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EFFECTS OF TREE INCLINATION ANGLE ON THE GROWTH, YIELD AND FRUIT QUALITY OF MANFALOUTY POMEGRANATE UNDER ASSIUT ENVIRONMENTAL CONDITIONS.

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Abstract: This study was carried out during the three successive seasons of 2005, 2006 and 2007 at the Experimental Orchard, Assiut University, Egypt on Manfalouty pomegranate cultivar. Four tree groups were selected each of which have almost the same inclination angle of 90° (control), 60°, 45° and 30° from the soil surface in order to study the effect of tree inclination angle on the growth, yield and fruit quality. The increase in the tree-inclination led to a significant increase in the number of suckers in the other direction of inclination of the main trunk. The 90 degree angle of inclination led to a significant increase in the upper shoot length (cm), fruit set (%), yield (kg), commercial yield (%), average fruit weight (g), grains weight (%), total soluble solids (%), reducing sugars (%) in addition to significant reductions in both of fruit splitting (%) and total acidity (%). Whereas, the reverse occurred as the inclination angle decreased gradually to 60° or 45° or 30° especially in the following seasons. The results recommended keeping the growth of trees approximately vertical (90° inclination angle) in order to reduce the growing of suckers on the strong trunk. This can be done through training a single trunk which would consequently increase the fruit set, yield and fruit quality and decrease fruit-splitting (%) under the conditions of experiment.

Key words: Manfalouty pomegranate, inclination, growth, sucker, fruit set, fruiting, yields, plant training.

Introduction

Manfalouty pomegranate is the principal cultivar grown in Assiut Governorate where pomegranate culture is commercially conducted.

The actual planting distance and number of main stems for pomegranate plant in the orchard are the most important factors which control the successful growth and the productivity of the orchard. Mistakes made are likely to cause loss throughout the life of the orchards which are very difficult or impossible to correct.

If the whole stem is secured horizontally, lateral buds closest to the roots are the most strongly stimulated. When the reversal took place in summer, then during the following spring, the uppermost buds produced the largest branches. On the other hand, if the reversal was delayed until winter period the lowermost buds will produce the largest branches. When *Syringa* and *Prunus* shoots are bent horizontally during the summer there is a loss of apical dominance in the following spring, whereas if the treatment is delayed until winter the dominance is retained. So, there are 'propriétés fixéés' induced by gravity which determine the pattern of bud growth (Wilkins, 1984).

Gravity, therefore, influences bud growth and buds can be conditioned to respond to reorientation. Gravimorphic effects have been interpreted in terms of gravity-induced alterations to auxin (Audus, 1959) or cytokinin distribution (Phillips, 1975). Although in *Coleus* (Abeles and Gahagan, 1968) and *Pinus, Pyrus* and *Prunus* (Leopold *et al.*, 1972) gravimorphic treatments led to enhanced endogenous ethylene production which could affect outgrowth.

The angle between the main trunk and the lateral branch, the crotch angle, has a profound effect upon the subsequent growth and cropping of the branch. A narrow angle results in a vigorous, non-precocious shoot. When it finally bears fruit, such a branch frequently breaks away from the tree as the branch union is inherently weak. Wider angle branches, with crotch angles of 60-90° are better to bear a heavy crop. Such branches are also less vigorous and more precocious. Shoots dropping below the horizontal level tend to become very weak and produce fruit of poor quality (Chang-YaDong *et al.*, 1997 and Jackson and Looney, 1999).

Training pomegranate tree into 3 or 4 main stems/tree was responsible for improving the perfect flower percentage and yield (El-Kassas *et al.*, 2002).

The inclination of the main trunk of the plant has a great influence on number of suckers. The suckers grow in vertical direction or inclined in the other direction of the main trunk inclination.

The objective of this study was to find out the effect of trees inclination angle on the growth, yield and fruits quality of Manfalouty pomegranate.

Materials and Methods

This study was carried out during the three successive seasons of 2005, 2006 and 2007 at the Experimental Orchard, Assiut University, Egypt on Manfalouty pomegranate (*Punica granatum* L.). Twelve thirty-one years old trees, planted at spacing of 5x5 meters were so chosen as to form four groups each of which consisted of three trees having almost the same approximate inclination angle (90°, 60°, 45° and 30°) from the soil surface with a control having an inclination angle of 90°. All trees received the ordinary management of horticultural practices applied at the pomegranate orchard. The experiment was conducted as a complete randomized design with three replicates, one tree each.

The following measurements were recorded during each of the three successive seasons:

Stability of Inclined trunk of the Plant:

This parameter was measured on a sample from the same trees. The nature of any plant is usually flexible and it grows with inclined trunks. Consequently, the suckers grow in the other direction of inclination of the main trunk (Fig. 1). This is very essential from the point of view of stability. If the main trunk grows in vertical direction (Fig. 3), then there is no need for existence of suckers for stability. The weight of main trunk is denoted as (w) which acts at distance x from the point of fixation of the trunk in the ground. The main trunk is inclined with a certain angle of inclination as shown in Fig. 1. Then the overturning moment which acts for collapse of main trunk equals W.X. This moment is resisted by the moments induced by the suckers. Each sucker has a certain weight W_i and it acts at certain distance Xi from the point of fixation as shown in Figure (1). Then the resisting moment of suckers equals

$$W_iX_1 + W_2X_2 + W_3X_3 + \dots\dots\dots W_iX_i$$

Then for purpose of stability

$$WX = W_iX_1 + W_2X_2 + W_3X_3 + \dots\dots\dots\dots + W_iX_i$$

Thus, as the inclination of main trunk increases, then number of suckers and their weights increase and vice versa. This can be seen clearly from investigation of different plants.

Moreover, ten spring new shoots were chosen and labeled per tree to measure some vegetative parameters at middle of October including:

Upper Shoot length:

- The average length of shoots (cm) were recorded by measuring the length of labeled shoots per tree and then the average shoot length was calculated.

Fruit set percentage:

The number of perfect flowers which succeeded to set fruits were counted at the end of flowering season, then, the fruit set was estimated relative to the total number of such complete flowers.

Fruits of each treatment were harvested at the beginning of October to determine the following:

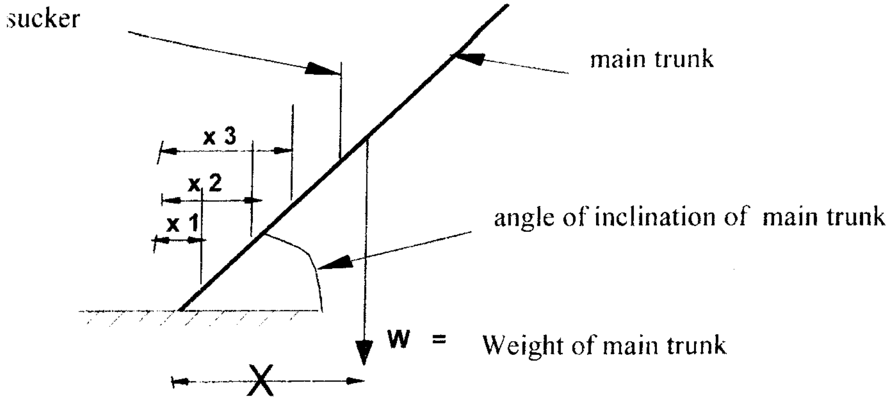

Fig. (1): Necessity of suckers for stability of main trunk

Yield components:

- Yield (kg) per tree.
- Commercial yield percentage from the total yield (the fruits free of undesirable characteristics as cracking and sunburn) was calculated.
- Percentage of fruit splitting from the total yield per tree was calculated.

Fruit characteristics:

To study the physical and chemical fruit properties, ten fruits were randomly taken from each replicate. Average fruit weight (g), then the grains weight percentage to the whole fruit weight was calculated. The following chemical fruit juice constituents were estimated:

- Percentage of total soluble solids by using a hand refractometer.
- Total acidity (expressed as (g) of citric acid per 100 ml of juice) by titration with 0.1 NaOH using phenolphthaline as an indicator.
- Total soluble solids/acid ratio was calculated.
- Reducing sugars percentage according to Lane and Eynon procedure as outlined in A.O.A.C. (1985).

All the obtained data were tabulated and analyzed according to Snedecor and Cochran (1990) using t-Dunnett test for establishing the significance of differences between various treatment means.

Results and Discussion

Figure 2 illustrates the relation between the angle of inclination of main trunk and number of suckers for two cases of weight of main trunk (40 kg, and 27 kg). It is clear that as the angle of the inclination of the main trunk increased, the number of suckers increases for purpose of stability, depending on the weight of the main trunk (Fig. 2).

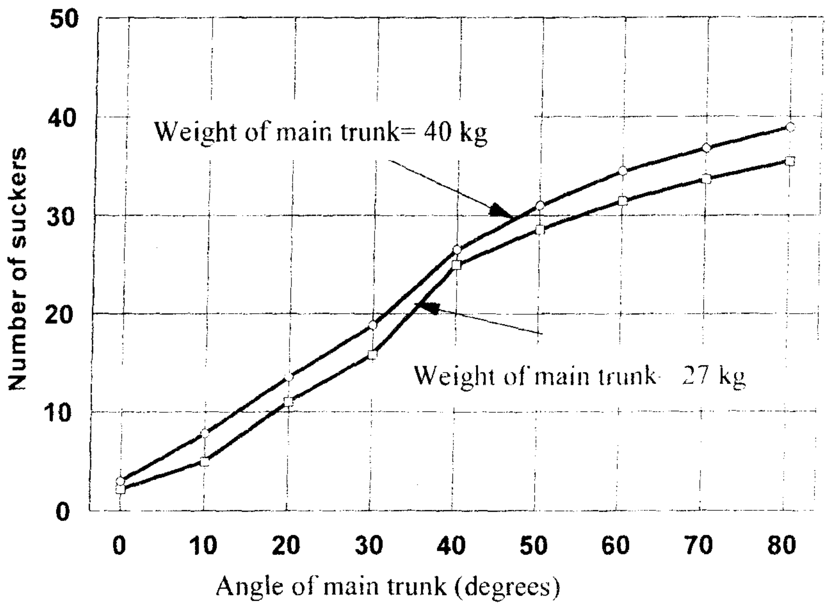

Fig.(2): Effect of the main trunk inclination angle on number of suckers for different weights of main trunk

Also, Figure 3 illustrates the relation between the weight of the main trunk and the number of suckers, for two cases of angle of inclination (45 and 30 degrees). Again, as the weight of the main trunk is high, the number of suckers increased depending on the angle of inclination of main trunk (Fig. 3).

Apparently, such suckers are needed for the purpose of stability of the inclined main trunk. On the other hand, the existence of such suckers affects the productivity of the plant because the suckers consumes the mineral nutrients of the main trunk. For such reasons, it is recommended to overcome such phenomenon. It is suggested that the main trunk should grow approximately vertical. This can be done manually by noticing the growth of the trunk and putting some supports to make it grow vertically.

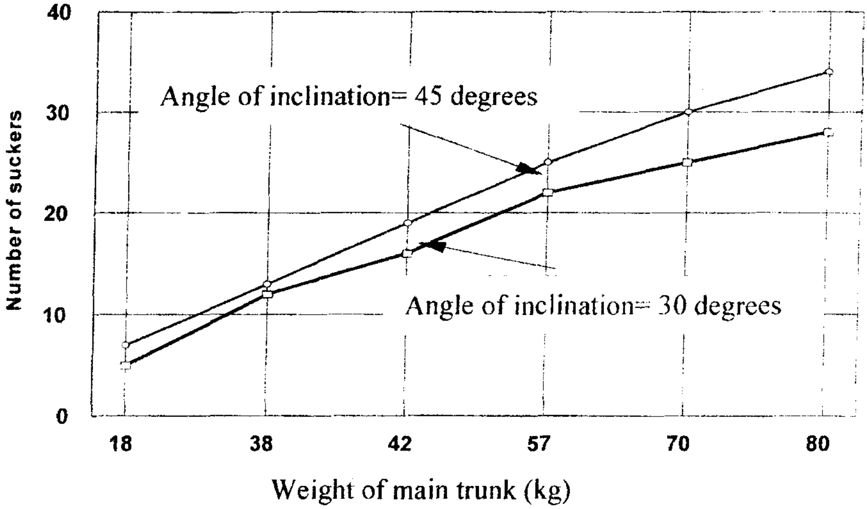

Fig.(3): Effect of main trunk weight on the number of suckers for different angles of inclination

1 – Effect of inclination angle on upper shoot length (cm)

Results in Table (1) show that inclination angle "90°" significantly increased the length of upper shoot as compared with the other inclination angles. The obtained shoot length values were 66.56, 62.56, 52.78 and 47.44 cm as averaged for the three studied seasons at 90, 60, 45 and 30°, respectively. These results indicated that the suckers which are grown for the purpose of stability of inclined main trunk may affect the productivity of the plant by consuming the nutrients of the main trunk.

2- Effect of inclination angle on the yield and its components:

2.1- Fruit set percentage and yield weight tree (kg):

Results presented in Table (1) revealed that the inclination angle "90°" significantly increased the fruit set percentage and the yield weight per tree as compared to the other inclination angles. The recorded values of fruit set percentage were 54.11, 48.44, 41.00 and 36.44% as averaged for the three studied seasons at 90°, 60°, 45° and 30°, respectively. The effectiveness of inclination angle "90°" approximately could be attributed to its effect in decreasing the suckers on the trunk that lead to the accumulation of mineral nutrients and carbohydrates causing favorable condition for obtaining high fruit set percentage. These results were in agreement with those of Chang-YaXong *et al.* (1997) and Jackson and Looney (1999).

The obtained results indicated that yield weight (kg)/tree at inclination angle 90°, 60°, 45° and 30° reached 82.67, 66.11, 53.22 and 36.33 kg/tree (average of the three studied seasons), respectively.

The increment percentage of yield weight per tree due to inclination angle "90°" over other angles "60, 45 and 30" were 125.0, 155.3 and 227.6 (average of the three studied seasons), respectively. Such an increase of yield per tree was mainly due to the vertical growth of the trunk which does not need suckers for the purpose of stability.

2.2- Commercial yield percentage per tree:

Results in Table (1) indicated that the inclination angle "90°" significantly increased the commercial yield percentage as compared to the other inclination angles "60, 45 and 30°" with the obtained commercial yield percentages being 85.89, 77.33, 64.00 and 62.78%, respectively. These results might be attributed to the role of shoots drooping below the horizontal level which tend to become very weak and produce fruit of poor quality (**Jackson and Looney, 1999**).

3- Effect of inclination angle on physical and chemical properties of fruits:

3.1- Fruit splitting percentage:

Splitting percentages of the fruits as influenced by inclination angle are presented in Table (1). Inclination angle "90°" caused a significant reduction in fruit splitting percentage, as compared to the other inclination angles "60, 45 and 30°" with averages of 6.57, 7.11, 10.44 and 12.06% in the three studied seasons, respectively. Such results could be due to the decreasing in the loss of mineral nutrients which was used to grow suckers in the greater inclination.

3.2- Fruit weight and grain weight percentage/fruit:

The results in Table (2) showed that the fruit weight and grain weight percentage/fruit significantly increased by inclination angle 90° as compared to the other angles of 60, 45 and 30°. The fruit weight values were 550.0, 525.0, 417.2 and 405.0 as averaged over the three seasons, respectively. Such increment of fruit weight may be due to the vertical growth of trunk which decreases growing of suckers and accumulation of carbohydrates and mineral nutrients in the part above the tree causing a suitable condition for obtaining heavy fruit weight.

On the other hand, the grain weight percentages per whole fruit were 58.50, 56.33 and 52.67% on an average for the three seasons at inclination angle of "60, 45 and 30°" respectively, as compared to 62.17% for the inclination angle "90°" (averaged over the three seasons).

The corresponding decrease in values due to the inclination angle "60, 45 and 30°" than "90°" were 5.9, 9.4 and 15.3% (average of the three studied seasons), respectively.

These results could be explained as due to the effect of inclination of the main trunk which allowed the growth of the suckers to stabilize the main trunk. On the other hand, the existence of such suckers enhanced the accumulation and transportation of mineral nutrients to it, thus causing unsuitable conditions for fruit growth and reducing the grain weight percentage (as shown in the table 2).

4 - Chemical constituents juice:

Results in Table (2) showed that the inclination angle "90°" improved the fruit quality in terms of increasing the TSS%, the reducing sugars % and decreasing titratable acidity percentage. Hence, TSS/acid ratio was significantly increased with inclination angle "90°" as compared to the inclination angles "60°, 45° and 30°". The recorded values of TSS% were 16.39 (average of the three seasons) for 90° angle against 14.99, 14.53 and 14.21%, for the others, respectively.

Meanwhile, the recoded values of titratable acidity percentage were 1.079% (average of the three seasons) due to the inclination angle "90°" against 1.221, 1.277 and 1.299% for inclination angles "60, 45 and 30°", respectively.

Hence, the percentage of TSS/acid ratio due to above mentioned inclination angles were 15.20, 12.70, 11.39 and 10.96 as averaged over the three seasons, respectively.

These results could be explained as due to the effect of the vertical angle which decreased the suckers thus, allowing more assimilation and more nutrients to move to the other parts of the tree and increasing fruit quality by decrease in the acidity and increasing of TSS/acid ratio.

Also, the obtained values of % reducing sugars were 11.64% (average of the three seasons) at the inclination angle "90°" as compared with 11.52, 11.43 and 11.28%, for other angles, respectively.

Such effects on sugar contents as a result of vertical angle which decreased the suckers may be attributed to the accumulation of the organic compounds in the other parts of the tree which resulted in good conditions for fruit growth and quality.

Table (1): Effect of tree inclination angle on upper shoot length (cm), fruit set percentage, yield (kg)/tree, commercial yield percentage and fruit splitting percentage of Manfalouty pomegranate cultivar during 2005, 2006 and 2007 seasons.

Angle (in degrees)	Upper shoot length (cm)				Fruit set (%)				Yield (kg)/tree				Commercial yield (%)				Fruit splitting (%)			
	2005	2006	2007	Mean	2005	2006	2007	Mean	2005	2006	2007	Mean	2005	2006	2007	Mean	2005	2006	2007	Mean
90° (control)	65.33	66.33	68.00	66.56	51.67	54.67	56.00	54.11	81.00	83.00	84.00	82.67	84.33	86.67	86.67	85.89	6.87	6.50	6.33	6.57
60°	62.67	62.33	62.67	62.56	48.00	49.33	48.00	48.44	65.00	66.33	67.00	66.11	77.00	77.00	78.00	77.33	8.00	7.00	6.33	7.11
45°	54.00	53.00	51.33	52.78	40.33	42.67	40.00	41.00	56.67	52.67	50.33	53.22	65.00	64.00	63.00	64.00	10.00	10.50	10.83	10.44
30°	48.33	47.33	46.67	47.44	38.00	36.33	35.00	36.44	37.67	36.00	35.33	36.33	64.00	63.00	61.33	62.78	12.00	12.50	11.67	12.06
T-Dunnett 0.05	3.51	3.45	4.17	1.75	2.89	4.35	3.77	1.75	8.83	8.48	7.88	3.95	6.19	6.17	4.98	2.73	0.30	0.65	1.35	0.41
F-test	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**

Table (2): Effect of tree inclination angle on fruit weight (g), grains/fruit weight percentage, total soluble solids percentage (TSS), titratable acidity percentage, TSS/acid ratio and reducing sugar percentage in fruit juice of Manfalouty pomegranate cultivar during 2005, 2006 and 2007 seasons.

Angle (in degrees)	Fruit weight (g)				Grains/fruit weight (%)				Total soluble solids percentage (TSS)				Titratable acidity (%)				TSS/acid ratio				Reducing sugar (%)			
	2005	2006	2007	Mean	2005	2006	2007	Mean	2005	2006	2007	Mean	2005	2006	2007	Mean	2005	2006	2007	Mean	2005	2006	2007	Mean
90° (control)	520.0	550.0	580.0	550.0	62.00	62.00	62.50	62.17	16.37	16.27	16.53	16.39	1.100	1.077	1.060	1.079	14.87	15.10	15.63	15.20	11.50	11.63	11.80	11.64
60°	510.0	525.0	540.0	525.0	59.50	58.50	57.50	58.50	15.10	14.97	14.90	14.99	1.220	1.213	1.230	1.221	12.40	12.33	13.53	12.76	11.42	11.50	11.63	11.52
45°	440.0	413.3	398.3	417.2	56.67	56.33	56.00	56.33	14.73	14.53	14.33	14.53	1.267	1.277	1.287	1.277	11.63	11.40	11.13	11.39	11.35	11.42	11.53	11.43
30°	430.0	405.0	380.0	405.0	55.00	52.00	51.00	52.67	14.20	14.30	14.13	14.21	1.257	1.317	1.323	1.299	11.33	10.83	10.70	10.96	11.15	11.28	11.40	11.28
T-Dunnett 0.05	26.90	19.93	25.27	11.38	2.41	1.99	2.16	1.03	0.45	0.33	0.54	0.21	0.07	0.04	0.04	0.03	0.92	0.61	2.90	0.84	0.17	0.12	0.17	0.07
F-test	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**

Finally, it could be concluded that the approximately vertical growth of the tree will prevents the growing of suckers which in turn enhances the endogenous contents of the carbohydrates and other nutrients of the tree and consequently hastens the maturity and increasing fruit growth and quality.

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تأثير زاوية ميل الأشجار على نمو ومحصول وخصائص ثمار الرمان المنفلوطى تحت ظروف أسيوط البيئية

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تمت الدراسة خلال مواسم 2005 ، 2006 ، 2007 بمزرعة كلية الزراعة – جامعة أسيوط على أربعة مجموعات من الأشجار أفراد كل مجموعة منها متماثلة فى زاوية ميلها تقريبا عن سطح التربة كالآتى 90° (الكنترول) ، 60°، 45° ، 30° ، لدراسة تأثير زاوية الميل على نمو ومحصول وخصائص ثمار الرمان المنفلوطى .

أدت زيادة ميل جذع الأشجار إلى زيادة معنوية فى عدد السرطانات فى الجانب العكسى من جانب الميل . كما أعطت زاوية الميل 90° (تقريبا) زيادة معنوية فى طول الأفرع العليا الحاملة للمحصول ونسبة العقد وكمية المحصول (كجم) ونسبة المحصول التجارى وزيادة وزن الثمرة ونسبة الحب والمواد الصلبة الذائبة والسكريات المختزلة مع نقص معنوى فى نسبة التشقق والحموضة ، بينما حدث عكس ذلك تدريجيا كلما تناقصت زاوية الميل إلى 60° أو 45° أو 30° تقريبا وخاصة فى السنوات التالية .

توصى النتائج بالمحافظة على ميل جذع الأشجار بزاوية 90° تقريبا (النمو القائم) لتقليل خروج السرطانات على الجذع ويتحقق ذلك بالتربية على جذع واحد قوى قائم مما يؤدى إلى زيادة نسبة العقد والمحصول مع تقليل نسبة التشقق وتحسين جودة ثمار الرمان المنفلوطى تحت ظروف هذا البحث .