stage	
			Season 1997		
1850	37.70 c	75.3 a	13.79 c	11.70 b	97.91 a
3700	39.02 b	53.4 b	33.89 a	6.81 c	94.10 b
5550	43.84 a	41.5 c	25.48 b	16.76 a	85.20 c
			Season 1998		
1850	40.20 bc	72.94 a	13.21 c	10.00 b	96.08 a
3700	44.10 bb	52.85 b	34.93 a	5.33 c	93.11 b
5550	46.34 a	41.66 c	24.18 b	21.12 a	86.96 c

* June drop stage: (20th June – 1st July)
** Fruit development stage: (20th Sept. 20th October)
*** Pre- harvest stage: (20th Novemb. – 20th Dec.)

Table (5)Effect of different irrigation rates on yield and water use efficiency of Washington navel orange trees (seasons of 1997&1998)..

Irrigation rate m³ / fed / yr.	Number of fruits /tree	Yield /tree (kg)	Calculated yield / fed (ton)	Water use efficiency (WUE)*
		Season 1997		
1850	92.0 c	14.45 c	2.427 c	1.31 c
3700	153 b	33.90 b	5.700 b	1.54 a
5550	212 a	45.80 a	7.690 a	1.39 b
		Season 1998		
1850	98.33 c	16.62 c	2.792 c	1.51 c
3700	189 b	38.44 b	6.458 b	1.75 a
5550	228 a	52.89 a	8.885 a	1.60 b

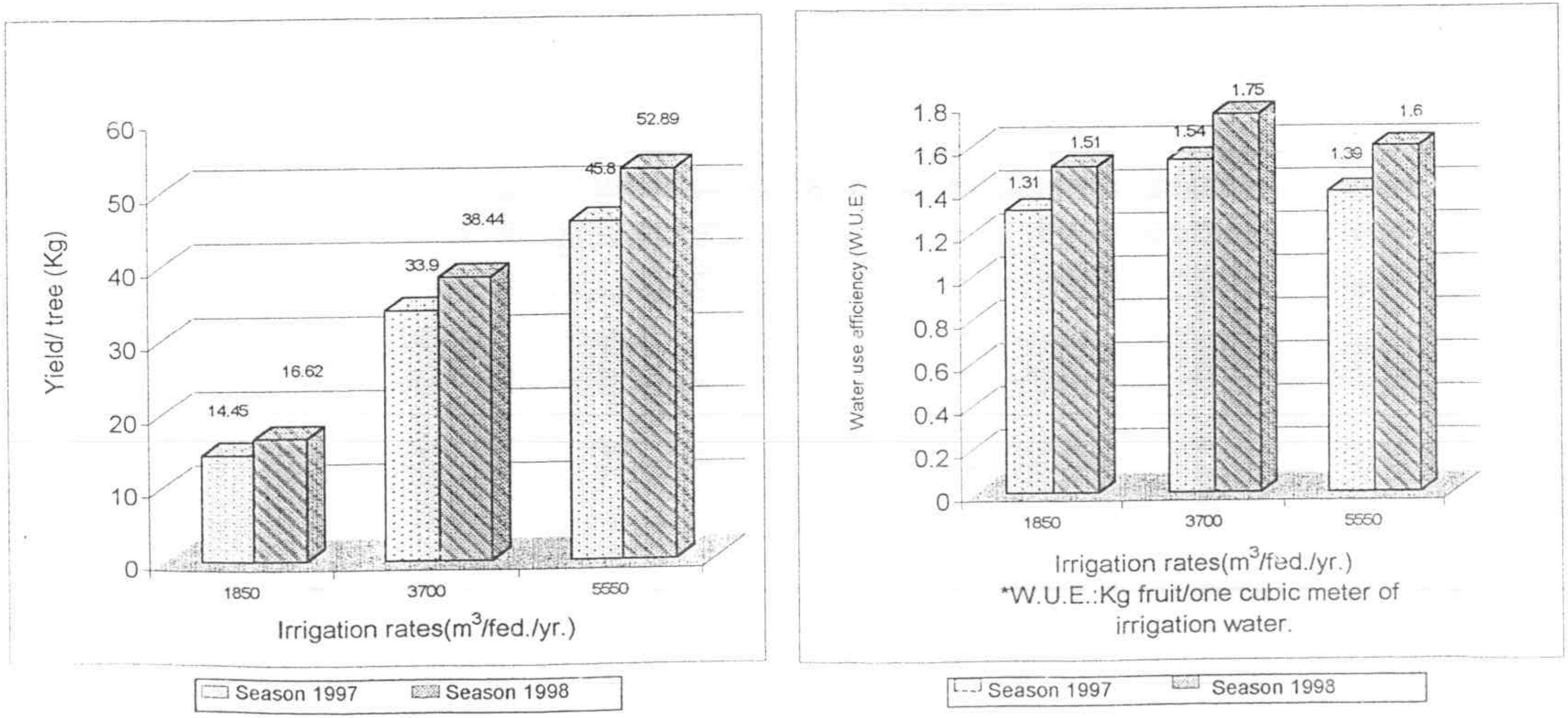
* WUE: kg fruit / one cubic meter of irrigation water

Moreover water use efficiency was calculated as the yield (kg fruits) produced by one cubic meter of irrigation water as shown in Table (5).and Fig(2)

Generally, water use efficiency values ranged between 1.31 and 1.39 in the first season and from 1.51 to 1.60 in the second season. The effect of applied irrigation rates were significant in both seasons. Thus, the water use efficiency indicated its highest values 1.54 and 1.75, in the two seasons respectively with the intermediate irrigation level (3700 m^3 /fed./yr.), then decreased to reach (1.31 and 1.51) with the lowermost level, followed by moderate values (1.39 and 1.60) with the uppermost level. These results clearly indicate that the medium level of irrigation rate(3700 m^3/fed./year) applied to Washington navel orange trees, in this location, was the most economical level in water use, in comparison with the upper and lower irrigation rates.

The obtained results concerning fruit number per tree and yield/tree were in harmony with related literature. **Wiegand & Swanson** (1984) on Valencia orange and Ruby red grapefruit; **Bielorai** (1987) on Shamouti orange reported that yield increased with increasing irrigation water level. **Koo & Smajsirlo** (1988) mentioned that greatest yields occurred when about 81% of the area under the tree canopy was irrigated. **Bielorai** *et al* (1984) on Shamouti orange stated that yield increases were due to more fruit number per tree.**Plessis&Plessis** (1987) and **Eliades** (1994) on grapefruit found a highly significant correlation between monthly water use and monthly fruit growth rate and the yield reduction at lower irrigation rates was accounted for by both smaller fruit size and fewer fruit

Fig (2) :- Effect of different irrigation rates on yield and water use efficiency of Washington navel orange trees (Seasons 1997 & 1998)



number. **Dettori & Filigheddu** (1994) on navel orange found that irrigation to replace 80% of the water used gave higher yield and quality compared with replacing 100% of consumed water.

4.1.5. Fruit physical properties:

Results of Table (6) reveal the effect of tested irrigation treatments on fruit weight (gm), dimensions (cm), juice volume (ml) and peel thickness (cm).

4.1.5.1. Fruit weight:

The data show that fruit weight generally ranged from 178.16 to 216.16 g in the first and second seasons, respectively and from 199.07 to 232.60 (g) in the second season

The irrigation water rate exerted obvious effect on average fruit weight. Thus, the heaviest fruits (221.57 and 241.79 gm in the two seasons) resulted from the intermediate irrigation level (3700 m^3/fed./yr.), descendingly followed by the uppermost level (5550 m^3) with average fruit weight (216.16 ,232.60 gm).On the contrary, the lightest fruits (178.16 and 199.07 gm) came from the lowermost irrigation level (1850 m^3/fed./yr.). However, the differences between intermediate and uppermost levels were so small to be significant. Increasing irrigation level over 1850 m^3 /fed./yr. significantly increased the average of fruit weight. Such trend was similar in both seasons.

4.1.5.2. Fruit dimensions:

The fruit dimensions generally increased as the irrigation water levels increased. The average of axial and equatorial measurements generally ranged between 6.1 and 7.7 cm, in the first season and from 7.4 to 8.8cm in the second season for axial length; the corresponding values for equatorial dimension were 6.20 to 7.50 cm in the first season and from7.10 to 8.30 cm in the second season. The effect of irrigation water level on fruit dimensions were significant between lowermost level and both of intermediate and uppermost levels. Increasing irrigation level to (5550 m^3) failed to add significant increment of fruit size compared with that of intermediate level. Anyhow, fruit dimensions in the second season were more obviously notical than those of the first one.

4.1.5.3. Peel thickness

Peel thickness, generally, ranged from 0.47 to 0.55 cm in the first season and from 0.45 to 0.6o cm in the second season. The effect of irrigation levels significantly increased peel thickness in both intermediate and uppermost levels compared with that of the lowermost level. The thicker peel was due to the uppermost, level descendingly followed by intermediate level but without significant differences between them (0.55and 0.52 cm, respectively in the first season and 0.60and 0.50 cm, in the second season). The thinner peel resulted from the lowermost irrigation level (0.47 and 0.45 cm in the two seasons , of study respectively).

4.1.6 . Fruit chemical properties

Table (7) indicates the total soluble solids (TSS), acidity and TSS/acid ratio as well as ascorbic acid contents in fruit juice of Washington navel orange trees as affected by the tested irrigation levels in both seasons.

4.1.6.1. Total soluble solids (TSS)

It is clear that (TSS) percentages generally ranged from 11.5 to 12.7 % in the first season and from 12.10 to 13.57 % in the second season. Irrigation levels exerted clear effect on fruit juice (TSS) in both seasons. The least values (11.5&12.0% in the first and second seasons, respectively) came from the uppermost irrigation level (5550 m^3). However, reducing irrigation level to (3700m^3) resulted in (TSS) of 11.9 & 12.97%, respectively. With the lowest irrigation level (1850 m^3), the (TSS) became 12.7 & 13.57% in both seasons, respectively.

4.1.6.2. Juice acidity

Concerning fruit juice acidity, data indicate that it generally ranged from 0.63 to 0.76% in the first season and from 0.51 to 0.64% in the second season. The effect of irrigation level on juice acidity showed opposite trend to that of (TSS). Thus, the least juice acidity values in both seasons (0.63 & 0.51%, respectively) were gaind by the lowermost irrigation level (1850 m^3). The intermediate level increased juice acidity to reach 0.69& 0.57%, respectively. In addition, more juice acidity increments were induced by the uppermost level (0.76 & 0.64%, respectively).

4.1.6.3. TSS /acid ratio

Regarding fruit juice TSS:acid ratio it is quite evident that it, generally ranged from 15.13 to 20.16 % in the first season and from 26.61 to 18.91% in the second season. In both seasons increasing irrigation level reduced the TSS/acid ratio. The highest values (20.16 & 26.61%) came from the lowermost irrigation level. The least values 15.13&18.91% in the two seasons, respectively resulted from the uppermost level.

Table (6) Effect of different irrigation water levels on some physical properties of harvested Washington navel orange fruits (seasons of 1997&1998).

Irrigation rates m^3./fed./yr.	Fruit weight (g)	Fruit dimensions (cm)		Peel thickness (cm)
		axial	equatorial	
Season 1997				
1850	178.16 **b**	6.1 **b**	6.20 **b**	0.47 **b**
3700	221.57 **a**	6.6 **b**	7.50 **a**	0.52 **a**
5550	216.16 **a**	7.7 **a**	7.50 **a**	0.55 **a**
Season 1998				
1850	199.07 **b**	7.4 **b**	7.10 **b**	0.45 **c**
3700	241.79 **a**	8.4 **a**	7.90 **a**	0.50 **b**
5550	232.60 **a**	8.8 **a**	8.30 **a**	0.60 **a**

Table (7) Effect of different irrigation water levels on some chemical fruit quality parameters of harvested Washington navel orange fruits (seasons of 1997&1998).

Irrigation rates m^3./fed./yr.	T.S.S (%)	Acidity (%)	T.S.S./acid ratio	Ascorbic acid (mlg./100ml)
Season 1997				
1850	12.7 **a**	0.63 **b**	20.16 **a**	48.55 **b**
3700	11.9 **b**	0.69 **b**	17.25 **b**	50.49 **ab**
5550	11.5 **c**	0.76 **a**	15.13 **c**	52.53 **a**
Season 1998				
1850	13.57 **a**	0.51 **b**	26.61 **a**	46.17 **b**
3700	12.97 **b**	0.57 **b**	22.75 **b**	49.78 **b**
5550	12.10 **c**	0.64 **a**	18.91 **c**	56.51 **a**

4.1.6.4. Ascorbic acid content

Considering fruit juice ascorbic acid (mg/100 ml juice) content, it is obvious that it generally, ranged from 48.55 to 52.53 in the first season and from 46.17 to 56.51 in the second season. The effect of irrigation water levels was significant in both seasons with the uppermost irrigation level as compared with intermediate and lowermost levels. Differences between lowermost and intermediate levels were insignificant in both seasons. The highest ascorbic acid content was gained by the uppermost irrigation level (52.53 & 56.51 mg/100 ml juice in the two seasons, respectively), descendingly followed by the intermediate (50.49 & 49.78, respectively) .However, the least values resulted from the lowermost irrigation level were (48.55 & 46.17 respectively).

Briefly, increasing irrigation level from 1850 to 5550 m^3/ fed./ year. obviously increased fruit weight, peel thickness, juice volume as well as juice acidity and ascorbic acid, while depressed total soluble solids percentage. The continued application of higher irrigation levels in the second season realized more improvement in both fruit physical and chemical properties.

The obtained results concerning fruit physical and chemical properties are in a general agreement with the findings of **Bielorai** (1987) on grapefruit and orange, He reported that fruit quality was high with the uppermost irrigation treatments. **Plessis & plessis** (1987) cited that highly significant correlation between monthly water use and monthly fruit growth. **Josan** ***et al*** (1993) found that less watering produced fruits with a significantly higher TSS and significantly lower ascorbic acid. In addition **Eliades** (1994) on grapefruit decided that the yield reduction at lower irrigation rates was due to both smaller fruit size and fewer fruits number per tree.

4.2.Response of Washington Navel orange trees to fertilizer treatments

4.2.1. Effect of nitrogen:

4.2.1.1.Vegetative growth:

It is clear from Table (8) that tree canopy volume (m^3) increased significantly with increasing applied nitrogen to the trees. That was true in both seasons of study. Moreover, high levels of nitrogen gave twice increase or more in comparison with low levels of nitrogen.

Concerning percentage of shoot length increase, data presented in Table (8) showed that it increased significantly up to the level 90 kg N per feddan then significant increase disappeared when trees fertilized with the highest level of nitrogen.

Regarding shoot thickness increase it is quite evident that shoot thickness increased significantly with increasing applied N to the trees. However, in the first season of study no significant difference was noticed between the second and third level of applied N.

Concerning percentage increase of leaf number it is found that values increased significantly as applied nitrogen to trees increased. Such effect was more clear in the second season than in the first one.

Referring to leaf area data indicate that in both seasons it increased toward the highest rate of applied nitrogen. However, no significant difference was noticed between 30 kg and 60 kg treatment (N1 and N2). Besides, nitrogen fertilization effect was more obvious in the second season than that in the first one.

Considering percentage of leaf dry weight it is quite evident that leaf dry weight increased with increasing the level of applied nitrogen to trees. Such effect was similar in both seasons of study. Nevertheless, the difference between trees received 30 kg per feddan (N1) and those received 60 kg N per feddan N2 was not clearly noticed statistically. Moreover, navel orange trees showed more response to nitrogen fertilization in the second season than in the first one.

Generally, it is easy to conclude that increasing nitrogen fertilization caused a clear increase in tree canopy volume, shoot length, shoot thickness, number of leaves per shoot, leaf area, and leaf dry weight. The uppermost nitrogen rate (120 kg N per feddan recorded the highest effect followed descendingly by 90 and 60 kg N levels. However, lowermost nitrogen treatment (30kgN) gave the lowest values in this respect. Higher nitrogen rates in the second season obviously improved vegetative growth compared with that of the first one.

The obtained data was in a general agreement with the related literature. Thus, **Dasberg** ***et. al*** (1983) on Shamoti orange and **Nath & Mohan** (1995) on lemon reported that 800 g N/tree resulted in the greatest increase in cross - sectional area, tree height and spread of the tree. **Willis** ***et. al*** (1991) on Hamlin orange noticed a positive linear correlation between fertilizer rate

Table (8) Effect of different nitrogen fertilization rates on some vegetative growth characteristics of Washington navel orange trees(seasons1997&1998).

Nitrogen level kg./fed/yr.	Tree canopy volume (m^3)	Percentage increments of:			Leaf area (cm^2)	Leaf dry weight (%)
		Shoot length	Shoot thickness	Leaf number		
Season 1997						
30 (N1)	1.44 d	145.71 c	27.86 c	55.25 c	24.04 c	43.62 c
60 (N2)	1.61 c	202.91 b	40.82 b	73.97 b	24.84 bc	41.54 c
90 (N3)	2.33 b	239.79 a	46.65 b	83.48 b	26.83 b	41.14 b
120 (N4)	2.93 a	248.30 a	73.32 a	96.04 a	32.92 a	38.48 a
Season 1998						
30 (N1)	1.52 d	163.90 c	37.86 d	62.02 c	26.16 c	40.13 c
60 (N2)	1.70 c	193.21 b	52.17 c	82.32 c	27.27 c	40.57 c
90 (N3)	2.61 b	246.72 a	61.60 b	109.47 b	28.02 b	41.82 b
120 (N4)	3.09 a	266.90 a	103.42 a	132.44 a	36.93 a	40.23 a

Table (9) Effect of different nitrogen fertilization rates on some leaf chemical constituents of Washington navel orange trees (seasons of 1997;1998).

Nitrogen level kg/fed/yr.	N (%)	P (%)	K (%)	Fe (ppm)	Zn (ppm)	Mn (ppm)
Season 1997						
30 (N1)	2.28 d	0.12 b	1.29 d	71.00 c	39.67 c	34.33 c
60 (N2)	2.37 c	0.14 a	1.57 c	86.00 b	45.33 b	41.33 b
90 (N3)	2.45 b	0.16 a	1.78 b	105.67 a	47.00 b	47.00 a
120 (N4)	2.63 a	0.17 a	1.84 a	106.67 a	51.67 a	48.00 a
Season 1998						
30 (N1)	2.31 c	0.13 b	1.31 d	71.67 d	44.33 b	35.33 c
60 (N2)	2.41 b	0.14 b	1.59 c	88.67 c	46.67 ab	42.33 b
90 (N3)	2.48 b	0.17 ab	1.80 b	106.33 b	53.00 a	48.00 a
120 (N4)	2.71 a	0.18 a	1.87 a	111.33 a	58.00 a	50.00 a

(total kg N/tree /yr.) and trunk diameter - **Drphanos & Eliades** (1994) on Valencia orange showed that, trees received the lowest nitrogen application had conspicuously less foliage.

4.2.1.2. Leaf nutrients content:

Effect of different levels of nitrogen fertilization on leaf nutrients content is shown in Table (9). It is obvious that in both seasons leaf nutrients content i.e. N, P, K, Fe, Zn and Mn increased as the level of applied nitrogen was raised to highest level, Nevertheless, no significant difference was obtained between trees received 60kg /fed. N and 90 kg /fed. as leaf phosphorus and Zn nutrients were concerned. Regarding leaf Mn content data showed that significant difference was noticed between 90 and 120 kg N per feddan treatments.

Generally, one can conclude that increasing applied nitrogen up to 120 kg. / feddan promoted all studied leaf nutrients which recorded the highest values followed by 90 kg N / feddan treatment which occupied the second rank for N, K and Zn nutrients in the first season and N,K and Fe in the second season. However, lowest nitrogen dose (30 kg N per feddan) gave least leaf nutrient contents in both seasons.

Considering the nutrient contents, the obtained results confirm those reported by **Dasberg** ***et al*** (1983) on Shamoti orange, **Savooshi** *et al* (1991) on Valencia and **Intrigliolo** ***et al*** (1993) on navel orange trees. They found that leaf nutrient content was closely related to the fruit yield and soil nutrient content; also nitrogen application significantly increased leaf N concentration. Moreover, **Okada** *et al* (1994) on Satsuma mandarin found that leaf N status was between 2.8 and 3.3% under the optimum application rate.

In addition, **Okada & Ooshiro** (1994) on Statsuma trees, **Androulakis** *et al* (1994) and **Futch& Alva** (1995) on grapfruit reported that increasing N rates increased leaf N content , but reduced leaf P and k . Leaf nitrogen was between 2.2 - 2.4% in mature spring flush foliage over the 3-year period of application.

4.2.1.3. Fruit set and periodic fruit drop:

4.2.1.3.1. Fruit set:

As shown in Table (10) fruit set indicated an obvious response to increasing nitrogen fertilization to trees in both seasons. Differences between studied nitrogen rates were always so high to reach the significant level. However, such significant effect between 90 and 120 kg N feddan was not statistically noticed.

4.2.1.3.2. Periodic fruit drop:

Data presented in Table (10) and Fig (3) showed that in both seasons fruit June drop percentage decreased with increasing added N for trees. Nevertheless, no significant difference was observed between 90 and 120 kg N per feddan treatments.

Concerning fruit drop during fruit development stage, data disclosed that fruit drop percentage decreased with increasing the level of applied N to trees. However, received 60 kg N/fed./yr treatment gave the lowest percentage of fruit drop in the both seasons.

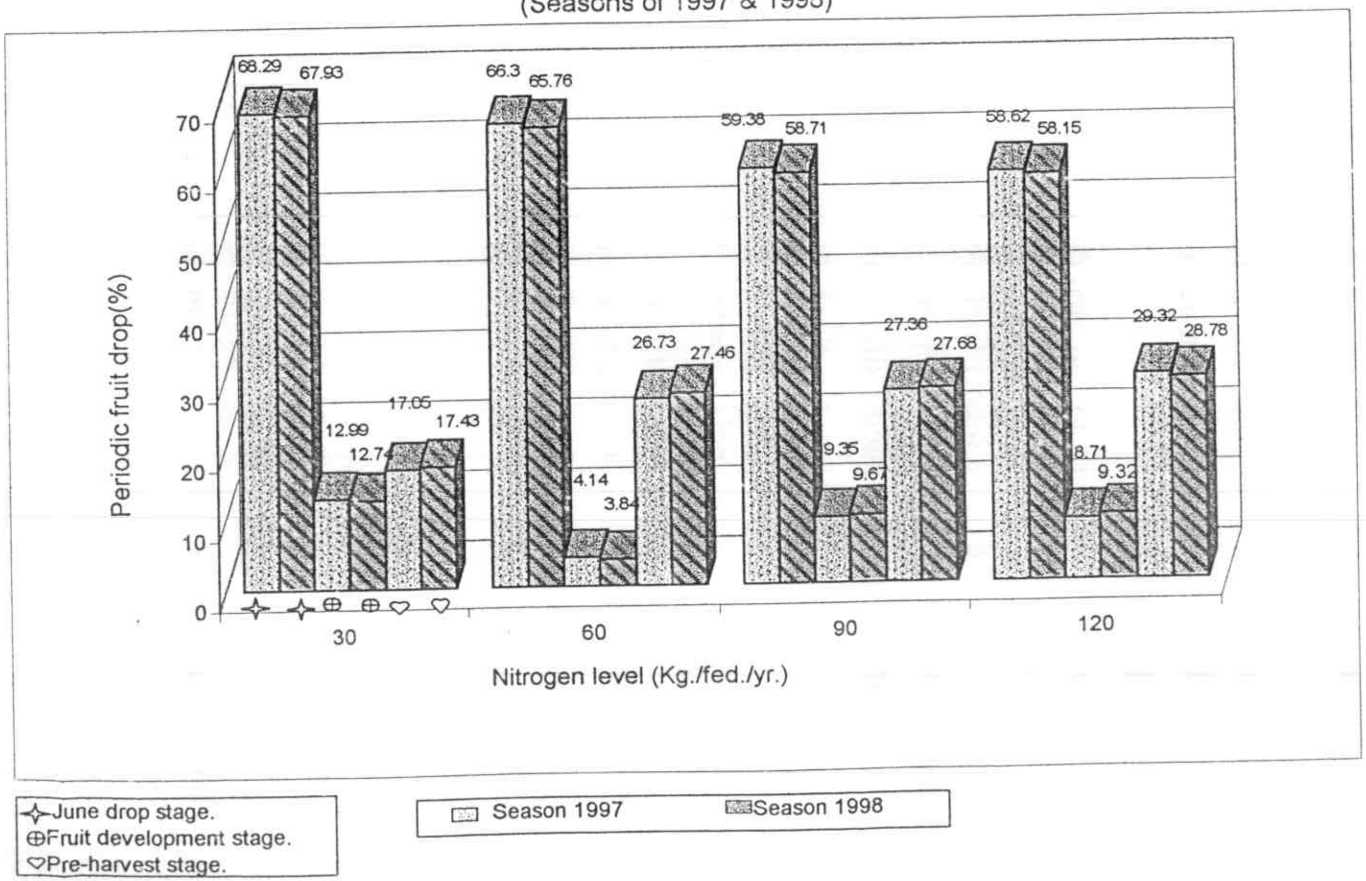
Moreover, as drop percentage at pre-harvest stage was concerned it is clear that in both seasons drop percentage increased significantly with increasing applied nitrogen to trees up to 120 kg N per feddan.

In addition, data of total fruit drop percentage showed that values in this respect decreased with increasing the amount of applied nitrogen to the trees. However, the difference between 90 and 120 kg nitrogen per feddan treatments was so small to be statistically significant.

Generally, it is safe to say that the effect of N rates were more clear during the first stage (at June drop). So low nitrogen application resulted in a higher fruit drop percentage. Anyhow, during the second stage (at fruit development) fruit drop was clearly limited and indicated a slight reduction with 60 kg N per feddan level. Moreover, at the third stage (at preharvest) the effect of N application levels used showed statistically significant effect with a trend opposite to that of the first stage.

The obtained herein results are in general agreement with **Muller** (1987) who investigated fruit drop of Valencia trees and reported that after fruit set the fruit numbers declined gradually at first, and subsequently more rapidly, so that only 2% of the original numbers of fruits that had set remained on the tree. Shortage of soil moisture and N and high temperature, were the main factors causing fruit drop as reported by **yi *et al*** (1995) on mandarins trees. Present data are in general agreement with that mentioned by **El-nabawy *et al*** (1975) on Washington navel orange,**Tominaga-S** (1982)on satsuma and **Koo-RCJ** (1985)on Valencia and Temple orange.

Fig (3) :- Effect of different nitrogen fertilization levels on periodic fruit drop of Washington navel orange trees (Seasons of 1997 & 1998)



4.2.1.4. Yield parameters:

As number of fruits per tree was concerned, it is quite evident from Table (11) and Fig (4) that in both seasons number of fruits per tree increased towards the increase of applied N to navel orange trees. However, the significant difference between 30, 60 and 90 kg N per feddan treatments were nil. On the other hand, trees fertilized with high level of nitrogen gave statistically highest number of fruits over the other treatments used in this study. That was true in both seasons.

On the other hand, yield (kg/ per) tree augmented with increasing the amount of applied N to trees. However, no significant difference was observed between 60 and 90 kg N/ feddan treatments in both seasons. Meanwhile, the effect of N fertilization on total yield per tree was more obvious in the second season of study.

Furthermore, the effect of applied nitrogen fertilizations on calculated yield per feddan as shown in Table (11) indicated that calculated yield increased with increasing the amount of applied nitrogen to trees. However, in both seasons, no significant difference was observed between 30 and 60 kg N per feddan treatments on one hand, and 60 and 90 kg N per feddan treatments on the other.

Moreover, data of the nitrogen use efficiency i.e. kg fruits produced by one kg. of added nitrogen as shown in Table (11) and Fig (3) indicated that it decreased significantly with increasing the applied nitrogen to trees up to 90 kg N per feddan treatment. Anyhow, no significant difference was observed between 90and 120 kg N per feddan rates. That was true in both seasons.

Table (10) Effect of different nitrogen fertilization levels on fruit set, periodic drop and total fruit drop throughout two studied seasons(1997&1998)

Nitrogen levels kg/fed./yr.	Fruit set (%)	Periodic drop (%)			Total fruit drop (%)
		* June drop stage	** Fruit development stage	*** Pre-harvest stage	
	Season 1997				
30 (N1)	29.45 c	68.29 a	12.99 a	17.05 d	98.33 a
60 (N2)	33.60 b	66.30 b	4.14 d	26.73 c	97.17 b
90 (N3)	38. 58 a	59.38 c	9.35 b	27.36 b	96.09 c
120 (N4)	39. 32 a	58.62 c	8.71 c	29.32 a	96.65 c
	Season 1998				
30 (N1)	31.44 c	67.93 a	12.74 a	17.43 c	98.10 a
60 (N2)	36.19 b	65.76 b	3.84 d	27.46 b	97.06 b
90 (N3)	41.12 a	58.71 c	9.67 b	27.68 b	96.02 c
120 (N4)	42.34 a	58.15 c	9.32 c	28.78 a	96.25 c

- June drop stage: (20th June –1st July)
- ** Fruit development stage: (20th Sept. 20th October)
- *** Pre- harvest stage: (20th Novemb. – 20th Dec.)

Table (11) Effect of different nitrogen fertilization rates on yield and nitrogen use efficiency of Washington naval orange trees (seasons 1997&1998).

Nitrogen level kg./fed./yr.	Number of fruits /tree	Yield /tree (kg)	Calculated yield / fed (ton)	Nitrogen use efficiency(NUE)*
		Season 1997		
30 (N1)	92.33 b	19.39 c	3.26 b	108.67 a
60 (N2)	94.33 b	21.32 bc	3.58 b	59.67 b
90 (N3)	97.00 b	22.30 b	3.75 ab	41.67 c
120 (N4)	110.67 a	25.75 a	4.33 a	36.08 c
		Season 1997		
30 (N1)	98.00 b	23.58 c	3.96 c	132.0 a
60 (N2)	100.67 b	25.94 b	4.08 bc	86.0 b
90 (N3)	107.0 b	27.64 b	4.64 b	51.56 c
120 (N4)	128.33 a	37.32 a	6.27 a	52.25 c

* (NUE): kg fruits produced by / one Kilogram add nitrogen fertilizer

Conclusively, increasing nitrogen fertilization rate from 30 to 120 kg / fed / yr. significantly increased number of fruits per tree, yield per tree and calculated yield per feddan. In this respect, **Deidda & Casu** (1980/81), **legaz** *et al* (1983) **Marshanyiya & Mikeladge** (1983) and **Dasberg** *et al* (1983) on orange they reported that nitrogen fertilization attained good yield with (150 - 750g N/tree).Further more, significant effects of nitrogen were found on fruit yield and on the number of fruits/tree. In addition, **Bielorai** (1987) pointed out that yield increased with nitrogen supply. **Sarooshi** *et al* (1991) on orange decided that trees produced maximum yield at higher rates of applied nitrogen.

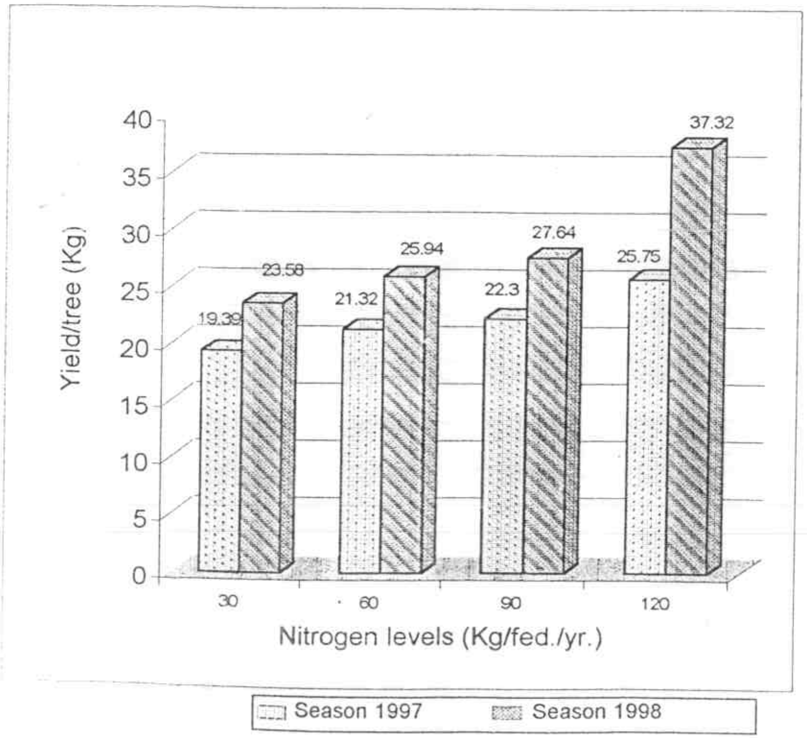
However, **Intrigliolo** *et al* (1993) on Navellna orange trees, mentioned that higher doses of N (1000 gm/ tree) resulted in lower yields. **Androulakis** *et al*(1994) on grapefruit reported that N at higher rate (1.0 kg/tree) gave lower yields than (0.5 kg N / tree). Moreover, **Nath & Mohan** (1995) on Assam lemon reported that application of 800 gm N/tree resulted in the highest mean annual fruit yield and further increases in N rate caused a reduction in yield.

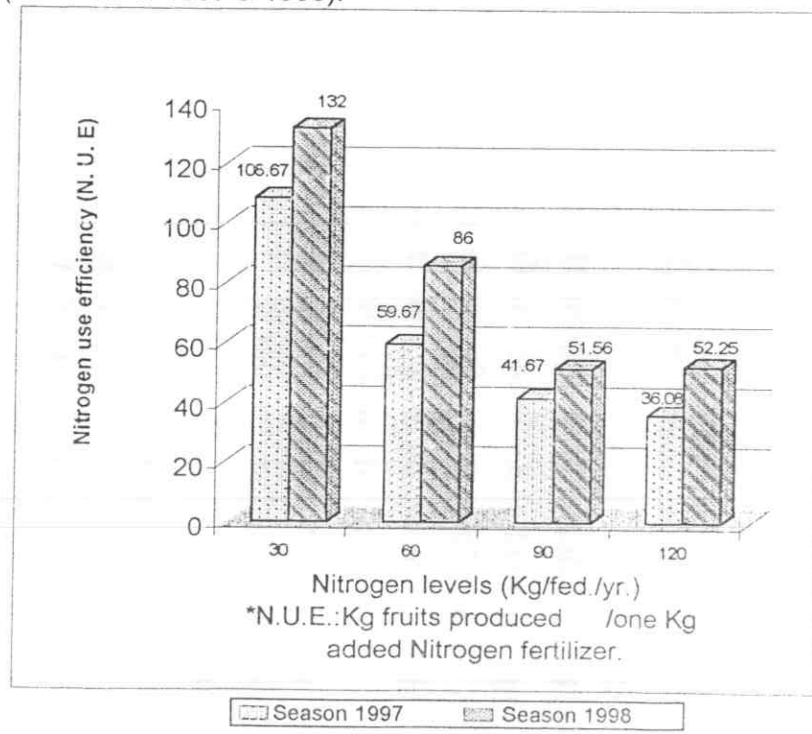
4.2.1.5. Fruit physical properties:

4.2.1.5.1.Fruit weight:

Concerning fruit weight of Washington navel orange as affected by different rates of applied nitrogen, data presented in Table (12) indicate that fruit weight increased toward the highest level of N (120 kg N per feddan). Such effect was statistically observed in the second season. On the contrary, in the first season no significant difference was noticed between 60 ,90, and 120 kg N per fedlan treatments

Fig (4) :- Effect of different Nitrogen fertilization rates on yield and nitrogen use efficiency of Washington navel orange tree (Seasons of 1997 & 1998).





4.2.1.5.2. Fruit dimensions:

It is clear from Table (12) that in the first season fruit dimensions increased with increasing the level of applied nitrogen. However, the significant difference between the three last treatments used in this study was nil. The trend was changed to the reverse when axial dimension of fruits was concerned in the second season with no significant difference between 30 and 60 kg N treatments were observed. Considering equatorial dimension of fruits, data indicate that values increased with increasing the level of applied N. Anyhow, no significant difference was noticed between 30 and 60 treatments from one hand and 60 and 90 kg/N/fed treatments from the other.

4.2.1.5.3. Fruit Peel thickness:

Data presented in Table (12) indicate that fruit peel thickness increased with increasing the applied N to trees. That was true in both seasons of study. Moreover, no significant difference was observed between 30 and 60 kg N per feddan treatments on one hand and 60 and 90 kg N per feddan treatments on the other.

4.2.1.6. Fruit chemical properties:

Table (13) involved total soluble solids, acidity, total soluble solids: acid ratio, and ascorbic acid contents in fruit juice of Navel orange as affected by different rates of applied N.

4.2.1.6.1. Total soluble solids (TSS):

Data of fruit juice TSS showed that it increased with increasing the applied N to trees. Furthermore, trees received the highest level of N (120 kg N per feddan) gave significantly fruits with highest amount of TSS among the other treatments used. In the same time, no significant effect was excreted

Table (12) Effect of different levels of nitrogen fertilization on some physical properties of Washington navel orange fruits (seasons of 1997&1998).

Nitrogen level Kg/fed./ yr.	Fruit weight (g)	Fruit dimensions (cm)		Peel thickness (cm)
		axial	equatorial	
Season1997				
30 (N1)	209.93 b	7.99 b	7.14 b	0.35 c
60 (N2)	226.13 a	8.30 ab	7.78 a	0.39 bc
90 (N3)	229.96 a	8.63 a	7.82 a	0.47 b
120 (N4)	232.57 a	8.71 a	7.92 a	0.60 a
Season1998				
30 (N1)	210.90 d	7.98 b	7.48 c	0.39 c
60 (N2)	230.54 c	7.85 b	7.76 bc	0.41 bc
90 (N3)	238.13 b	7.46 c	8.15 b	0.49 b
120 (N4)	250.60 a	8.85 a	8.54 a	0.86 a

Table (13) Effect of different levels of nitrogen fertilization on some chemical fruit quality parameters of harvested Washington navel orange fruits (seasons of 1997&1998).

Nitrogen level Kg/fed./ yr.	T.S.S (%)	Acidity (%)	T.S.S./acid ratio	Ascorbic acid (mg./100ml)
Season 1997				
30 (N1)	9.5 c	0.75 a	12.67 c	25.78 d
60 (N2)	9.9 bc	0.69 a	14.35 bc	28.58 c
90 (N3)	10.3 b	0.62 bc	16.61 b	33.24 b
120 (N4)	11.3 a	0.55 c	20.6 a	41.38 a
Season 1998				
30 (N1)	9.9 c	0.59 ab	16.78 c	33.70 c
60 (N2)	10.1 bc	0.61 a	16.56 c	33.38 c
90 (N3)	10.7 b	0.56 b	19.11 b	39.38 b
120 (N4)	11.6 a	0.54 b	21.48 a	42.64 a

between 30 and 60 kg N treatments on one hand and 60and 90 kg N treatments on the other. That was true in both seasons of study.

4.2.1.6.2. Juice acidity:

Concerning fruit juice acidity it is clear that acidity decreased with increasing the applied rates of N fertilization. Anyhow, no significant difference was noticed between 30 and 60 kg N treatments as well as between 60 and 90 kg N treatments.In other words, data of fruit juice acidity indicate the effect of N rates fertilization on juice acidity gave opposite trend to that of TSS.

4.2.1.6.3. TSS: acid ratio:

In both seasons, increasing N fertilization significantly increased juice TSS: acid ratio. However, no significant difference was obtained between 30 and 60kg N treatments. Besides, in the first season significant difference between 60 and 90 kg N treatments was nil.

4.2.1.6.4.Juice ascorbic acid content:

Data of Table (13) disclosed that juice ascorbic acid content increased with increasing the amount of applied N to trees. Moreover, no significant difference was obtained between 30 and 60 kg N treatments. On the other hand, fruits of the second season were more rich in ascorbic acid as compared with the corresponding ones of the first season.

Generally, from the aforementioned results one can say that increasing N fertilization to Navel orange trees increased fruit weight, peel thickness, juice volume, juice TSS and TSS: acid ratio and decreased juice acidity simultaneously.

The obtained results are in harmony with the fintings of **Deidda & Casu** (1981), **Okada** *et al.* (1994) on Satsuma mandarin and **Nath & Mohan** (1995) on Lemon. They reported that the highest N application increased the TSS value. Also, **Dasberg** *et al* (1983) On orange, **Bielorai** *et al* (1984) on Shamouti orange and **Nath & Mohan** (1995) on Assam lemon mentioned that high N rate caused thicker fruit peel. Moreover, **Bielorai** (1987) on grapefruit and orange reported that fruit quality was high with higher level of nitrogen applicatiation. Adversely, **Nath & Mohan** (1995) on Assam lemon noticed that the highest value for acidity were obtained with high rates of nitrogen. Whereas juice content and ascorbic acid concentrations were lowest with high N rates (800 g N/tree) i.e about 134.4 kg N/fed./yr.).

4.2.2. Effect of potassium:

4.2.2.1. Vegetative growth:

The main features of tree vigor i.e. tree canopy volume, leaf area as well as percentages of shoot length, shoot thickness leaf number increments and leaf dry weight as affected by different levels of potassium fertilization in both seasons of study are presented in Table (14).

It is clear that trees received the highest rate of potassium (250 kg per feddan) gave the highest values as compared with those treated with the lowest rate of potassium fertilization (100 kg per feddan). The difference was so high to be statistically significant.

Moreover, as percentage of shoot length and shoot thickness increase were considered it is found that trees fertilized with the lowest amount of potassium fertilization gave the shortest and thinnest shoots among the other treatments used in this study. Increasing the applied potassium to trees induced an increase in shoot length and thickness in both seasons. The significant difference was noticed. In the same time no significant difference was observed between high and medium levels of applied K used in this study.

Considering percentage of leaf number per shoot increment it is well noticed that it increased significantly with increasing the amount of applied potassium to Washington navel orange trees. Besides, values of the second season was highest as compared with the corresponding ones of the first one. Furthermore, in both seasons potassium fertilization showed a significant effect on leaf area. Thus, trees received the highest treatment of potassium fertilization gave leaves with larger area as compared with those treated with the other treatments used in this study.

Referring to leaf dry weight percentage it is found that it increased statistically as amount of applied potassium to trees increased. That was true in both seasons. Moreover, data of in Table (14) indicated that values of leaf dry weight of the second season was higher than that of the first one.

Generally, from the aforementioned results one can say that potassium fertilization improved vegetative growth parameters of Washington navel orange trees used in this study. In other

Table (14) Effect of different Potassium fertilizer rates on some vegetative growth characteristics of Washington navel orange trees(seasons of 1997&1998).

Potassium fertilizer (K_2SO_4) Level kg./fed./ yr.	Tree canopy volume (m^3)	Percentage increments of:*			Leaf area (cm^2)	Leaf dry weight (%)
		Shoot length)	Shoot thickness	Leaf number		
Season 1997						
100	1.27 c	145.38 c	26.86 b	53.92 c	15.46 c	40.23 c
168	1.59 b	180.10 b	42.15 a	73.97 b	17.95 b	41.53 b
250	1.72 a	208.76 a	44.93 a	94.56 a	22.44 a	42.93 a
Season 1998						
100	1.45 c	161.90 c	36.86 b	61.69 c	17.34 c	40.57 c
168	1.63 b	192.50 b	52.17 a	82.32 b	23.97 b	42.10 b
250	1.79 a	240.83 a	59.75 a	100.40 a	26.37 a	43.10 a

*As a percent of initial shoot measurements at the beginning of growth.

Table (15) Effect of different Potassium fertilizer rates on some leaf chemical contents of Washington navel orange trees (seasons 1997&1998).

Potassium fertilizer (K_2SO_4) Level kg./fed./ yr.	N (%)	P (%)	K (%)	Fe (ppm)	Zn (ppm)	Mn (ppm)
Season 1997						
100	2.35 c	0.17 a	1.24 c	72 c	41.67 c	32.3 c
168	2.62 b	0.14 a	1.37 b	87 b	46.33 b	42.3 b
250	2.74 a	0.16 a	1.47 a	110 a	52.67 a	47.7 a
Season 1998						
100	2.28 c	0.16 a	1.33 c	69 c	54.33 b	36.5 c
168	2.57 b	0.14 a	1.47 b	90 b	55.33 b	43.5 b
250	2.95 a	0.12 a	1.54 a	108 a	61.67 a	48.6 a

words, vegetative growth measurements increased with increasing applied potassium to trees.

4.2.2.2. Leaf nutrients content

Table (15) disclose that regardless of leaf P content, leaf nutrients content. i.e. N, k, Fe, Zn and Mn increased with increasing applied K to trees. Such effect was mostly significant in both seasons of this study.

. In respect of related literature, **Vanniere & Marchal** (1992) on Clementine mandarin trees, reported that application of K had a significant correlation between leaf K and N. It was noticed that leaf K correlation with leaf P was reduced and that with leaf N dissappeared in the off year. In addition **Cicala & Catara** (1994) on Tarocco orange trees, reported that K treatments (0 -1 kg/tree, KNO3) produced an increase in the level of leaf K.

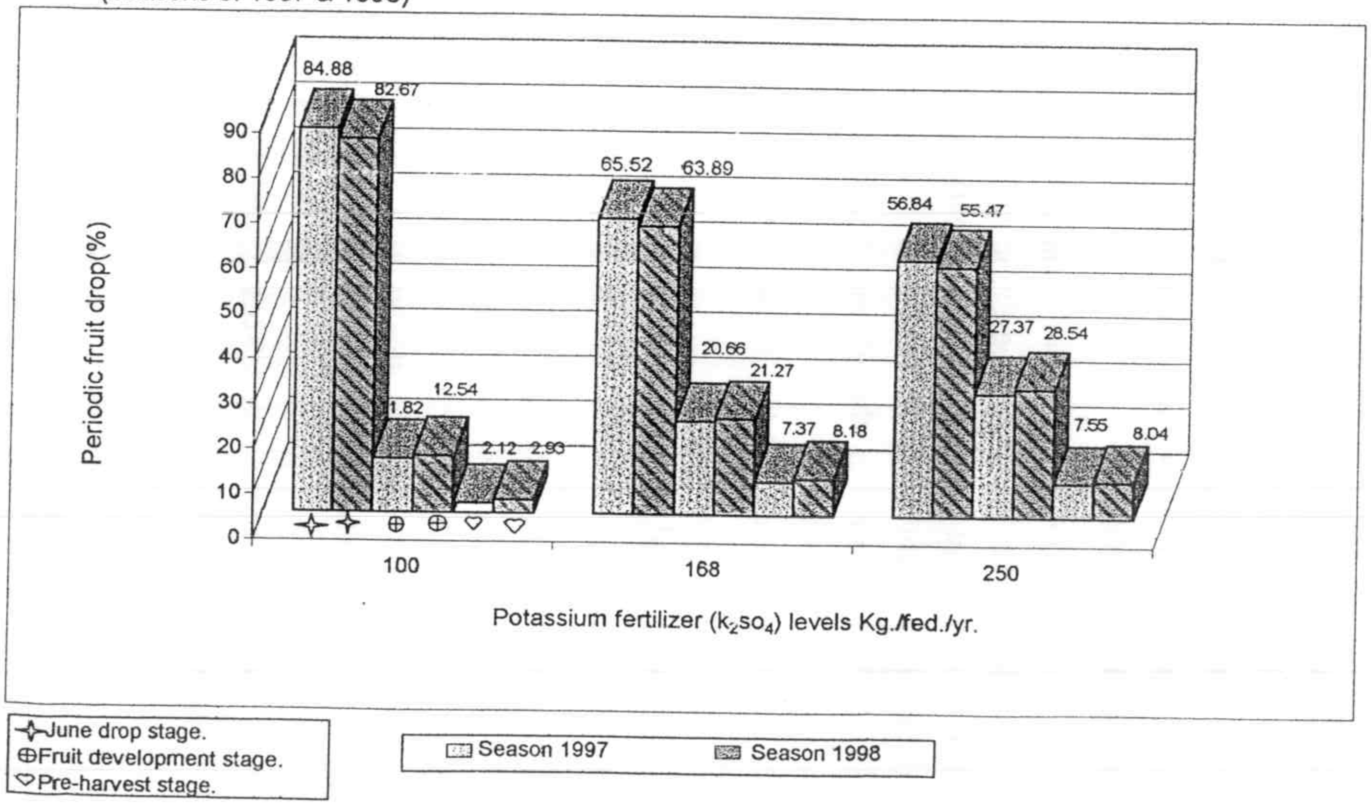
4.2.2.3. Fruit set and periodic fruit drop

4.2.2.3.1. Fruit set:

As shown in Table (16) and Fig (5) it is clear that fruit set percentages indicated an obvious response to levels of K fertilization in both seasons. In this respect, fruit set of Washington navel orange trees increased in response to the increase in K fertilization rate. The difference between treatments was almost high to be statistically significant. Moreover, the values of the second season were higher than the corresponding one of the first season.

This is in agreement with **Awan** *et. al*. (1985)report on sweet lime, who mentioned that fruit set percentages were highest with potassium fertilization at o.5 kg / tree.

Fig (5) :- Effect of different Potassium levels on periodic fruit drop of Washington navel orange trees (Seasons of 1997 & 1998)



4.2.2.3.2.Periodic fruit drop:

Data presented in Table (16) show the effect of different potassium rates on the three stages of fruit drop i.e. June drop, fruit development and pre- harvest drop during the two studied seasons.

Concerning fruit June drop, most of the drop occurred during the period after fruit set. Meanwhile, in both seasons, fruit June drop decreased with increasing the levels of applied potassium to the tree. Anyhow, the difference between the treatments was significant in either season of 1997 or season of 1998.

Referring to fruit shedding at fruit development, it showed adverse trend as compared with that of June drop trend. In other words, fruit drop percentage at fruit development stage increased significantly with increasing the application of potassium level.

Furthermore, fruit drop at pre- harvest stage was low when the lower level of applied potassium used, then suddenly increased with increasing the rates of potassium to the trees. However, the significant difference between medium and high level of applied potassium was nil.

Considering total fruit drop percentage, data shown in table (16) indicate that in both seasons it decreased significantly with increasing the level of applied potassium.

Generally, it is worth to mention that fruit drop percentage curve was more higher in the first stage of fruit growth (fruit June drop) then decreased toward the last stage of fruit growth

Table(16) Effect of different of Potassium fertilizer rates on fruit set, periodic drop and total fruit drop throughout two studied seasons(1997&1998)

Potassium fertilizer K_2SO_4 rates kg/fed,/yr.	Fruit set (%)	Periodic drop (%)			Total fruit drop (%)
		* June drop stage	** Fruit development stage	*** Pre-harvest stage	
	Season 1997				
100	39.2 c	84.88 a	11.82 c	2.12 b	97.92 a
168	41.04 b	65.52 b	20.66 b	7.37 a	93.58 b
250	42.74 a	56.84 c	27.37 a	7.55 a	91.10 c
	Season 1998				
100	40.08 c	82.67 a	12.54 c	2.93 b	97.50 a
168	42.38 b	63.89 b	21.27 b	8.17 a	92.93 b
250	46.22 a	55.47 c	28.54 a	8.04 a	91.06 c

* June drop stage: (20th June –1st July)
** Fruit development stage: (20th Sept. 20th October)
*** Pre- harvest stage: (20th Novemb. – 20th Dec.)

Table (17) Effect of different Potassium fertilizer rates on yield and Potassium use efficiency of Washington navel orange trees (seasons 1997&1998).

Potassium fertilizer K_2SO_4 level kg /fed./ yr.	Number of fruits /tree	Yield /tree (kg)	Calculated yield / fed (ton)	Potassium use efficiency (KUE)*
Season 1997				
100	108.67 b	20.25 c	3.40 c	34.00 a
168	127.67 a	25.15 b	4.23 b	25.18 b
250	134.67 a	27.90 a	4.79 a	19.01 c
Season 1998				
100	113.00 b	22.35 c	3.76 c	37.60 a
168	133.33 a	27.04 b	4.54 b	27.02 b
250	141.67 a	30.43 a	5.11 a	20.28 c

* (KUE): kg fruits produced by / one kilogram added Potassium fertilizer.

(Pre-harvest). This trend was true in both seasons as well as with the three rates of potassium fertilization.

In respect of fruit drop **Moreira** *et al* (1996) found that counting of dropped orange fruits showed that fruit retention was improved particularly with potassium fertilization. Present data are in a general agreement with that mentioned by **Rabe-*et al*** (1996) on tangor cv and **Kouka** ***et al*** (2000) on Balady orange They revealed the obvious importance of K fertilization to increase fruit set and depress fruit drop

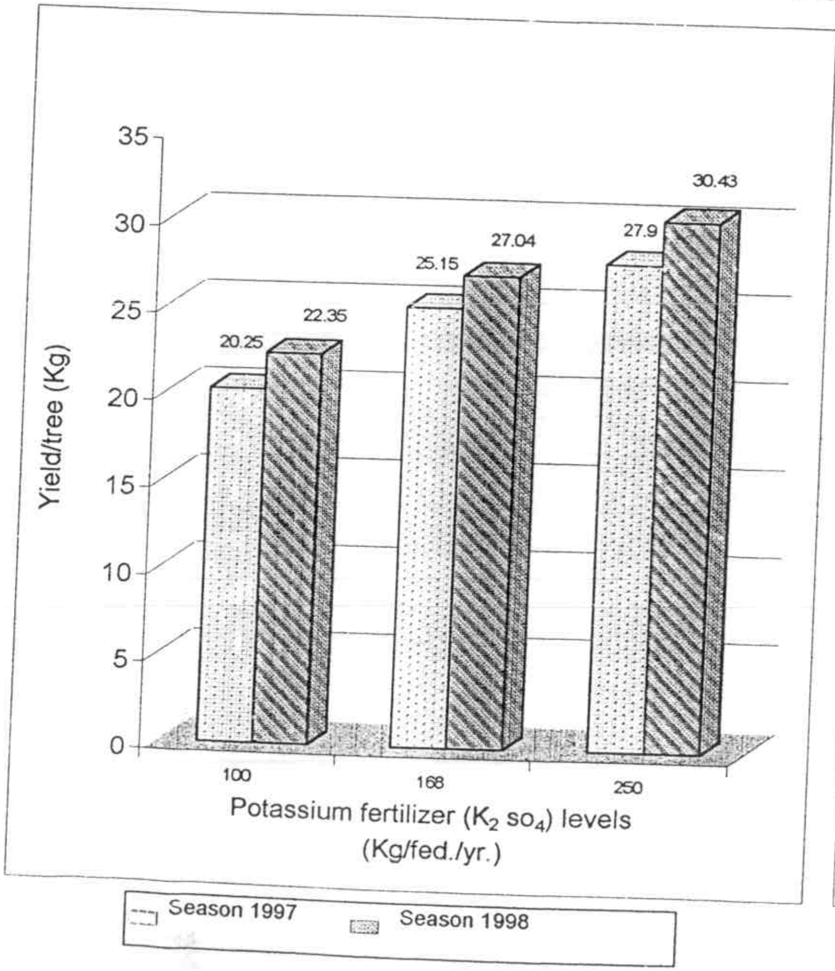
4.2.2.4. Yield parameters:

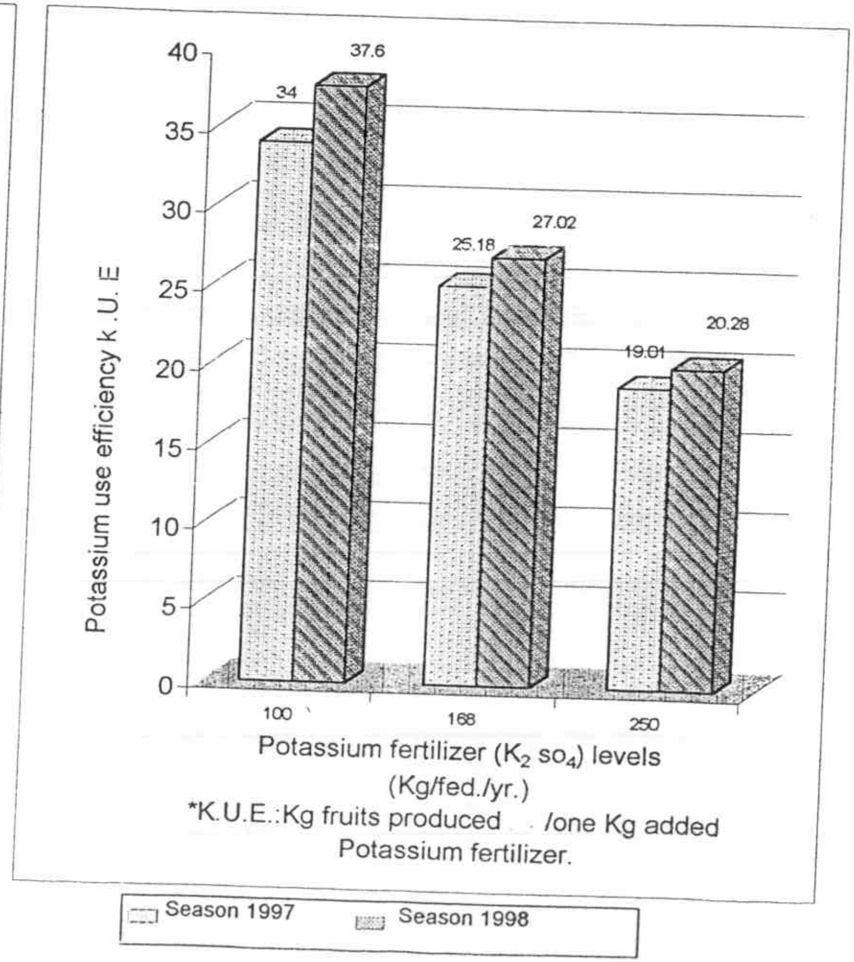
Yield of Washington navel orange trees as affected by different rates of potassium fertilization is expressed in Table (17) and dis-closed in Fig (6) either as number of fruits per tree or yield (kg). It is found that in both seasons number of fruits per tree increased with increasing the level of applied potassium to the trees. Nevertheless, no significant difference was obtained between medium and high level of potassium (168 and 250 kg potassium sulphate per feddan

Concerning either total yield (kg) per tree or calculated yield per feddan it is well noticed that it took the same trend of number of fruits per tree. but significant difference between different treatments used in this study was clearly observed.

Furthermore,data of potassium use efficiency are expressed in Table(17)and Fig(6) It is clear that it decreased significantly with increasing the applied potassium to the trees in both seasons. Moreover, it is quite evident that in this respect values of the second season were higher than the corresponding ones of

Fig (6) :- Effect of different potassium fertilizer levels on yield and potassium use efficiency of Washington navel orange trees (Seasons of 1997 & 1998).





the first one. Such result means that the trees responded to potassium fertilizer in the second season more than in the first season. Meanwhile, the drop of KUE may be due to the great consumption of added potassium in tree activities such as promoting leaves, shoots and root production of the young trees under study.

As for related literature, **Plessis** (1983) on Valencia orange decided that yield being raised with increasing potassium application. **Plessis & Koen** (1994) on Eurka lemon, reported that increasing K content in leaves increased average of yield/tree. Moreover, **Okada** ***et al*** (1994) on Satsuma mandarin decided that leaf K concentration fell to below 0.7% resulted in decreased. yield.In addition, **Cicala & Catara** (1994) on Tarocco orange trees mentioned that there was significant positive correlation between leaf potassium content and resulted yield.

4.2.2.5. Fruit physical properties:

Table(18)reveals the effect of tested potassium rates on fruit physical properties which included fruit weight, fruit dimensions, juice volume, and peel thickness in both seasons of study.

4.2.2.5.1. Fruit weight:

It is clear that in both seasons fruit weight increased with increasing the level of applied potassium to Navel orange trees. However, the significant difference between the first and second level was so small to be noticed. Moreover, in the first season of study the same statistical difference was observed between the second and the third level of applied potassium.

Table (18) Effect of different Potassium fertilizer rates on some physical properties of Washington navel orange fruits (seasons of 1997&1998).

Potassium fertilizer Level K_2SO_4 kg/fed/yr.	Fruit weight (g)	Fruit dimensions (cm)		Peel thickness (cm)
		axial	equatorial	
Season 1997				
100	186.36 b	7.79 b	7.36 b	0.44 c
168	196.85 ab	7.95 ab	7.65 b	0.53 b
250	207.72 a	8.13 a	8.21 a	0.60 a
Season 1998				
100	198.33 b	7.47 c	7.23 c	0.46 b
168	202.73 b	7.98 b	7.60 b	0.52 b
250	214.81 a	8.50 a	8.56 a	0.64 a

Table (19) Effect of different of Potassium fertilizer rates on some chemical fruit quality parameters of harvested Washington navel orange fruits (seasons of 1997&1998).

Potassium fertilizer K_2SO_4 Level kg/fed/yr.	T.S.S (%)	Acidity (%)	T.S.S./acid ratio	Ascorbic acid (mg./100ml)
Season 1997				
100	9.37 b	1.06 a	8.84 c	31.80 c
168	11.23 a	0.77 b	14.58 b	34.03 b
250	11.27 a	0.62 b	18.18 a	34.80 a
Season 1998				
100	11.2 c	0.68 a	16.47 c	30.3 c
168	12.4 b	0.52 b	23.85 b	42.5 b
250	13.4 a	0.50 b	26.80 a	43.8 a

4.2.2.5.2. Fruit dimensions:

Fruit dimensions indicate that both fruit axial and equatorial dimensions increased toward the high level of potassium treatment. Moreover, in the first season of study no significant difference could be detected between the low and medium rate of potassium fertilization. That was true in both fruit dimensions studied.

4.2.2.5.3. Juice volume:

Trees received the high rate of potassium fertilization gave fruits with higher juice volume as compared with the corresponding ones treated with the lower rate of potassium fertilization. Anyhow in season 1997 no statistical difference was noticed between the low and medium rate.

4.2.2.5.4.Peel thickness:

It is well noticed that potassium application increased the thickness of fruit peel. In other words, fruit peel thickness increased with increasing the amount of applied potassium to trees. That was true in either season1997or season 1998.In addition, no significant difference was noticed between the low and medium levels of applied potassium in the second season of study.

4.2.2.6.Chemical fruit properties:

Table (19) involved total soluble solids, acidity, TSS : acid ratio and ascorbic acid content in fruit juice of Navel orange trees as affected by different rates of potassium

4.2.2.6.1.Total soluble solids:

Data indicate that in both seasons potassium fertilization increased fruit juice total soluble solids. The effect from the statistical point was more clearly observed in the second season.

4.2.2.6.2. Juice acidity:

Concerning the effect of potassium fertilization on fruit juice acidity, data indicated an opposite effect as compared to that of fruit juice TSS. In other words juice acidity decreased with increasing the level of applied potassium.

Meanwhile, no significant difference was obtained between the medium and high level of applied potassium to trees. That was true in both seasons.

4.2.2.6.3.TSS: acid ratio:

In either season 1997 or 1998 fruit juice TSS: acid ratio increased significantly with increasing applied potassium to trees. Such effect was more obvious in the second season of study.

4.2.2.6.4. Ascorbic acid content

The ascorbic acid content in fruit juice as shown in Table (19) increased significantly as potassium fertilization also increased.

Conclusively, potassium fertilization to trees increased fruit weight, fruit dimensions, juice volume, peel thickness, TSS, TSS: acid ratio and ascorbic acid contents while in the same time depressed fruit juice acidity content.

The present results are in a general harmony with **Plessis** (1983) on Valencia orange, **Plessis &Koen** (1994) on Eureka lemon and **Okada** *et al* (1994) on Satsuma mandarin they mentioned that when fruit size is typically small, it was associated with a low K uptake as leaf K concentration fell to bellow 0.7%. Moreover, fruit size increased as K fertilization increased. In addition, **Cicala & Catara** (1994) on Tarocco orange trees, noticed that there was a significant correlation between leaf K content and fruit number, juice volume, juice acidity, fruit weight, rind thickness and TSS contents.

4.3.Response of Washington navel orange trees to soil mulch treatments.

4. 3. 1. Vegetative growth:

4. 3. 1. 1. Tree canopy volume:

The yearly increases in the tree canopy volume (i. e. the difference between tree canopy volume at the end and beginning of each growing season), generally ranged from 1.42 to 1.8 m^3 in the first season and from 1.65 to 1.93 m^3 in the second season. The tested soil mulch treatments significantly affected yearly increase in the tree canopy volume in both seasons. The least values (1.42 & 1.65 m^3 in the two seasons, respectively) were recorded by the control treatment (unmulched soil). The highest values (1.80 & 1.93 m^3, respectively) were gained by 20 cm soil mulch thickness treatment. The intermediate soil mulch thickness (10 cm thickness treatment) gave in between values (1.67 & 1.73 m^3, respectively).

4. 3. 1. 2. Increase in Shoot length and thickness:

As shown in Table (20), the increases in shoot length (as a percentage based on the initial shoot length at the beginning of growth season), generally ranged from 193.86 to 212.35% in the first season and from 167.97 to 245.76% in the second season. The soil mulch thickness significantly affected the increases in shoot length in both seasons. The least increases (193.86% & 167.97% in two seasons) resulted from control treatment (unmulched soil). However, 10cm soil mulch thickness, greatly promoted increases in shoot length to reach 202.39 & 232.46%, respectively. More increases of soil mulch thickness (20 cm) induced more significant increases in shoot length (212.35 & 245.76%, respectively).

The increases in shoot thickness, generally, ranged from 33.16 to 88.89% in the first season and from 33.33 to 112.22% in the second season. The least increases (33.16 & 33.33%, in two seasons, respectively) were resulted by the control treatment. Soil mulch treatments obviously promoted the increase in shoot thickness to reach 77.78 & 66.11 %; respectively when soil mulch was 10 cm, while it reached 88.89 & 112.22% when soil mulch was 20 cm thicken.

4. 3. 1. 3. Leaves number per shoot and leaf area:

Table (20) shows number of leaves per shoot and leaf area as affected by soil mulch in both seasons of study. The increases in number of leaves/shoot, generally, ranged between 64.51 to 164.82% in the first season and between 63.13 to 159.80% in the second season (as a percentage based on the initial number of leaves/shoot at the beginning of growth season). Soil mulch treatments (10 & 20 cm straw thickness) greatly increased the number of leaves/shoot compared to that of control treatment (unmulched soil). The least increases (64.51 & 63.13 %, in two seasons, respectively) were recorded by the control treatment, while mulched soil treatments significantly increased the leaves number/shoot and obtained (127.64 and 164.82% in the first season and 107.44 - 159.80% in the second season. More thickness of soil mulch (20cm thickness) added around 37% & 52% to the increases of leaves number/shoot realized by thinner soil mulch treatment (10 cm thickness) in the first and second season, respectively.

Soil mulch treatments (10 & 20 cm straw thickn) significantly increased the average leaf area compared to unmulched soil. The average leaf area in trees of control treatment was 32.50 & 32.07 cm^2 in the two seasons, respectively. Meanwhile, average leaf area was significantly increased to reach 34.2 & 35.6 cm^2, respectively for 10 cm soil mulch thickness and 34.9 & 35.9 cm^2, respectively for 20 cm soil mulch treatment. It is worth to mention that thickness of soil mulch had insignificant effect in this respect.

Soil mulching beneath the tree canopy significantly affected tree vigor, since it promoted the increase in shoot length and thickness as well as leaves number per shoot and average leaf area compared with trees grown on unmulched (bare) soil. The present results are in complete harmony with those mentioned by **Dzhabnidze** (1983) on Satsuma who reported that soil mulching (peat, tarred paper, green herbage and black plastic) improved shoot and budwood yields and increased standard shoot yield. Moreover, **Ishii & Kadoya** (1993) on Satsuma trees reported that trees in mulched plots were more vigorous than those in the clean cultivation plots.

Table (20) Effect of different soil mulch thickness on some vegetative growth characteristics of Washington navel orange trees (seasons of 1997&1998).

Soil mulch thickness (cm)	Tree canopy volume (m^3)	Percentage increments of: Shoot length *	Shoot thickness	Leaf number	Leaf area (cm^2)	Leaf dry weight (%)
	Season 1997					
Control	1.42 c	193.86 c	33.16 c	64.51 c	32.50 b	40.93 b
(10cm)thick.	1.67 b	202.39 b	77.78 b	127.64 b	34.20 a	42.77 a
(20cm)thick.	1.80 a	212.35 a	88.89 a	164.82 a	34.90 a	42.82 a
	Season 1998					
Control	1.65 c	167.97 c	33.33 c	63.13 c	32.07 b	40.38 b
(10cm)thick.	1.73 b	232.46 b	66.11 b	107.44 b	35.60 a	42.88 a
(20cm)thick.	1.93 a	245.76 a	112.22 a	159.80 a	35.90 a	42.17 a

* As a percent of initial shoot measurement at the beginning of growth.

Table (21) Effect of different soil mulch thickness on some leaf chemical constituents of Washington navel orange trees (seasons of 1997&1998).

Soil mulch thickness (cm)	N (%)	P (%)	K (%)	Fe (ppm)	Zn (ppm)	Mn (ppm)
Season 1997						
Control	2.16 b	0.13 a	1.06 b	74 c	42.7 b	38 b
(10cm)thick.	2.43 a	0.15 a	1.26 a	90.3 b	45.0 b	43.0 a
(20cm)thick.	2.58 a	0.17 a	1.36 a	104 a	53.0 a	47.0 a
Season 1998						
Control	2.18 b	0.13 a	1.10 b	77 c	55.3 a	35 b
(10cm)thick.	2.50 a	0.16 a	1.27 a	93 b	54.3 a	44.0 a
(20cm)thick.	2.68 a	0.18 a	1.37 a	108 a	56.3 a	48.7 a

Many investigators reported that improving of growth vigor of trees grown on covered soil was due to reduced water loss and increased root density as mentioned by **Richardson & Mooney** (1994) on Satsuma trees. In addition, **Jiang *et al*** (1997) on Satsuma and sweet orange indicated that trees grew well because mulching reduced soil temperature in summer and increased it in winter.

4. 3. 1.4. Leaf dry weight:

Table (21) show the effect of different soil mulch thickness on leaf dry matter content of Washington navel orange trees throughout the two experimental seasons.

Soil mulch treatments significantly increased leaf dry matter content compared to unmulched soil (control). However, differences between samples in 10 and 20-cm soil mulch thickness were not obvious in both seasons. The average values indicate that leaf dry matter percentages ranged from 40.93 to 42.82% in the first season and from 40.38 to 42.17% in the second season.

4. 3. 2. Leaf nutrients content:

As shown in Table (21), soil mulch treatments, promoted all determined nutrients in leaves, with the exception of phosphorus, compared with that of bare soil (control treatment). However, increasing soil cover thickness (from 10 to 20 - cm thickness) failed to add any significant increments in leaf (N, K and Mn) contents. This trend was true in both seasons.

Conclusively, soil mulch treatments promoted N, K, Zn, Mn and Fe accumulation in leaves. This was in a general agreement with the findings of **Mooney & Richardson** (1994) on satsoma mandarin and **Nakhlla & Ghali** (1996) on Washington navel orange. They reported that application of plastic sheets on the soil surface significantly affected leaves chemical composition and both N and K contents were greatly increased.

4. 3. 3. Fruit set and fruit drop:

4. 3. 3. 1. Fruit set:

As shown in table (22) the fruit set percentage indicate an obvious response to soil mulching procedure, this was insured in both seasons. Differences between the tested treatments (0&10 and 20 cm straw soil mulch thickness) were always statistically significant. However, increasing soil cover thickness from zero (control) to 10 cm thickness promoted fruit set by around 6% in the first season and 5 % in the second season, while the further increase in soil cover thickness (20 - cm thickness treatments) promoted fruit set by around 7% in the first season and only around 2 % in the second season.

4. 3. 3. 2. Periodic fruit drop:

Table (22) Fig. (7) show the total yearly fruit drop and its periodic drop throughout the three main stages of fruit growth (i.e. June drop stage, fruit development stage and pre - harvest drop stage).

During June drop stage, data in Table (22) show that fruit drop occurred mostly during this period 75.3 & 55.83 and 54.36% for 0,10 and 20 - cm soil cover thickness, respectively in the first season and the corresponding values in the second

Table (22) Effect of different soil mulch thickness on fruit set, periodic drop and total fruit drop throughout two studied seasons (1997&1998)

Soil mulch thickness (cm)	Fruit set (%)	Periodic drop (%) * June drop stage	** Fruit development stage	*** Pre-harvest stage	Total fruit drop (%)
	Season 1997				
Control	37.70 **c**	75.30 **a**	13.79 **b**	11.70 **a**	97.91 **a**
10(cm)	40.01 **b**	55.83 **b**	30.84 **a**	9.98 **b**	96.67 **b**
20(cm)	42.90 **a**	54.36 **b**	31.45 **a**	8.55 **c**	94.29 **c**
	Season 1998				
Control	40.26 **c**	72.94 **a**	13.21 **b**	10.00 **a**	96.08 **a**
10(cm)	42.30 **b**	54.65 **b**	31.23 **a**	10.30 **a**	96.18 **a**
20(cm)	43.24 **a**	54.04 **b**	31.17 **a**	08.87 **b**	94.22 **b**

* June drop stage: (20th June –1st July)
** Fruit development stage: (20th Sept. 20th October)
*** Pre- harvest stage: (20th Novemb. – 20th Dec.)

Table (23) Effect of different soil mulch thickness on yield and water use efficiency of Washington navel orange trees (seasons of 1997&1998).

Soil mulch thickness (cm)	Number of fruits /tree	Yield /tree (kg)	Calculated yield / fed (ton)	Water use efficiency (WUE)*
	Season 1997			
Control	98 **c**	17.46 **c**	2.933 **c**	1.59 **c**
(10cm)thick.	163.3 **b**	36.31 **b**	6.099 **b**	3.29 **b**
(20cm)thick.	182 **a**	41.88 **a**	7.036 **a**	3.80 **a**
	Season 1998			
Control	98.33 **c**	19.58 **c**	3.289 **c**	1.78 **c**
(10cm)thick.	182.67 **b**	41.56 **b**	6.982 **b**	3.77 **b**
(20cm)thick.	207.33 **a**	49.37 **a**	8.293 **a**	4.48 **a**

* WUE: kg fruit / one cubic meter of irrigation water.

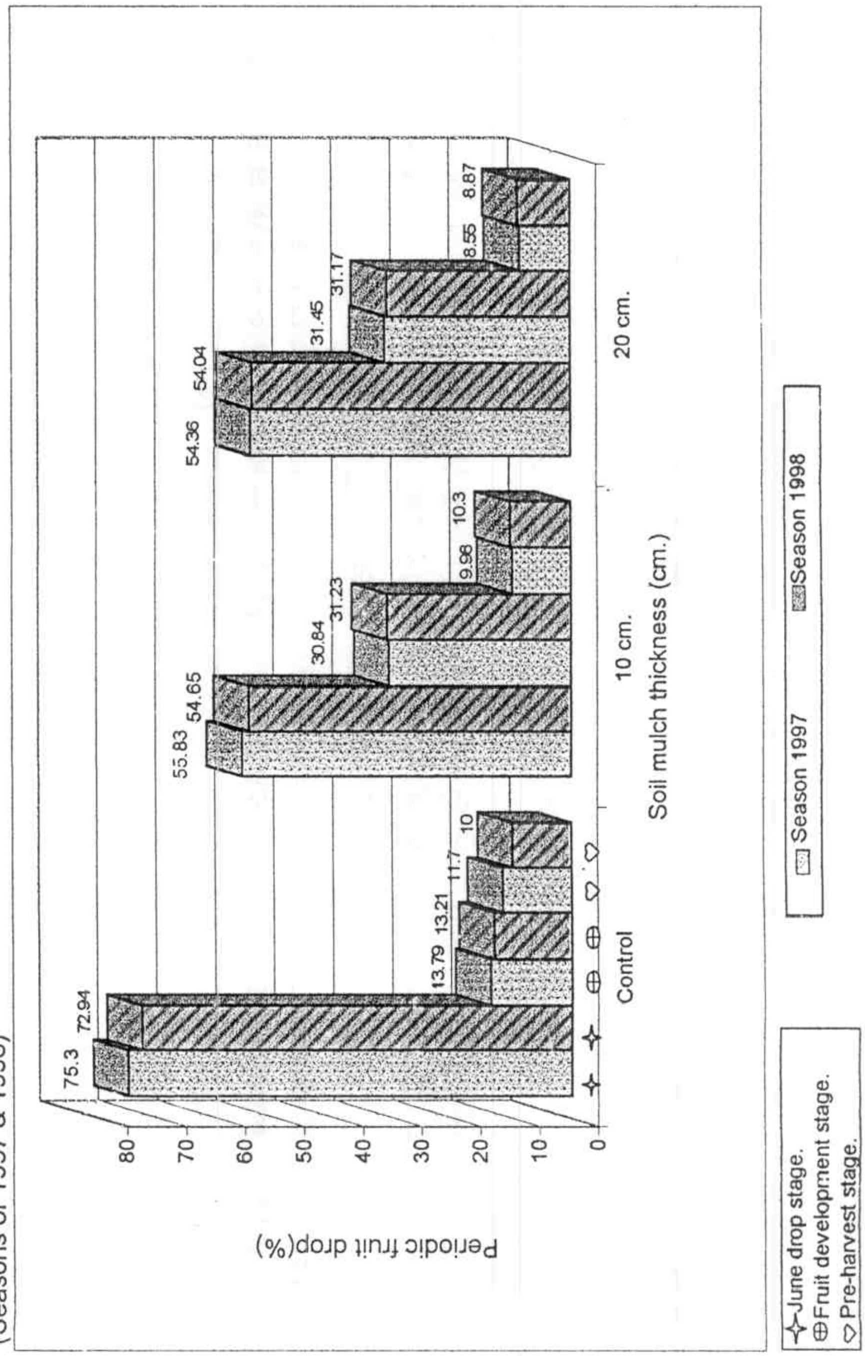


Fig (7) :- Effect of different soil mulch thicknes on periodic fruit drop of Washington navel orange trees (Seasons of 1997 & 1998) season were 72.94 & 54.65 and 54.04%, respectively). Covering soil surface with rice straw significantly reduced fruit drop percentage. This behavior was obvious in the two experimental seasons.

During fruit development stage; results indicated an opposite trend and fruit drop percentages recorded higher values with soil mulch treatments (30.84 & 31.45% for 10 and 20- cm soil mulch thickness, respectively in the first season and 31.23 & 31.17% respectively in the second season) compared with bare soil (control) treatment which recorded lower percentages (13.79 & 13.21% in the two seasons, respectively).

During the Pre-harvest stage; control treatment returned again to record the highest fruit drop percentages in both seasons (11.70& 10.0%, respectively). Meanwhile mulched soil treatments slightly reduced fruit drop percentage to reach the lowermost values (8.55 & 8.87% in the two seasons, respectively) with the thickest soil mulch treatment (i.e. 20 - cm straw thickness).

Concerning total fruit drop during the whole season it is clear that it, generally, ranged from 97.91 to 94.29 % in the first season and from 96.08 to 94.22% in the second season. Regarding the effect of soil mulch treatments on total fruit drop, it is found that bare soil (control) induced the highermost fruit drop percentages (97.91 & 96.08% in the two seasons, respectively). The mulched soil (10 - cm straw thickness treatment) decreased total fruit drop by around 1% in the first season and failed to yield this reduction in the second season compared with the control treatment. The thickest soil mulch (20 - cm straw thickness treatment) depressed total fruit drop again by around 2% in both seasons.

Generally, soil mulch treatments (10 and 20 - cm straw thickness) tended to reduce the total fruit drop percentage compared with the control (unmulched soil). There were slight differences between the two mulching treatments especially in the second season. In a general view, the trend of fruit drop percentages descendingly decreased throughout the three considered stages of fruit drop (i.e. June drop, fruit development drop and pre - harvest drop). This trend was true for both mulched (10 and 20- cm straw thickness) and unmulched (control) treatments.

The obtained results are in harmony with **Nakhlla & Ghali** (1996) who studied the effect of soil mulch treatments using polyethylene sheets on navel orange trees grown in sandy loam soil and irrigated by drip system. Data revealed that both June or total fruit drop significantly decreased by mulching the soil surface compared with control. However, the trend of fruit drop was not consistent. Present data are in a general agreement with that mentioned by **Protopapadakis** (1989) on navel orange and **Lohar *et al*** (1995)on mandarin orange

4. 3. 4. Yield parameters:

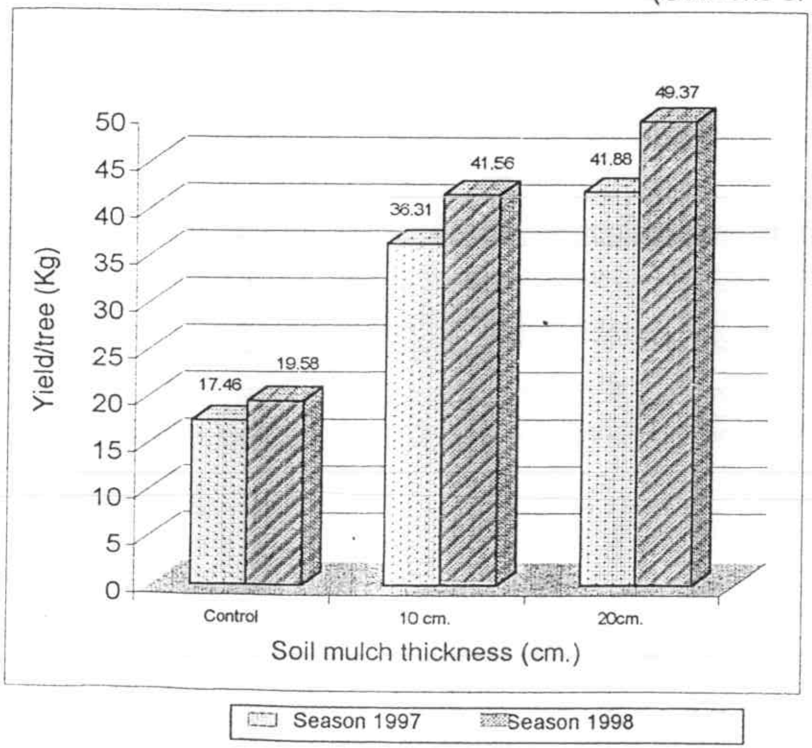
Table (23) and Fig. (8) demonstrate number of fruits/tree, the yield/tree (kg), calculated yield per feddan (ton) and water use efficiency as affected by soil mulch treatments in both seasons.

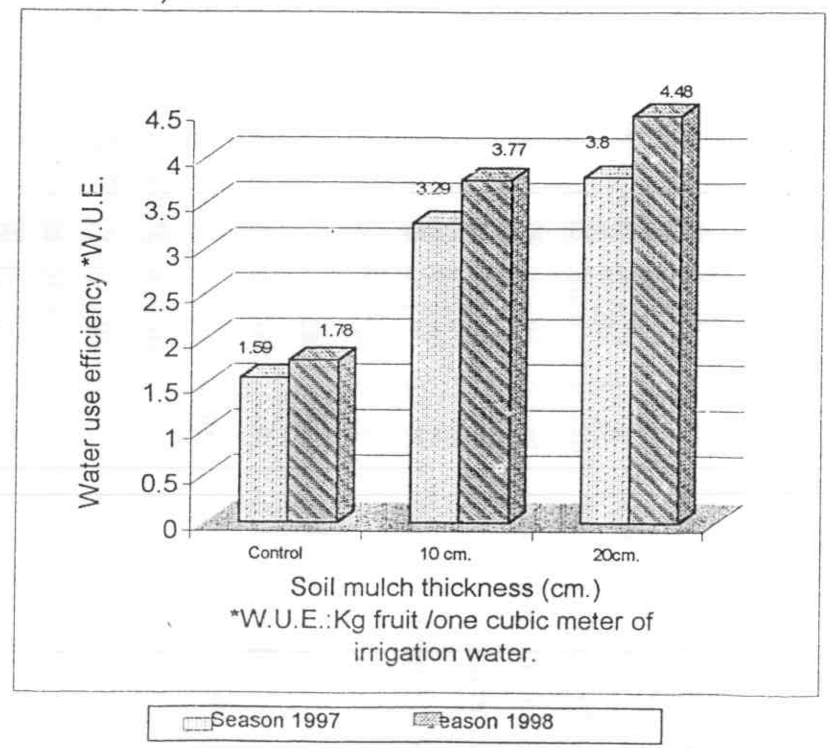
Concerning number of fruits/tree it generally ranged between 98 to 182 fruits in the first season and between 98.33 to 207.33 fruits in the second season. Thus the effect of soil mulch treatments was obvious as compared with; the control treatment (unmulched soil) produced in average 98 & 98.33 fruits in the first and second seasons, respectively. The mulched soil (10 - cm straw thickness treatment) increased number of fruits to reach 163.3 & 182.67 respectively. However, increased thickness of soil mulching (20-cm thickness treatment) added significant increases in both seasons and obtained 182 & 207.33 fruits/tree, respectively.

In regard to yield/tree kg as presented in Table (23) it ranged from 17.46 to 41.88 Kg in the first season and from 19.58 to 49.37 Kg in the second season. Soil mulching induced relatively higher yield compared to that obtained by unmulched soil (control). The effect of mulching was statistically significant in both seasons. The contro! treatment produced only 17.46 & 19.58 kg in the two seasons respectively. Meanwhile mulched soil increased the resulted yield/tree to reach 36.31 & 41.56 kg respectively for 10.cm straw thickness treatment. More addition of straw i.e. 20 - cm thickness treatment added another increments in yield to reach 41.88 & 49.37 kg, respectively.

In addition, calculated yield per feddan, generally, ranged from 2.933 to 7.036 tons in the first season and from 3.288 to 8.293 tons in the second season. It's worth to mention that resulted yield significantly increased as the straw mulch thickness was increased. Continuous application to another season (second year) greatly improved the obtained yield compared to the first season. This was true in both mulched and unmulched treatment (2.933 tons in the first season vs. 3.289 tons in the second season for control treatment). The corresponding values for soil mulch treatments were 6.099 vs.

Fig (8) :- Effect of different soil mulch thickness on yield and water use efficiency of Washington navel orange trees (Seasons of 1997 & 1998).





6.982 tons (10-cm thickens) and 7.036 vs. 8.293 tons for 20.cm thickness treatment, respectively.

Considering water use efficiency, i.e. kg fruits/one cubic meter of the supplied irrigation water (1850 m^3/fed./yr.),as represented in Table (23) and Fig (8) the obtained values, generally, ranged from 1.59 to 3.80 in the first season and from 1.78 to 4.48 in the second one. The effect of soil mulching was significant in both seasons. Thus, the water use efficiency indicated the least values (1.59 &1.78 kg fruit/m^3 of irrigation water, in the two seasons) with unmulched soil (control treatment), then increased significantly to reach 3.29 & 3.77 kg / m^3, respectively with 10-cm straw thickness treatment, followed by another increment up to 3.80 & 4.48 kg/m^3 respectively with 20 - cm straw thickness treatment.

Conclusively, soil mulching significantly increased the number of fruits/ tree, yield per tree and water use efficiency values. This was insured in both seasons and the second season was leading in this respect compared to the first one. Concerning the effect of soil mulching on yield, many investigators have reported similar findings, i.e. **Richardson *et al*** (1993) on mandarine and **Mostert** (1993) on Valencia orange trees. They reported that soil mulching with polyethylene enhanced flower development and total flower number and yield/ unit canopy valume. With grapefruit trees, mulching increased yields/tree by about 20% higher than without plastic mulch. In addition, **Nakhlla & Ghali** (1996) on Washington navel orange pointed out that perforated plastic sheets significantly increased fruit production compared with bare soil as control treatment.

As for water use efficiency, related literature declared that soil mulching (plastic soil cover) under grapefruit trees affected the average of annual water saving that amounted to 24% or 2.6 m^3 water/tree as determined by **Mostert** (1993). He reported that water use efficiency over 6 years of water supply were 9 kg/m^3 under plastic compared with 8 kg/m^3 in uncovered soil (control). In addition, studies of **Nakhlla & Ghali** (1996) on Washington navel orange reported that soil mulching with perforated plastic sheets increased fruit production and improved the value of water use efficiency.

4. 3. 5. Fruit physical properties:

Table (24) reveals the effect of soil mulch treatments on the fruit weight (gm), Juice volume (ml) and peel thickness (cm) as well as fruit dimensions (cm) in the two experimental seasons.

4. 3. 5. 1. Fruit weight:

Data show that fruit weight, generally ranged from 178.16 to 230.1 g in the first season and from 199.07 to 238.1 g in the second season. The soil mulch treatments exerted obvious effect on average fruit weight, the heaviest fruits (230.1 & 238.1 g in two seasons) resulted from 20 - cm straw thickness treatment, descendingly followed by 10 cm thickness treatment with average fruit weight of (222.33 & 227.50 g). The lightest fruits (178.16 & 199.07 g) came from the control treatment (unmulched soil). However, the differences between treatments were significant in both seasons. As such the increments in fruit weight due to soil mulch treatments were around 25% in the first season and 14% in the second season compared to the control treatment. Increasing straw thickness to 20 - cm added only around 4 - 5% to fruit weight in the two seasons.

4. 3. 5. 2. Fruit dimensions:

Table (24) shows the axial and equatorial dimensions of Washington navel orange fruits as affected by soil mulch treatments in both seasons. The fruit axial dimension was 6.1& 7.55 and 8.57 cm for 0 & 10 and 20 - cm straw thickness treatments, respectively in the first season. The corresponding values for equatorial dimension were 6.2, 7.04 and 7.85 cm in the first season and 7.1, 7.63 and 7.92cm, in the second season. Both fruit dimensions were significantly affected by soil mulch treatments compared to unmulched soil of control. Increasing straw mulch thickness (from 10 - 20- cm) significantly increased axial fruit dimension in both seasons, but failed to show such response with equatorial dimension.

4. 3. 5. 3. Peel thickness:

Peel thickness Table (24), generally, ranged from 0.47 to 0.60 cm in the first season and from 0.45 to 0.62 cm in the second season. Soil mulching induced thicker fruit peel than unmulched soil. Thus, the thinner peels were obtained by control treatment (0.47 & 0.45 cm in both seasons, respectively). Meanwhile, the thicker peel resulted by 10 and 20cm straw thickness treatments without significant differences between them (0.53 &0.60 cm for 10 and 20cm mulch thickness treatments, respectively in the first season and 0.55 & 0.62 cm, respectively in the second season).

4. 3. 6. Fruit chemical properties:

Table (25) indicates the total soluble solids, (TSS) (%), acidity (%), TSS/acid ratio and ascorbic acid contents in fruit juice as affected by soil mulch treatments.

Table (24) Effect of different soil mulch thickness on some physical properties of Washington navel orange fruits (seasons of 1997&1998).

Soil mulch thickness (cm).	Fruit weight (g)	Fruit dimensions (cm)		Peel thickness (cm)
		axial	equatorial	
Season 1997				
Control	178.16 **c**	6.10 **c**	6.20 **b**	0.47 **b**
(10cm)thick.	222.33 **b**	7.55 **b**	7.04 **a**	0.53 **a**
(20cm)thick.	230.10 **a**	8.57 **a**	7.85 **a**	0.60 **a**
Season 1998				
Control	199.07 **c**	7.40 **c**	7.10 **b**	0.45 **b**
(10cm)thick.	227.50 **b**	7.91 **b**	7.63 **a**	0.55 **a**
(20cm)thick.	238.10 **a**	8.67 **a**	7.92 **a**	0.62 **a**

Table (25) Effect of different soil mulch thickness on some chemical fruit quality parameters of harvested Washington navel orange fruits (seasons of 1997&1998).

Soil mulch Thickness (cm)	T.S.S (%)	Acidity (%)	T.S.S./acid ratio	Ascorbic acid (mg./100ml)
	Season 1997			
Control	12.70 **a**	0.63 **b**	20.16 **a**	48.55 **a**
(10cm)thick.	10.37 **b**	0.78 **a**	13.29 **b**	32.20 **b**
(20cm)thick.	11.33 **b**	0.83 **a**	13.65 **b**	28.80 **b**
	Season 1998			
Control	13.57 **a**	0.51 **b**	26.61 **a**	46.17 **a**
(10cm)thick.	12.00 **b**	0.55 **a**	21.82 **b**	32.50 **b**
(20cm)thick.	12.76 **b**	0.58 **a**	22.03 **b**	32.10 **b**

4. 3. 6. 1. Total soluble solids (TSS):

The (TSS) percentage generally ranged from 11.33-12.7% in the first season and from 12.76 - 13.57% in the second season. Soil mulching induced clear effect on (TSS) in both seasons. The highest values (12.7 & 13.57% in the two seasons, respectively) came from unmulched soil (control treatment. However, using soil mulch, i. e. 10 or 20 cm straw thickness treatments as compared with the control treatment, significantly reduced (TSS) values to10.37 & 11.33%, respectively in the first season and 12.0 & 12.76% in the second season without significant differences between them. Thus, soil mulching reduced the (TSS) by around 11% in the first season and 6% in the second season below with unmulched soil.treatment

4. 3. 6. 2. Juice acidity:

The effect of soil mulch treatments on juice acidity indicated a trend opposite to that of (TSS). Thus, The highest juice acidity in both seasons were (0.78 & 0.83% for the two mulching treatments in the first season and 0.55 & 0.58% in the second season). Meanwhile, unmulched soil treatment (control) significantly decreased juice acidity to reach 0.63 & 0.51% in the two seasons, respectively. Thus, soil mulching increased juice acidity by around 19% & 7% in the two season, respectively over unmulched soil treatment.

4. 3. 6. 3. TSS/acid ratio:

As show in Table (25), using soil mulching, tended to decrease TSS/acid ratio compared with that of bare soil. However, the difference between the two rates of straw thickness (i.e. 10 and 20cm thickness treatments) was insignificant in both experimental seasons. Thus, TSS/acid ratio could be arranged as follow: 20.16& 13.29 and 13.65% for 0& 10 and 20cm straw thickness, respectively in the first season. The corresponding values in the second season were 26.61& 21.82 and 22.03%, respectively.

4. 3. 6. 4. Ascorbic acid:

The ascorbic acid level (mg/100 ml of the juice), generally, ranged from 28.80-48.55 in the first season and from 32.10-46.17 in the second season. Soil mulching significantly reduced juice ascorbic acid content in both seasons compared with that of the control. The highest level was gained by unmulched soil treatment (control) being 48.55 & 46.17mg, in the two seasons,respectively, descendingly followed by mulched soil treatments (i.e. 10 and 20 cm)straw thickness treatments without significant differences between them which attained 32.20 & 28.80 mg/100 ml juice, respectively in the first season and 32.50 & 32.10 mg in the second season.

From the previous results one can say safely that, soil mulching obviously increased fruit weight, number of fruits/tree. yield/tree and water use efficiency as well as fruit dimensions, juice volume, peel thickness and juice acidity. Whereas depressed fruit juice TSS. TSS/acid ratio and ascorbic acid contents.

The obtained herein results are in harmony with **Hyun** ***et. al*** (1993) on Satsuma mandarin, **Richardson** ***et. al*** (1993) and **Nakhlla & Ghali** (1996) on Washington navel orange trees they reported that soil mulching by polyethylene produced a biggest size fruits and increased fruit juice volume.

4.3.7. Root studies

4.3.7.1. Number of roots.

Data presented in Table (26) show the effect of soil mulch treatments on number of roots per tree soil sample in the different tree directions, average number of roots/treatment and total roots number/four soil samples per tree including (fibrous, intermediate and skeletal roots number), as well as the amount of growing root percentage and root growth activity.

From Table (26) it is clear that the soil mulch treatments significantly increased the average roots number/tree for soil sample compared to unmulched soil (control). This was true with three types of roots (i.e. fibrous, intermediate and skeletal). Concerning fibrous roots,(Fig 9) the control attained an average 5675 roots /sample (including four tree directions), then increased to reach 7175 roots/sample in the soil mulched by 10-cm straw thickness, while increasing soil cover thickness (20 -cm straw thickness treatment) added more average number of fibrous roots which recorded 11350 roots/sample. The obtained data revealed a similar trend with both intermediate and skeletal roots as follows. Average number of intermediate roots/sample were 950, 900 and 1500 for 0&10 and 20-cm straw thickness treatments, respectively. The corresponding number of skeletal roots were 1000, 950 and 1525 roots/sample, respectively.

Differential response to tree's directions.

Table (26) shows the differential response of three types of roots to the soil mulch treatments in different locations of soil sampling around the tree (i.e. east, west, north and south).

As for, fibrous roots number, 20 - cm straw mulch thickness treatment occupied the first rank in the locations (north and east of the tree directions) and in second rank for (west and south), while 10-cm straw thickness treatment was in the first rank for(west and south) and in the second rank for (east) and in the third rank for (north direction). Meanwhile, control trees failed to be in the first rank, but they came in the second for (west, north and south directions) and in the third rank for (east).

Concerning intermediate roots, the thickest soil mulch i.e. 20-cm straw thickness recorded the highest number of roots/soil sample in all tree directions. However, 10-cm straw thickness treatment, came in the second rank for (north & east directions) and in the third rank for (south & west). On the other hand, unmulched soil (control) came in the second rank in sampies taken from (south, east and west directions) and in the third rank for (north).

Referring to skeletal roots, it is worth to mention that, 20 cm soil mulch treatment occupied the first rank in samples from (south, north and east directions) and in the second for (west). Meanwhile, 10-cm soil mulch treatment was in the second rank for (south, north and east) and in the third rank for (west). Control treatment was in the first rank only in (west) and in the second rank for (east and south) and in the third rank in (North) .

Total number of roots / tree soil sample

Data presented in Table (26) show the total number of roots (included three types of roots i-e. fibrous, intermediate and skeletal) per tree samples (collected from the four directions of each tree) the effect of soil mulching was much more pronounced with 20cm straw thickness treatment which recorded 45400, 6000, 6100 and 57500 roots / tree soil samples (fibrous, intermediate, skeletal and total roots, respectively). However, thinner soil cover, i.e. 10- cm straw mulch treatment attained 28700, 3600, 3800, and 36100 roots/tree soil samples, respectively. On the other hand unmulched soil recorded the lowest number of roots / tree soil samples (22700, 3800, 4000 and 30500 roots respectively).

Amount of growing roots:

Table (26) and Fig (10) presented the amount of growing roots, (i-e .the percentage of fibrous roots based on total roots number). The least amount of root growth (74.43%) was gained by control treatment (unmulched soil). Meanwhile, mulched soil by 10 and 20. cm straw thickness significantly increased the amounts of growing roots to reach 79.50 - 78.96 % respectively.

Root growth activity:

Data in Table (26) and Fig (11) revealed the root growth activity (absorbing roots number/10cm of intermediate + skeletal roots). It reflects the distribution of fibrous roots on the skeleton of root system (old and thicker roots).The higher number of roots/ 10 cm of old root (intermediate + skeletal) was detected under 20-cm straw thickness treatment (491.34 roots/10cm), descendingly followed by 10-cm thickness of straw mulch which attained 315.38 roots/10cm, then bare soil (control) came later in this respect and recorded the least rate of root growth activity (215.57 roots/10cm).

4.3.7.2. Root length:

Table (27) show the effect of soil mulch treatments on root length (m) / soil sample in different tree directions, average root

Table (26) Effect of soil mulch thickness on Washington navel orange roots number.

(A) Number of roots / soil sample *.

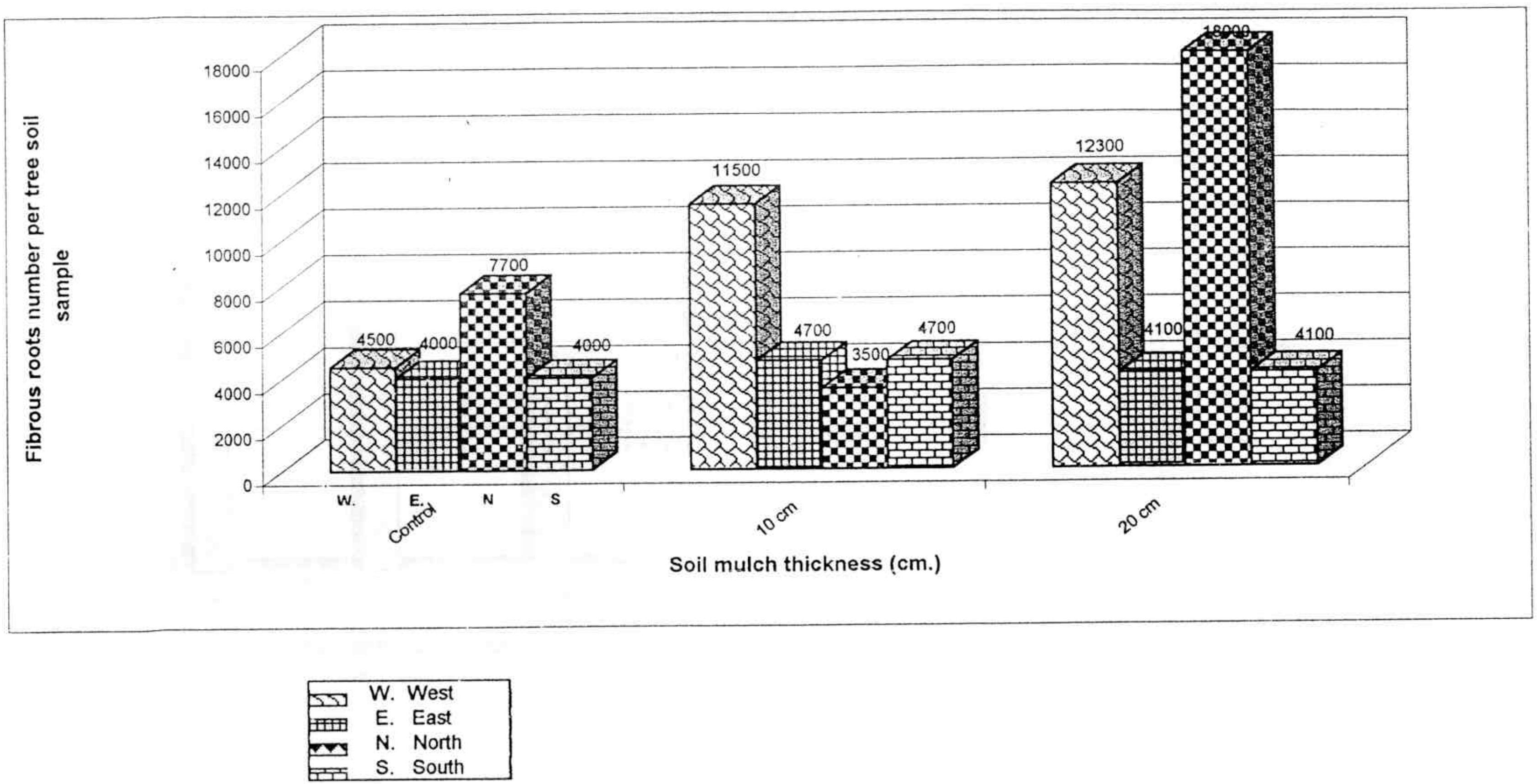
Soil mulch thickness	Soil samples in different directions beneath tree canopy				Average
	West	East	North	South	
	Fibrous roots				
Control	4500 c	4000 b	7700 b	4000 b	5675 c
10 cm	11500 b	4700 a	3500 c	4700 a	7175 b
20 cm	12300 a	4100 b	18000 a	4100 b	11350 a
	Intermediate roots				
Control	1100 b	600 b	1300 c	800 b	950 b
10 cm	800 c	700 b	1500 b	600 c	900 b
20 cm	1700 a	1600 a	1800 a	900 a	1500 a
	Skeletal roots				
Control	1200 b	1200 a	1000 c	600 b	1000 b
10 cm	1100 b	800 c	1200 b	700 b	950 b
20 cm	1700 a	1000 b	2000 a	1400 a	1525 a

*Soil sample 50x50x50 cm dimensions.

(B)Total number of roots (in four directions)per tree and root growth parameters

Soil mulch thickness	Fibrous roots	Intermediate roots.	Skeletal roots	Total root number/tree samples	Amount of growing roots (%)	Root growth activity
Control	22700	3800	4000	30500	74.43	215.57
10 cm	28700	3600	3800	36100	79.50	315.38
20 cm	45400	6000	6100	57500	78.96	491.43

Fig (9) :- Effect of soil mulch thickness on washington navel orange fibrous roots number per tree soil sample.



(10) :- Effect of soil mulch thickness on amount of growing roots

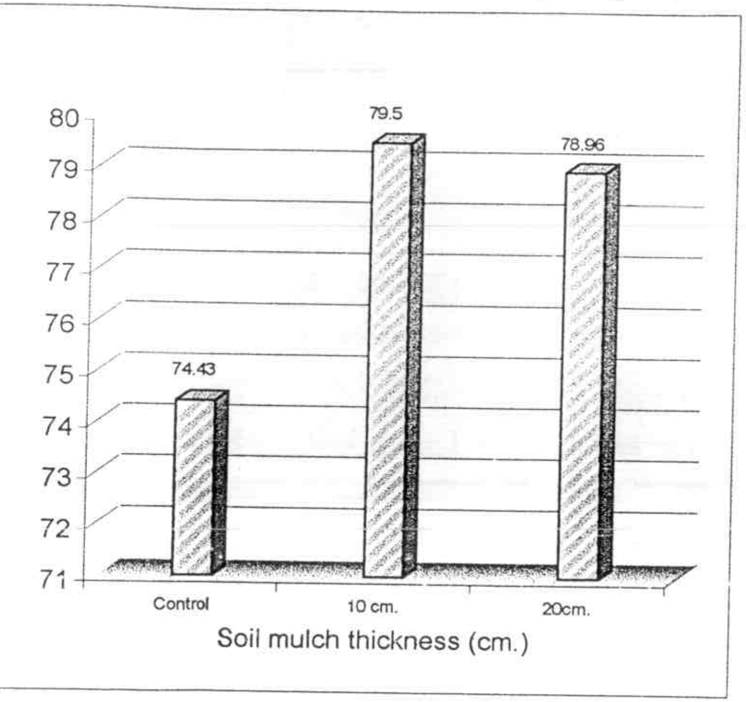
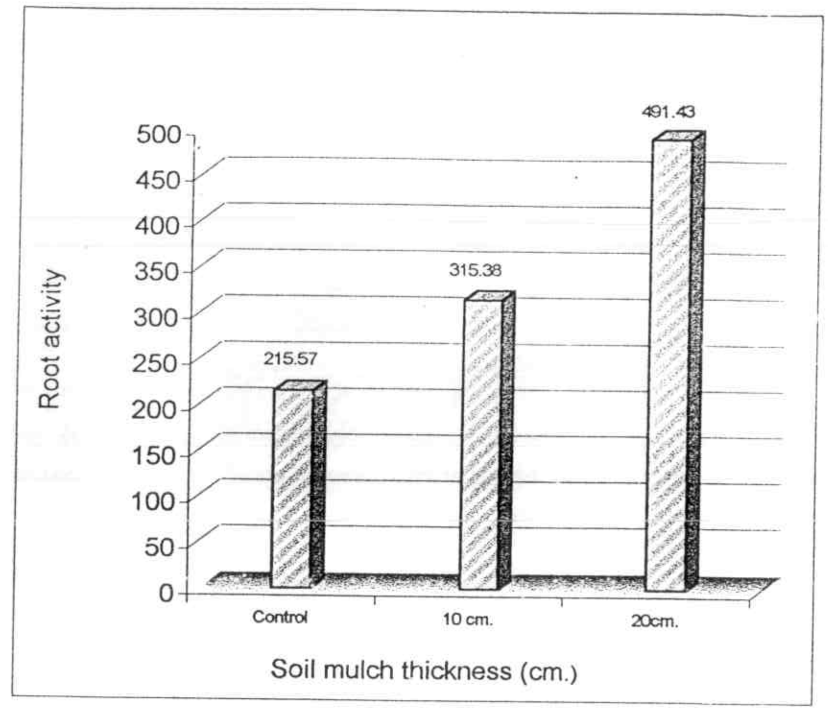


Fig (11) :- Effect of soil mulch thickness on root growth activity



length for each treatment and the total root length/four soil samples per tree (including fibrous, intermediate and skeletal root length), as well as the absorbing root percentage and root coefficient values.

Concerning fibrous roots, as illustrated in Fig (12) data showed a trend similar to that detected by number of roots. Thus, the average of root length was increased as the soil cover thickness increased. Regarding the intermediate roots, generally the mulched soil significantly induced more root growth than that of unmulched soil. Soil mulched with 20-cm straw attained the highest average of root length being 6.89 m/ sample followed by 10-cm thickness treatment 4.89 m / sample.However, control treatment recorded 2.7 m / sample .

Concerning skeletal roots, the length of skeletal roots revealed obvious response to soil mulching. The longest roots were recorded under the thickest soil cover, (i.e. 20-cm straw thickness treatment) which recorded 6.43 m/sample descendingly followed by 10-cm straw thickness treatment (4.13,m), then the control treatment came later and attained 3.74 m/ sample.

Differential response to tree's directions.

To assess the differential response of root length to tested treatments in various tree directions, data in Table (27) shows that 20 cm straw thickness treatment greatly enhanced the growth of fibrous roots and gained the longest roots in the four directions compared with other treatments, descendingly followed by 10 - cm straw thickness treatment which occupied the second rank for (east, west and north directions) and in the

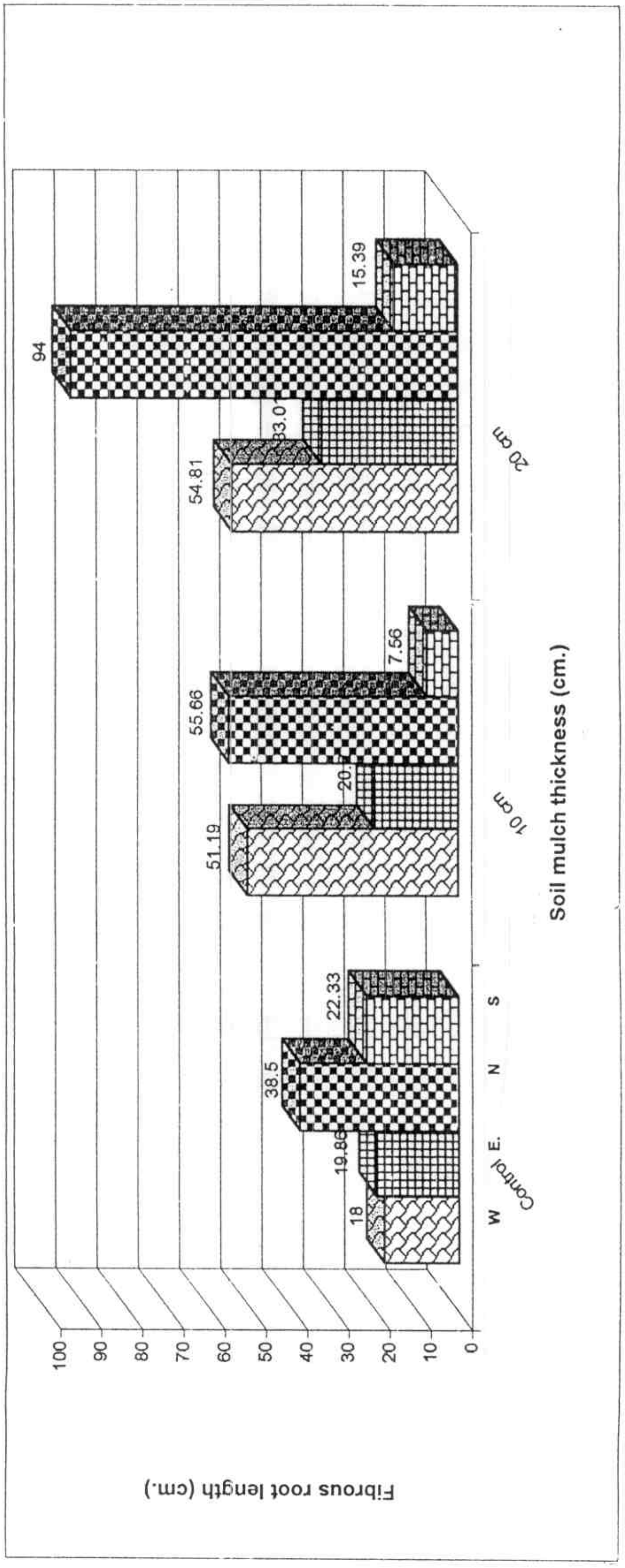


Fig (12) :- Effect of soil mulch thickmess on washington navel orange fibrous root length.

third rank for (the south direction). The least root length was detected by the control treatment and came in the second rank only in the south direction and in the third rank for (east, west and north directions).

Regarding intermediate roots, it followed the same trend showed by fibrous roots for the west, north and south directions, while the east direction indicated insignificant response between the three experimental treatments.

The longest skeletal roots, were detected in three directions namely, east, west and north by the 20-cm straw thickness treatment, however, the middle root length was obtained by 10-cm straw thickness treatment for east, west and north directions and came latest in the south direction. Shortest root length was detected for the control treatment in the east, west and north directions, while increased significantly only in the south direction of the trees.

<u>Total roots length / tree soil samples</u>

Table (27) shows the total length of roots/tree (i.e. four samples collected from different tree directions) as affected by soil mulch treatments. The longest roots were significantly detected in the 20-cm straw mulch thickness treatment. (176.5, 15.69, 21.25 and 213.51 m for fibrous, intermediate, skeletal and total roots length respectively). The corresponding values for 10-cm straw thickness treatment were (154.65, 18.02, 18.37 and 191.04 m, respectively). On the other hand, shortest roots were associated with control treatment which recorded 98.69, 24.50,17.59 and 140.78, m for fibrous, intermediate, skeletal and total roots length.

Table (27) Effect of soil mulch thickness on Washington navel orange roots

(A) Root length(m / soil sample).

Soil mulch thickness	Soil samples in different directions beneath tree canopy				Average
	West	East	North	South	
	Fibrous roots				
Control	18.00 c	19.86 c	38.50 c	22.33 b	24.67 c
10 cm	51.19 b	20.20 b	55.66 b	7.56 c	33.65 b
20 cm	54.81 a	33.01 a	94.00 a	15.39 a	49.30 a
	Intermediate roots				
Control	3.00 b	4.00 a	1.59 c	2.50 c	2.77 c
10 cm	4.52 a	4.02 a	7.50 b	3.50 b	4.89 b
20 cm	5.50 a	4.33 a	12.50 a	5.25 a	6.89 a
	Skeletal roots				
Control	3.00 c	1.88 c	4.09 c	6.00 a	3.74 c
10 cm	4.77 b	4.50 b	6.20 b	1.05 c	4.13 b
20 cm	5.11 a	6.35 a	10.01 a	4.25 b	6.43 a

* Soil sample :50 x 50 x 50 cm dimensions

(B) Total root length (in four directions)per tree and root activity parameters

Soil mulch thickness	Fibrous roots (m)	Intermediate roots. (m.)	Skeletal roots (m)	Total length (m.)	Absorbing roots (%)	Root coefficient
Control	98.69	24.5	17.59	140.78	70.10	0.43
10 cm	154.65	18.2	18.37	191.04	80.95	0.53
20 cm	176.57	15.69	21.25	231.51	82.70	0.39

Absorbing roots percentage.

Data of Table (27) and Fig (13) declared that absorbing roots percentage (i.e. the percentage of fibrous roots length to total roots length), generally, ranged from 70.10 to 82.70%. The lowermost percentage 70.10% resulted from unmulched treatment, while mulched soil significantly increased the percentages of absorbing roots (80.95 and 82.70% for 10 and 20-cm straw thickness treatments, respectively.

Root coefficient value

Table (27) and Fig (14) demonstrate the root coefficient values under soil mulch condition as well as unmulched soil of the control. The values indicate the branching ability of fibrous roots as a result of good soil conditions and favorable rizosphere. In this respect, 10 - cm straw thickness treatment was leading and recorded 0.53 cm/ one fibrous root, descendingly followed by 0 and 20 - cm straw thickness treatments (0.43 &0.39 cm/root, respectively.

4.3.7.3. Weight of roots

Data presented in Table (28) show the effect of soil mulch treatments on weight of roots/ soil sample in different tree directions, an average of roots weight (for each treatment) and the total weight of roots collected per tree as well as relative weight of growing roots.

Table (28) declared a significant effect of soil mulching on weight of roots (gm). Concerning fibrous roots,(Fig 15) it is clear that heaviest roots (an average being 630.25 gm /sample) were

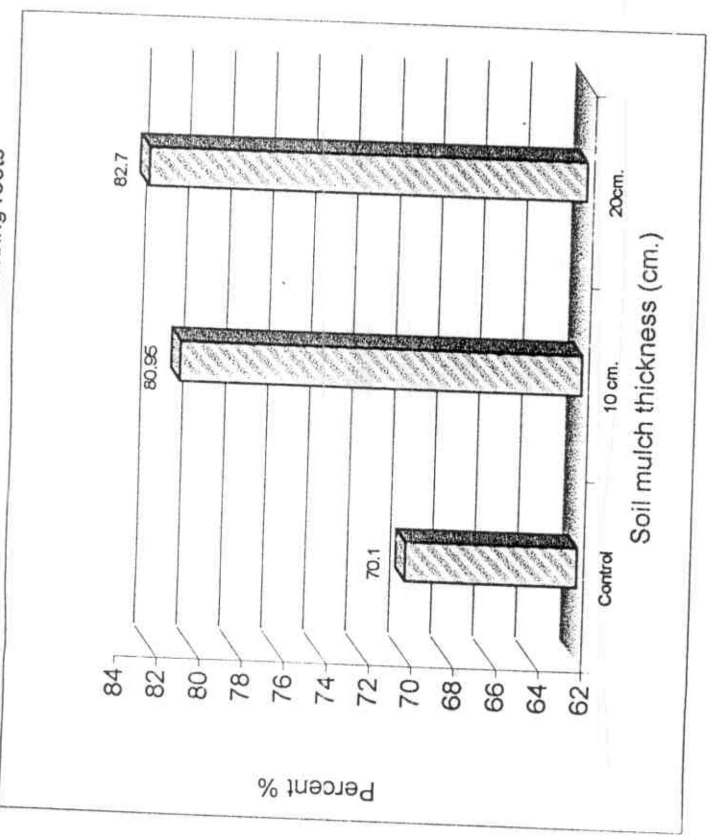


Fig (13) :- Effect of soil mulch thickness on absorbing roots

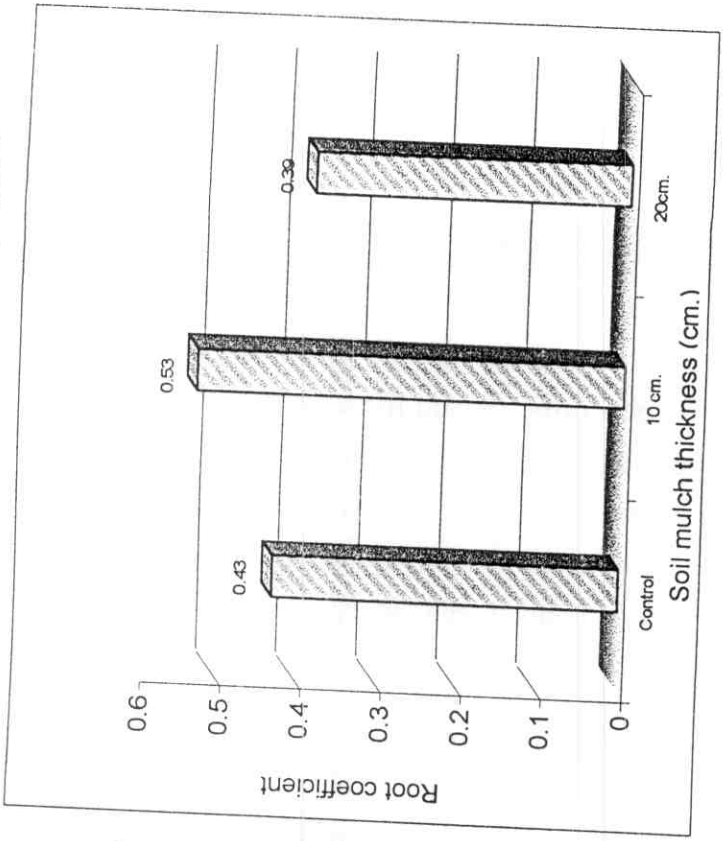


Fig (14) :- Effect of soil mulch thickness on root Coefficient

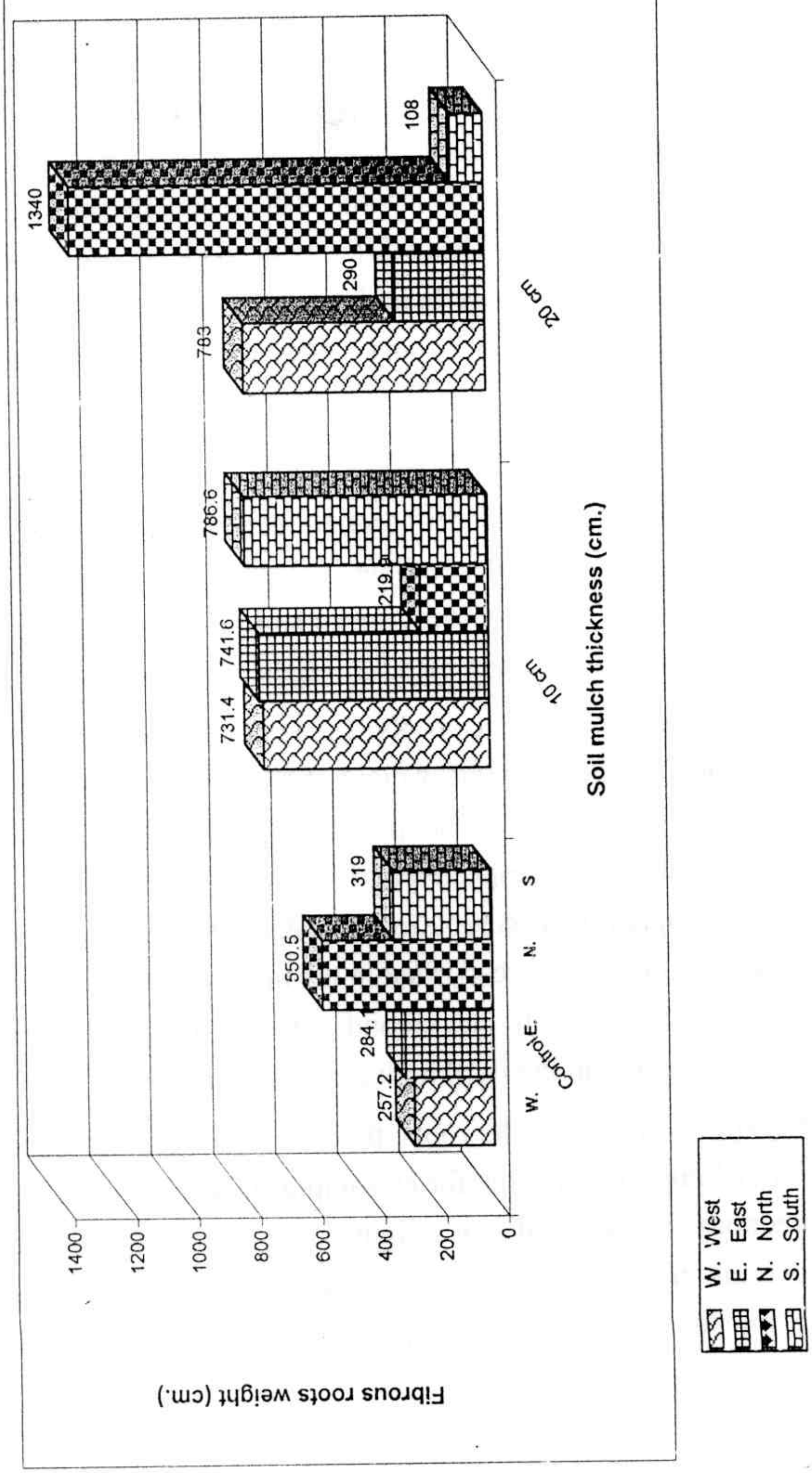


Fig (15) :- Effect of soil mulch thickness on washington navel orange fibrous roots weight.

obtained from samples of mulched soil with 20- cm straw thickness, while middle weight (619.9 gm / sample) obtained from the 10-cm thickness treatment. However, the least weight of roots (352.7 gm) was gained by the control treatment. Similar trend was detected with intermediate roots (342.4, 414.4 and 446.3 g/soil sample for 0,10 and 20-cm mulch thickness treatments, respectively. Meanwhile, with skeletal roots, the resulted weights in response to mulching were also statistically significant (2322.8, 3765.2 and 5762.6 g per sample, respectively).

Differential response to tree's directions

Table (28) shows the differential response of the three types of roots (fibrous, intermediate and skeletal) to the soil mulch treatments in different locations of soil sampling (i.e. east, west, north and south) as expressed by weight of roots.

With respect to fibrous roots, 20 – cm straw thickness treatment yielded the heaviest weight of roots in both west and north directions, followed by samples taken from east and south in second and third rank respectively. However, 10-cm thickness treatment occupied the first rank for (east &south directions)and in the second rank for (west), then in the third rank for (north). Control treatment, was in the second rank for (east, north and south directions) and in the third rank for west direction.

Regarding intermediate roots, there was no clear trend due to soil mulching, this was true for all samples taken from various tree directions. The skeletal root weight showed clear response to soil covering treatments. Thus, 20- cm thickness treatment was leading in this respect and recorded the heaviest weight of roots

Table (28) Effect of soil mulch thickness on Washington navel orange roots weight (g / soil sample)

(A) Roots weight (g / soil sample)*.

Soil mulch thickness	Soil samples in different directions beneath tree canopy				Average
	East	West	North	South	
	Fibrous roots				
Control	284.1 **b**	257.2 **c**	550.5 **b**	319.0 **b**	352.7 **c**
10 cm	741.6 **a**	731.4 **b**	219.9 **c**	786.6 **a**	619.9 **b**
20 cm	290.0 **b**	783.0 **a**	1340.0 **a**	108.0 **c**	630.25 **a**
	Intermediat roots				
Control	243.8 **c**	**121.6 b**	767.1 **a**	**237 b**	342.4 **c**
10 cm	493.4 **a**	**513 a**	519.0 **b**	132.1 **c**	414.4 **b**
20 cm	265.0 **b**	509 **a**	393.0 **c**	618 **a**	446.3 **a**
	Skeletal roots				
Control	3548.5 **c**	1194.0 **c**	1805.0 **c**	2743.5 **c**	2322.8 **c**
10 cm	4164.6 **b**	2146.4 **b**	4647.9 **b**	4101.7 **b**	3765.2 **b**
20 cm	5670.0 **a**	3322.0 **a**	8846.3 **a**	5212.0 **a**	5762.6 **a**

*Soil sample 50x50x50cm dimensions.

(B)Total weight of roots (in four directions)per tree and some root parameters

Soil mulch thickness	Fibrous roots (g)	Intermediate roots. (g)	Skeletal roots (g)	Total weight (g)	Relative weight of growing roots (%)
Control	1410.8	1760.9	9332.4	12504.1	100
10 cm	2479.5	1666.12	15060.6	19206.22	153.6
20 cm	2521	1785	16009	20315	162.47

for all tree directions, descendingly followed by 10-cm thickness treatment which came in the first 2nd rank for all directions. Lightest weights of roots were recorded by the control treatment and gave the least values for all tree directions.

Total roots weights / four soil samples per tree

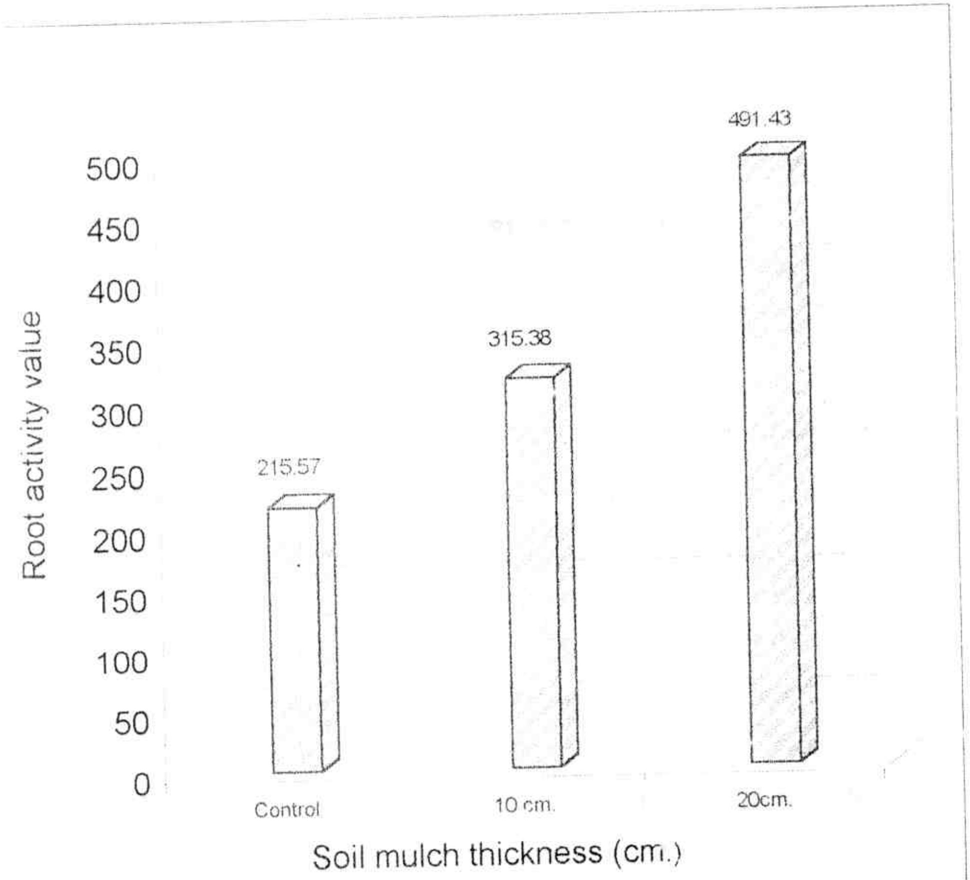
As shown in Table (28) soil mulch treatments significantly promoted root growth and clearly increased weights of roots as soil mulch thickness increased. Thus, unmulched soil (control) attained lowest weights of roots (included the fibrous, intermediate and skeletal roots) being 12504 (gm) compared to 19206 (gm) obtained in soil mulched with 10-cm straw thickness. Meanwhile, more straw thickness (i.e.20-cm thickness treatment) resulted in highest weights of roots being 20315 g.

Relative weight of growing roots

Table (28) and Fig (16) show the relative weight of growing roots. i.e. percentage of increment or decrement of root growth by soil mulch treatments compared to root growth of control (based on 100% for control). The effect of soil mulching was clear in both treatments and the relative weight of root growth increased significantly as soil mulch thickness was increased, the obtained results were 153.6 and 162.47% for 10and 20-cm thickness treatments, respectively compared with the control (being 100%).

Conclusively, soil mulching induced root growth indices (root number, length and weight as well as another root activities such as, absorbing root percent and, root growth activity)

Fig (16) :- Effect of soil mulch thickness on root growth activity



Amount of growing roots and relative weight of growing roots were significantly affected by soil mulching. This was true, for great extent, with the three types of roots (i.e. fibrous, intermediate and skeletal roots). These results are in general agreement with the findings of **Dzhingharadye & Dzhabnidye** (1985)on mandarin trees. They reported that green herbage and black plastic, as a soil mulching, gave the best results for total weight of feeder and conducting roots which increased from 2534 g/tree in control to 3764 & 3614 g/tree, respectively.

In addition, **Koudounas** (1994) on Valencia and Grapefruit trees reported that root weight was influenced by soil texture and moisture and this was correlated with the amount of feeder roots in all soil layers. Thereafter, **Nakhlla & Ghali** (1996) on Washington navel orange trees, decided that root dry weight clearly showed significant differences between bare soil treatment and other rates of mulching.

4.3.7.4. Root distributions

Table (29) show the root distribution in both vertical and horizontal directions as affected by soil mulch treatments.

Vertical root spread

From soil profile digged in an area located 1.5 m distance from the tree trunk, root distribution along soil profile layers was noticed and root penetration downward was recorded as follow

As an average of root depth, it generally, ranged from 43.0 to 48.25 cm. However, the significant differences could be detected where the highest value belonged to the control treatment (unmulched soil). Meanwhile, in mulched soil, the limits of vertical root extension ceased at 43.2 & 43.0 cm depth for 10 and 20-cm straw thickness treatments, respectively with insignificant differences between them.

Concerning vertical root extensions at different directions. (sites around the tree periphery), data revealed that at the north and east directions the roots were deeper and soils were exploited by roots to a depth 65.30 & 51.70 cm, respectively under soil surface for unmulched soil . However in mulched soil, roots were found in the top 42.8 & 42.40 cm at (north) and 42.3 & 42.8 cm at (east) directions for l0 and 20 - cm straw thickness treatments, respectively. On the other hand, opposite trend was detected in profile digged at (south) direction, the control treatment showed relatively shallow roots (33.7 cm) compared to 44.8 - 43.60 cm for the two mulched treatments, respectively. As for the (west) direction, data revealed insignificant differences between mulched and unmulched soils in this respect .

Conclusively, in the present experiment, generally, root vertical extension was much deeper in bare soil than those in mulched ones. This is confirmed by the fact that, roots search for soil moisture. Whereas irrigation lines, in the present study, were setted in the north direction, it is expected that root growth become restricted near the soil surface and sufficient soil moisture. This conclusion is in a general agreement with **Bielorai** (1986) on Grapefruit and Shamouti and **Nakhlla & Ghali** (1996) on Washington navel orange study in comparing the complete or partial soil wetting on the root distribution. They found that most of roots (80%) were in the upper 6ocm soil layer and extracted 85% of the available soil water. This also indicate that soil moisture, temperature and aeration might have played an active role in enhancing fibrous root extension.

More related literatures concerning root vertical extension are in a harmony with the obtained results of. **Bredell** (1977) on Valencia orange trees determined soil moisture content at different depths under both grass and bare soil and found that soil moisture at the upper 20 cm was lower in bare soil, but at the lower depths, exploited by roots, differences in soil moisture were slight.

In addition; **Dzhingharadye & Dzharbnidye** (1985) on mandarine, **Becera** (1986) on Maxican lime declared that root penetration in soil depths was greatest without mulching and more than 90% of roots were found in the top 6o cm soil layer. Moreover, **Lopez& Medina** (1986) on Maxican lime and **Koudounas**(1994)on Valencia and Grapefruit trees showed that 50-60% of feeder roots found in the top 30 cm of soil and 25-30% in the under layers to a depth of 60 cm. The same results were reported by **Kanber** ***et al*** (1996) and **Nakhlla & Ghali** (1996) on Washington navel orange. They reported that the amounts of tree roots decreased with soil depth and mere than 80% of the roots were in the top 60 cm soil layer.

Horizontal root spread

Data of Table (29) reveal obvious differences between the averages of tested treatments concerning horizontal root extension which ranged from 188.5 to 221.6 cm. The lowest value belonged to the unmulched soil (control treatment) and the highest value was recorded by soil mulched with 20-cm straw thickness treatment. Meanwhile 10-cm straw thickness treatment

Table (29) Effect of soil mulch thickness on root distribution in both vertical and horizontal directions under Washington navel orange trees canopy.

Soil mulch thickness	* Vertical root growth (cm) at one meter distance from the trunk.			
	North	South	West	East
Control	65.30 **a**	33.7 **b**	42.30 **a**	51.7 **a**
10 cm	42.80 **b**	44.8 **a**	42.70 **a**	42.3 **b**
20 cm	42.40 **b**	43.6 **a**	43.37 **a**	42.76 **b**
	Horizontal root growth (cm)			
Control	194 **c**	182 **c**	188 **c**	190.0 **c**
10 cm	243 **a**	187.3 **b**	198 **b**	202.4 **b**
20 cm	235 **b**	210 **a**	218.7 **a**	222.3 **a**
	Average root distribution		Soil area occupied by roots	
	Vertical	Horizontal	(m^2)	(%)
Control	48.25 **a**	188.5 **c**	11.16 **c**	44.60 **c**
10 cm	43.20 **b**	207.7 **b**	13.55 **b**	54.18 **b**
20 cm	43.0 **b**	221.6 **a**	15.34 **a**	61.34 **a**

*As a percent from soil area specified for each tree ($25m^2$)

was in between and the fibrous root spread reached 207.7cm in the horizontal distribution.

Comparing horizontal distribution of fibrous roots at different tree's direction, data indicate that in the control treatment (bare soil) the root extension was leading in the north - east directions followed by west-south directions. The wide extension of the root system was encouraged by the soil mulch treatments, thus 20-cm straw thickness treatment was leading in this respect and root extension was between 210.3 - 235cm at different trees directions as follow:(north, 235 cm), (east, 222.3 cm), (west, 218.7 cm) and (south, 210.3 cm). Descendingly in the second rank came 10-cm thickness treatment which varied between 187.3 - 243 cm and arranged as follow (north, 243), (east, 202.36), (west, 198 cm) and (south, 187.3).

Soil area occupied by roots:

Table (29) shows soil area occupied by root system as a result of soil mulch applications. The root system distribution in area around the tree trunk squared 11.16 m^2 in the bare soil representing 44.6% of the soil area specified for each tree (i. e. 25 cm^3). However, using soil mulch, 10-cm straw thickness. significantly increased soil area occupied by root system to reach 13.55m^2 represented 54.18% of the specified area per tree. Whereas increasing soil cover thickness to 20-cm, the root system was distributed throughout wider area and occupied 15.34 m^2 represented 61.34% of specified area/tree.

Concerning related literatures, the present data are in harmony with **Dzhingharadye & Dzhabnidye** (1985) on mandarin, **Becera** (1986) and **Lopez & Medina** (1986) on

Mexican lime. They mentioned that soil mulching, improved horizontal root development and 86% of roots were found within the radios of the tree canopy. Moreover, **Kanber *et. al*.** (1996) and **Nakhlla & Ghali** (1996) noticed that most of tree roots were concentrated in the area around tree trunk, then gradually decreased by increasing the distance from the trunk.

4. 3. 7. 5. Root density:

The diagramatic Table (30) and Fig (17) show fibrous roots density in the excavated soil samples (cm roots/500cm3 of soil) taken from top 50 cm of soil surface located at different directions of tree canopy (i. e. north, west, east and south) and at distance of (50 - 100 cm), (100-150 cm),(150 - 200 cm) and (200 - 250 cm) from tree trunk.

Concerning the general average of root density per tree's samples, the obtained data clearly show that the general average of root density per tree's samples were obviously increased as soil mulch thickness increased. The general average of root density of unmulched soil (control) was (149.18 cm/500 cm^3 of soil). However, under soil mulched by 10-cm straw thickness the average root density increased to reach (309.68 cm/500cm^3 of soil). Increasing soil mulch thickness to 20-cm straw greatly increased the resulted root density (389.6 cm/500 cm^3 of soil).

Comparing average root density in different directions beneath the tree canopy obviously insured that the north direction was leading in this respect (the nearest from the irrigation line) and recorded the highest root densities, descendingly followed by east, west and south directions. This was true for both mulched and unmulched soil. The obtained results per soil sample were as follow: in control treatment (

Table (3o) Effect of soil mulch thickness on fibrous roots density (cm. root length / 500 cm^3 soil) grown beneath Washington navel orange tree – canopy.

East
South ↔ North
West

Soil mulch treatments

zero soil mulch control treatment

	250	200	150	100	50	0	50	100	150	200	250
						0.0	Av. 139.8				250
						132					200
						202	line				150
		Av. 103.6				225.3					100
		0.0	0.0	149	265.9	@ t ree.	808	229	205	0.0	50
						353			Av. 185.5		100
						181.7	Irrigation				150
						136.3	Av.				200
						-		167.8			250

General Average/ tree =149/8

10cm soil mulch Thickness

	250	200	150	100	50	0	50	100	150	200	250
						384	Av. 289.3				
						132					
						388	Line				
		Av. 270.5				385.					
		-	353	368	361	@	354	567	389	20	
						344.7			Av.		
						587.3	Irrigation		342.5		
						413.7	Av.				
						0.0		336.4			

General Av./ tree =309.68

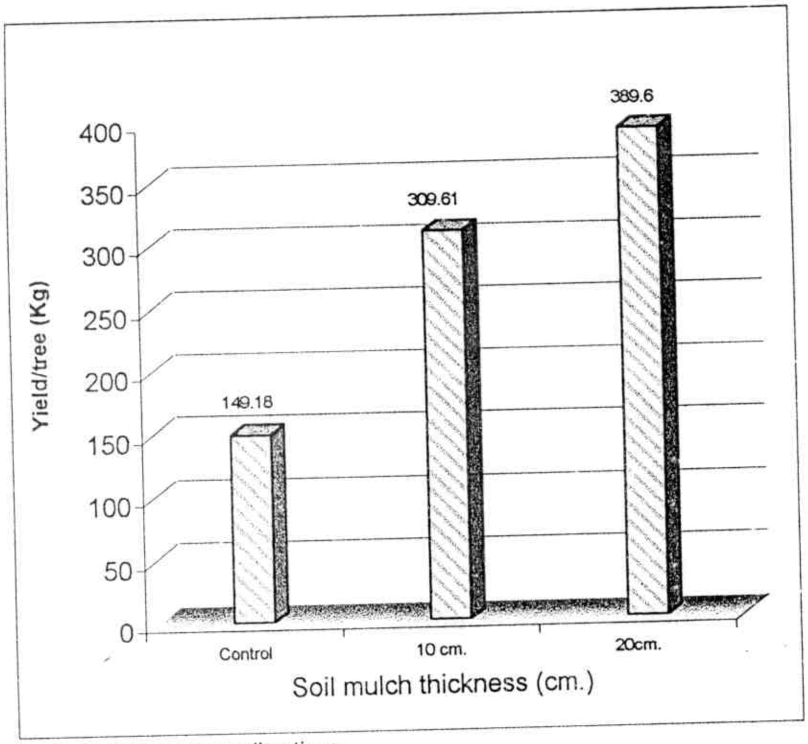
20-cm soil mulch Thickness

	250	200	150	100	50	0	50	100	150	200	250
						383		Av.			
						396.7		381.1			
						386	line				
		Av. 312.8				338.7					
		134	361	372	384	@	541	682	519	150	
						357.3			Av.		
						403	Irrigation		473		
						448.7	Av.				
						356.3		391.3			

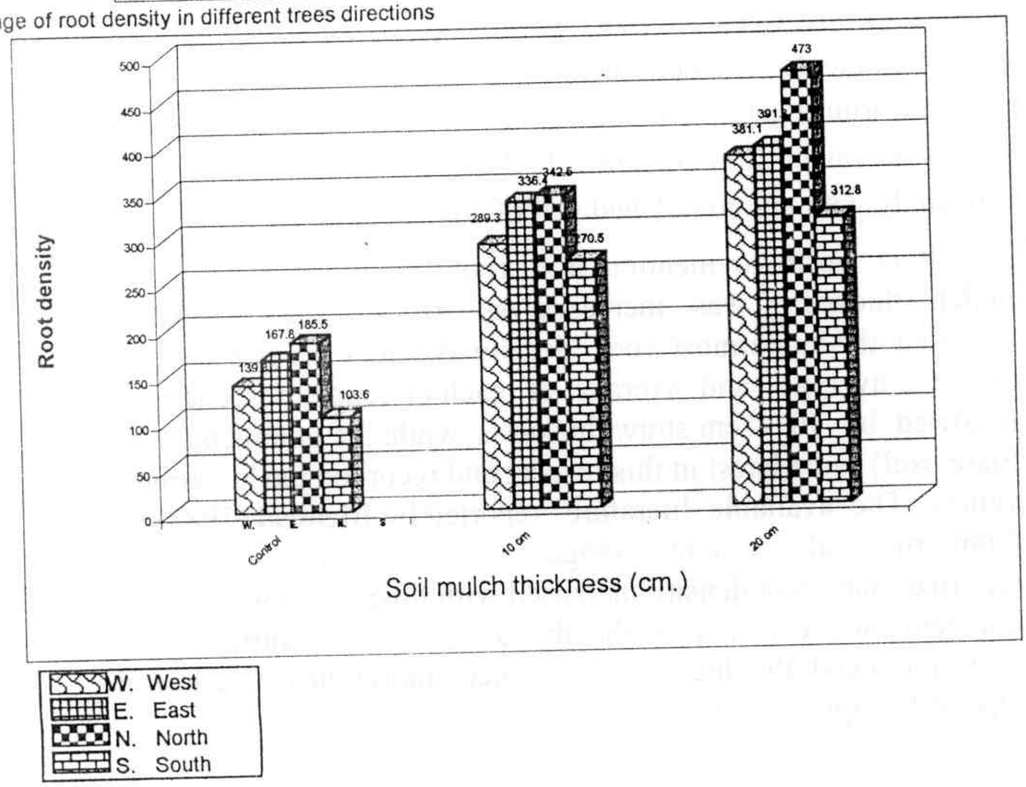
General Average/ tree =389.6

Fig (17) :- Effect of soil mulch thickness on Fibrous roots density (cm root length / 500 cm^3:

a:- General average



b:- Average of root density in different trees directions



north, 185.5 cm), (east, 167.8 cm), (west, 139.8 cm) and (south, 103.6 cm). On the other hand, with mulched soil, root densities were relatively higher, (north 342.5 cm), (east, 336.4 cm), (west, 289.3 cm) and (south, 270.5 cm) with 10 - cm straw thickness treatment. The corresponding densities for 20-cm straw thickness treatment were (north, 473 cm) (east, 391.3 cm), (west, 381.1 cm) and (south, 312.8 cm).

Root density just below the tree trunk and at the distances of (50 - 100, 100 - 150, 150 - 200 and 200 - 250 cm) were highest nearest the tree trunk and gradually decreased towards the periphery of tree canopy. Thus, samples taken from distances 50 - 100 and 100 - 150 cm recorded the highest root densities in all tested treatments. While samples taken from distance 150 - 200 cm obtained relative lower root density values compared to the nearest samples (i. e. root density decreased from inside to outside of the tree canopy). This trend was detected with the three treatments. The outermost samples (i. e. 200 - 250 cm from the tree trunk) gained the lowermost root densities in thick soil mulch treatment (20 - cm straw thickness) or appeared root - free especially with the unmulched soil of control treatment.

It is worth to mention that root density increased as soil mulch thickness was increased, so 20 cm straw thickness recorded the uppermost root density averages per tree samples (general average) and average of each direction, descendingly followed by 10 - cm straw thickness, while the unmulched soil (bare soil) came latest in this respect and recorded the lowermost values. The available literature reported by **Bielorai** (1986) on Grapefruit and Shamouti orange trees, in partially wetted soil, reported that root density increased with time in the wet- zones, but remained constant in the dry zone. Also, **Kanber *et. al*** (1996) noticed the highest root concentration near the lateral pipe in the upper soil layer.