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RESPONSES OF MATURE VALENCIA ORANGE TREES TO THREE METHODS OF PRESSURIZED IRRIGATION UNDER SOUTH El-TAHREER CONDITIONS

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ABSTRACT

Responses of mature Valencia orange [*Citrus sinensis* (L.) Osb.] trees budded on sour orange *(C. aurantium* L.) rootstock spaced at 5x5 m. in sandy soil of an orchard located at El-Khartoom village, South El-Tahreer Province, were studied during 1997 and 1998 seasons in relation to drip (DI), microsprinkler (MSI) and portable sprinkler (PSI) irrigation methods at three levels of water application : 80, 100 and 120 liters per tree per day during March to October period to be reduced to the half afterwards. Two drippers of 4 l. hr^{-1} and two microsprinklers of 16 l. $hr.^{-1}$ were used per tree for DI and MSI methods, respectively . One sprinkler of 2.5 m^3. hr^{-1}. was used per 14 trees for PSI method. Water application through DI, MSI and PSI covered $\approx$ 1.6, 6.4 and 100% of the alloted area per tree, respectively. Tree growth, shoot growth , leaf water content and yield per tree responded positively with area amount of the wetted zone. The highest and lowest yield efficiencies of the tree were observed in DI and PSI trees, respectively. The trees responded poorly to the level of water application. So, the 80 liters per tree per day represented the proper level that would be applied during March to October period. The fruit characters were not affected definitely by any of the irrigation methods or levels. Only fruits of the PSI trees were more juicy. Decreasing the planting distance with the hedgerows system was suggested to be followed for drip irrigation to increase the efficiency of water use and yield per unit of land area. Further studies to schedule the irrigation based on the amount of water

depletion from the root zone and the ground area of the trees are needed.

Key words: *drip system, irrigation methods.*

1. INTRODUCTION

Recent growth of Egypt citrus plantations has primarily occurred in the new land areas where the poor and highly permeable sandy soils are prevailing. The low water holding and nutrient retention capacities of such soils necessitate high frequent applications of irrigation water and nutrients. Conventional flood irrigation methods are not practically and economically well adapted to such conditions and rather they are prohibitive. Accordingly, permanent solid-set and portable sprinkler, microsprinkler and drip irrigation systems became popular in the new land regions. Smajstrla (1993) has reviewed and discussed the irrigation alternatives through five items: 1) clogging control, 2) production benefits, 3) system costs, 4) water conservation, and 5) favorable governmental regulations.

The emitter capacity for water delivery of such systems varies from 4 liters to 3 m^3. $hr.^{-1}$ to cover an area of 0.50 to 36.00 m. in diameter. Tree responses are influenced greatly by the amount of covered area and irrigation frequency. The high total yields were found to be correlated positively with area amount of the wetted zone (Bredell and Barnard, 1977; Koo, 1978; Koo, 1980; Bielorai, 1982; Smajstrla and Koo, 1984). Vegetative growth and leaf water potential were also associated with the ground area coverage (Proebsting *et al.*, 1984) as well as the stomatal conductance, soil water content, vapor pressure deficit (Zekri and Parsons, 1988) and root distribution (Koo, 1980; Sweitlik, 1992). Under high-frequent irrigations, the soil suction in the root zone is favorable to be maintained between 20 to 30 cb. (Marsh, 1973). As water stress increases, a reduction in vegetative growth (Marsh, 1973; Chalmers *et al.*, 1981; Marler and Davies, 1990; Khalil *et al.*, 2000), yield (Marsh , 1973; Chalmers *et al.*, 1981; Levin *et al.*, 1996; Khalil *et al.*, 2000), fruit size (Marsh, 1973; Levy *et al.*, 1979) and root growth (Bevington and Castle, 1985; Swietlik, 1992) was reported.

Local recommendations of the irrigation schedule for citrus trees in the new land areas are based mainly on determination of the amount of irrigation water per tree per day according to the tree age. The maximum amount of water recommended for the mature trees ranges between 80 to 150 liters per tree per day during the summer months. The comparative studies for the pressurized irrigation methods under our local conditions are relatively few, however. Response assessment of mature Valencia orange trees to portable sprinkler, microspinkler and drip irrigation methods at three levels of the prevailing and recommended amounts of irrigation water was the main objective of this study.

2. MATERIALS AND METHODS

This study was carried out during 1997 and 1998 seasons on 19-year-old Valencia orange trees budded on sour orange rootstock spaced at 5x5 m in an orchard of about 50 feddans located at El-Khartoom village, South El-Tahreer Province. The soil is sandy of 7.5% field capacity, 2.6% wilting point, 1.67 $g.cm^{-3}$ bulk density, 1.8 dSm^{-1}. EC and 8.4 pH.

2.1 Irrigation treatments

The treatments consisted of three irrigation methods and three levels of irrigation water randomlly distributed over four blocks.

2.1.1 Irrigation methods

The trees had been irrigated mainly with portable sprinkler irrigation system for the first five years before the microsprinkler and drip irrigation systems have been introduced. The orchard area was divided into four sections to represent the three irrigation methods in each as follows:

a) Portable sprinkler irrigation (PSI) delivered 2.5 m^3 water per hour to cover an area of ≈ 36 m in diameter, *i.e.* one sprinkler for 14 trees,
b) Micropsprinkler irrigation (MSI) delivered 16 $l.hr^{-1}$ to cover an area of ≈ 1m in diameter; two microsprinklers were used for one tree,

c) Drip irrigation (DI) delivered 4 $l.hr.^{-1}$ to cover an area of $\approx$ 0.50m. in diameter; two emitters were used per tree.

2.1.2. Irrigation levels

Three levels of water application : 80, 100, and 120 liters per tree per day were applied during March to October then reduced by 50% afterwards until Febraury. Therefore, the number of irrigation treatments were 3 methods x 3 levels of water application = 9 treatments. The irrigation water was artesian source of 1.3 $dS. M^{-1}$ EC and 7.8 pH. The irrigation was applied daily for MSI and DI methods and every seven days for PSI during the growing season to every two days for MSI and DI and every two weeks for PSI during the winter months.

2.2. Tree selection

Four trees were randomly selected from the middle rows of each treatment in each section. Thus, the total number o the selected trees per treatment = 4 trees x 4 sections (blocks) = 16 trees.

2.3. Vegetative growth measurements

Four branches of 2-3 cm diameter were selected at the four directions of each selected tree. Number of the current flushes was recorded till the end of the growing season. Average length of the current flushes was measured on 20 flushes. During spring summer and autumn , the fourth leaf below the shoot apex was collected from 10 current flushes at each tree direction to represent a leaf sample of 40 leaves per each selected tree. The leaf area was estimated according to Chou (1966). The tree height and canopy circumference were measured during winter of each season. The canopy volume was calculated according to Turrell (1946). The ground area, i.e, the land area covered by the tree canopy, was also calculated.

2.4. Leaf water status measurements

Two discs of 1 cm^2 area were taken from the opposite midrib sides in the middle of each leaf sample: one for estimating the relative water content (RWC) according to Chaudry (1969), and the other for estimating the osmotic pressure (OP) according to Gosov (1969).

2.5. Estimation of tree yield

Number and weight of fruits of each selected tree were recorded at harvest time.

2.6. Determination of fruit quality

Standard procedures for physical and chemical fruit analysis were followed on a 20-fruit sample collected during April randomly per each replicate .

2.7. Statistical analysis

Analysis of variance using Duncan's multiple range test was followed at ≤ 0.05 (Duncan, 1955).

3. RESULTS

3.1 Vegetative growth

Tree growth , shoot growth (Table 1) and leaf area (Table 2) were highly affected by the irrigation method. The maximum and minimum values were confined to the portable sprinkler irrigation (PSI) method and drip irrigation (DI) one, respectively. The level of water application had no obvious or definite effects.

By the end of 1998, the canopy volume (CV) reached 27.8, 69.2 and 173.2m^3 on average for trees under DI, MSI and PSI, respectively. The corresponding values of the ground area index (GAI), *i.e.*, the land area covered by the tree canopy to the total area alloted for the tree (25m^2), were 0.43, 0.67 and 0.84. The observed variations in the tree size were due largely to the variations in the tree height rather than to those observed in tree diameter.

Although the level of water application exerted significant effects on the tree size, however, no definite trends could be figured out.

Similar trends were obtained in respect to the effect of the irrigation treatments on the total number of new flushes, average flush length , and on the leaf area average.

3.2. Leaf water status

All leaves contained more than 70% relative water content (RWC) even during summer months (Table 2) . The highest values

Table (1): Effect of some pressurized irrigation methods and levels of water application on vegetative growth of mature Valencia orange trees.

Treatments		Tree growth		Shoot growth		Tree growth		Shoot growth	
method	level	Canopy vol. (m^3)	Ground area index	Total no. of shoots per branch	Avg. shoot length (cm)	Canopy vol. (m^3)	Ground area index	Total no. of shoots per branch	Avg. shoot length (cm)
		1997 season				**1998 season**			
DI	80	24.64^{e}	0.40^{d}	27.8^{d}	10.7^{c}	34.43^{e}	0.48^{d}	32.8^{a}	10.4^{c}
	100	14.13^{f}	0.29^{d}	34.8^{c}	12.0^{c}	21.57^{f}	0.37^{d}	33.4^{c}	11.5^{c}
	120	18.82^{f}	0.35^{d}	33.2^{c}	11.3^{c}	27.57^{f}	0.43^{d}	32.7^{c}	10.1^{c}
MSI	80	66.33^{c}	0.65^{b}	36.2^{bd}	13.3^{bd}	87.63^{c}	0.77^{ab}	38.9^{b}	13.2^{b}
	100	43.82^{d}	0.52^{c}	37.2^{bd}	13.5^{bd}	54.01^{d}	0.59^{c}	39.1^{b}	13.1^{b}
	120	46.85^{d}	0.55^{c}	38.2^{b}	13.6^{b}	59.83^{d}	0.64^{c}	38.5^{b}	14.4^{b}
PSI	80	89.05^{b}	0.72^{a}	44.4^{a}	16.5^{a}	101.73^{b}	0.78^{ab}	46.1^{a}	17.4^{a}
	100	103.54^{a}	0.81^{a}	43.0^{a}	16.6^{a}	122.48^{a}	0.90^{a}	45.3^{a}	16.6^{a}
	120	89.57^{b}	0.74^{a}	40.1^{a}	16.4^{a}	109.75^{a}	0.83^{a}	45.8^{a}	16.3^{a}

Means followed by the same letter do not differ at $P \leq 0.05$

Table (2): Effect of some pressurized irrigation methods and levels of water application on leaf area and leaf water content of mature Valencia orange trees.

Treatment		Spring			Summer			Autumn		
method	level	Leaf area cm^2	RWC %	OP bar	Leaf area cm^2	RWC %	OP bar	Leaf area cm^2	RWE %	OP bar
1997 season										
DI	80	14.3^{b}	72.3^{c}	15.8	14.5^{b}	70.5^{c}	16.4	17.2^{b}	80.2^{b}	15.2
	100	14.8^{b}	75.8^{b}	15.9	14.9^{b}	71.2^{c}	16.1	16.4^{b}	83.2^{b}	15.8
	120	15.3^{b}	74.7^{cb}	16.4	14.8^{b}	73.6^{b}	15.8	16.8^{b}	84.1^{b}	15.9
MSI	80	14.5^{b}	74.3^{cb}	16.2	15.3^{b}	71.3^{c}	15.9	17.1^{b}	83.1^{b}	15.9
	100	15.1^{b}	75.6^{b}	15.8	14.9^{b}	73.6^{b}	15.7	16.5^{b}	83.9^{b}	15.5
	120	14.3^{b}	74.3^{b}	15.4	15.1^{b}	73.9^{b}	16.2	16.4^{b}	82.2^{b}	15.6
PSI	80	18.5^{a}	81.2^{a}	15.8	17.9^{a}	76.2^{ca}	16.8	18.4^{a}	85.9^{a}	15.8
	100	20.2^{a}	79.8^{a}	15.9	18.2^{a}	75.6^{a}	15.8	20.2^{a}	87.3^{a}	14.9
	120	19.0^{a}	80.6^{a}	16.5	17.8^{a}	75.4^{a}	16.6	19.1^{a}	86.3^{a}	16.0
1998 season										
DI	80	16.3^{b}	75.8^{c}	15.8	15.3^{b}	75.5^{b}	16.1	15.9^{b}	82.4^{b}	15.8
	100	15.4^{b}	77.9^{cb}	16.1	15.8^{b}	76.3^{ab}	16.0	15.5^{b}	84.2^{b}	15.6
	120	15.8^{b}	79.3^{b}	16.9	15.5^{b}	76.8^{ab}	16.3	14.3^{b}	85.6^{b}	15.8
MSI	80	16.3^{b}	80.1^{b}	16.2	16.4^{b}	74.3^{b}	16.8	14.2^{b}	85.7^{b}	15.2
	100	16.1^{b}	81.9^{b}	16.8	15.8^{b}	76.3^{ab}	15.9	15.3^{b}	85.6^{b}	15.4
	120	15.5^{b}	82.4^{b}	16.4	16.2^{b}	75.5^{b}	16.0	15.4^{b}	86.3^{ab}	16.1
PSI	80	20.1^{a}	86.8^{a}	16.9	18.8^{a}	78.4^{a}	16.5	18.6^{a}	88.9^{a}	16.2
	100	18.9^{a}	84.6^{a}	16.2	19.3^{a}	78.3^{a}	15.9	19.5^{a}	88.1^{a}	16.5
	120	19.5^{a}	85.9^{a}	15.8	18.5^{a}	77.2^{a}	15.8	20.3^{a}	88.9^{a}	16.3

RWC = Relative water content, OP= Osmotic pressure.

Means followed by the same letter do not differ at $P \leq 0.05$

Table (3): Effect of some pressurized irrigation methods and levels of water Application on yield, average fruit weight and yield efficiency of mature Valencia orange trees.

Treatment		Yield per tree		Avg. fruit weight (g)	Yield efficiency $Kg\text{-}m^{-3}CV$	Yield per tree		Avg fruit weight (g)	Yield efficiency $Kg.m^{-3}CV$
method	level	number	weight (Kg)			number	weight (Kg)		
		1997 season						**1998 season**	
DI	80	225^{b}	40.0^{c}	177.8^{c}	1.62^{b}	240^{c}	52.0^{b}	216.7^{a}	1.51^{c}
	100	220^{b}	40.0^{c}	181.8^{bc}	2.83^{a}	255^{bc}	56.0^{ab}	219.6^{a}	2.60^{a}
	120	230^{b}	47.0^{b}	204.3^{b}	2.35^{a}	260^{bc}	57.5^{ab}	221.2^{a}	2.07^{b}
MSI	80	235^{b}	47.5^{b}	202.1^{b}	0.72^{d}	267^{b}	57.5^{ab}	215.8^{a}	0.66^{e}
	100	230^{b}	50.0^{b}	217.4^{b}	1.14^{c}	265^{b}	58.0^{ab}	218.9^{a}	1.07^{d}
	120	260^{a}	50.0^{b}	192.3^{b}	1.04^{c}	270^{b}	59.5^{a}	220.4^{a}	0.99^{d}
PSI	80	275^{a}	65.0^{a}	236.4^{a}	0.73^{d}	299^{a}	60.0^{a}	200.7^{a}	0.59^{e}
	100	26.5^{a}	59.5^{a}	224.5^{a}	0.57^{d}	290^{a}	60.0^{a}	206.9^{a}	0.49^{e}
	120	260^{a}	60.0^{a}	230.6^{a}	0.67^{d}	300^{a}	61.5^{a}	205.0^{a}	0.56^{e}

Means followed by the same letter do not differ at $P \leq 0.05$

Table (4): Effect of some pressurized irrigation methods and levels of water application on some fruit characters of mature Valencia orange trees.

Treatment method	Treatment level	Rind thic.	Juice (%)	Total soluble solids (%)	Total acid (%)	Solids acid ratio	Rind thic. (mm)	Juice (%)	Total soluble solids (%)	Total acid (%)	Solids acid ratio
		1997 season					1998 season				
DI	80	6.75	42.10	14.1	1.42	9.92	6.75	45.30	13.80	1.40	9.85
	100	6.95	43.20	13.4	1.40	9.57	6.85	43.50	14.30	1.45	9.86
	120	6.85	45.50	13.2	1.35	9.77	6.72	45.20	14.20	1.45	9.79
MSI	80	6.15	47.20	14.0	1.33	10.52	5.95	48.50	14.00	1.55	9.03
	100	6.22	45.31	13.9	1.45	9.58	5.85	49.10	13.75	1.40	9.82
	120	6.10	47.30	13.9	1.40	9.92	6.10	48.20	13.65	1.37	9.96
PSI	80	6.20	49.10	13.2	1.40	9.42	6.20	50.90	13.90	1.37	10.14
	100	6.30	52.15	13.8	1.35	10.22	5.85	52.15	13.80	1.42	9.71
	120	6.10	50.23	14.2	1.40	10.14	5.95	51.20	14.40	1.46	9.86

Means followed by the same letter do not differ at $P \leq 0.05$

of RWC were observed in the leaves of PSI trees. No significant differences were observed as a result of increasing the level of water application under a given irrigation method. Osmotic pressure (OP) of the leaf sap was neither influenced by the irrigation method nor irrigation level.

3.3 Tree yield, tree yield efficiency, and fruit weight

The tree yield (number and weight) was affected by the irrigation method with the same manner as the vegetative growth was (Table 3). Thus, the highest and lowest yield were obtained from the PSI and DI trees, respectively . In comparison with MSI and DI trees, the PSI ones gave increases in weight of the tree yield with about 25% and 46% in 1997 season and 3.8% and 9.4% in 1998 one, respectively . Under a given irrigation method, the level of water application had no real effects on the tree yield.

The situation was completely different in respect to effect of the irrigation treatments on the tree yield efficiency , *i.e.* Kg fruit per unit volume of the tree canopy. In 1977 season , it reached 2.32, 0.97 and 0.66 Kg. m^{-3} CV on average for DI, MSI and PSI trees, respectively. The corresponding values in 1998 season , were 2.07, 0.91 and 0.55 Kg. m^{-3}CV. Under a given irrigation method, the observed variations in tree yield efficiency due to the level of water application were consistent with those observed in the tree size.

In 1997 season , the largeest and smallest fruits were obtained from PSI and DI trees, respectively. However, the opposite trend held true in 1998 season. In both seasons, average fruit weight was not affected by the level of water application.

3.4. Fruit characters

Rind thickness, total soluble solids (TSS), total acids and TSS/acid ratio were not affected by any of the irrigation method or level (Table 4). Only fruits of the PSI trees were more juicy in comparison with those of the DI. The level of water application had no real effects on the fruit characters measured.

4. DISCUSSION

The PSI, MSI and PSI systems differ greatly in the amount of the wetted area. In the present study, while the PSI covered the entire orchard floor area, the two drippers of the DI and the two microjets of the MSI only covered 0.4 and 1.6 m^2 of the soil area under the tree, which represented ≈1.6% and 6.4% of the alloted area per tree, respectively. Thus, the present results suggest positive relations between coverage of the soil area and the tree size, ground area, shoot growth, leaf relative water content and the yield per tree.

The positive responses of vegetative growth to area amount of the wetted zone were previously reported (Proebsting *et al.*, 1984). Bredell and Barnard (1977), Koo (1978, 1980), Bielorai (1982) and Smajtrla and Koo (1984) have shown that increased irrigation coverage resulted in greater fruit yield. High leaf water potential and stomatal conductance values were associated with the large soil area coverage (Zekri and Parsons, 1988).

The present data indicated that the tree dimensions and ground area index (GAI) of PSI trees, followed by MSI one, were much higher than those figured out by Khalil (1999) for the standard trees of 5x5 m spacing. This means that the PSI trees and, to a less extent, the MSI ones became too crowded such that a great reduction in the tree yield efficiency was obviously observed. In such cases, the successive hedging and topping are required to maintain the trees in adequate dimensions, and hence, the pruning cost would be increased. On the other hand, the tree dimensions and GAI of DI trees were still in adequate range, even after 20 years from the planting date, the matter which resulted in the observed high efficiency of the tree yield and the pruning cost would be at a minimum level as a consequence. Thus, the present results suggest that decreasing the planting distance to be 5x4 m or 5x3 m in hedgerows system would be more suitable for DI method in respect to the yield efficiency per unit of land area as well the water use efficiency. In sandy soils, especially in arid regions, the horizontal movement of water is limited and the majority of the roots are confined to the soil volume of the wetted area (Levin *et al.*, 1979 ; Swietlik, 1992), the case which gives good advantages to the well-designed, well-managed drip and microsprinkler irrigation systems (Smajstrla, 1993).

The present results indicate that the 20-year-old Valencia orange trees responded poorly as the level of water application increased above 80 liters per day. Under a given irrigation method, the minimum level of water application (80- liters) was enough to give responses similar to the maximum one (120 liters). This result suggests that the 80 liters level would represent the maximum amount of water that would be applied per tree.

The PSI80 treatment, which covered the entire soil area, *i.e.* both the ground area and the area outside, or both the productive area and the nonproductive one, gave as much as the highest values of the tree size and tree yield . Thus, the adequate amount of water required to cover only the productive area would presumably be less than 80 liters per tree per day during March to October period.

Saad-Alla *et al.*, (1997) recommended 20 liters to 80 liters water application to drip per day per mature citrus tree with the minimum levels during winter months and the maximum level during July. However, further studies are needed under our local conditions to further adjust the schedule of irrigation in the light of the amount of soil water depletion and the ground area of the standard trees.

In conclusion the trees of drip irrigation in comparison with those of the other methods, are smaller in size, higher in tree yield efficiency , and the pruning cost would be at the minimum level. Decreasing the planting distance of drip irrigation trees in a hedgerows system would increase the water use efficiency and the yield per unit of the land area.Trees of the microsprinkler irrigation method stand in the midway between those of the drip and portable sprinkler irrigation methods.

The application of 80 liters irrigation water per mature tree per day during March to October periods represents the maximum level of water to be applied. Further studies under our local conditions to schedule the irrigation based on the amount of soil water depletion and the ground area of the tree are needed.

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إستجابة أشجار الفالنشيا البالغة لثلاث طرق رى مضغوط تحت ظروف جنوب التحرير

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معهد بحوث البساتين ، مركز البحوث الزراعية ، الجيزة ، مصر

الملخص

درست خلال موسمي 1997 ، 1998 ، إستجابة أشجار الفالنشيا البالغة، المطعومة على أصل النارنج على مسافة 5x5 م في أرض رملية لمزرعة في قرية الخرطوم بقطاع جنوب التحرير ، للرى بالتنقيط (أ) ، الرى بالرشاشات الصغيرة (ب) ، والرى بالرش النقالى (ج) تحت ثلاث مستويات إضافة لماء الرى : 80 ، 100 ، 120 لتر/شجرة /يوم خلال الفترة من مارس إلى أكتوبر لتقل إلى النصف خلال الفترة التالية . إستخدم نقاطين بتصريف 4 لتر /ساعة ، ورشاشين بتصريف 16 لتر / ساعة لكل شجرة للمعاملة (أ) و (ب) على الترتيب . كما إستخدم رشاشتى بتصريف 2.5 م^{3} / ساعة لكل 14 شجرة للمعاملة (ج) . غطى الرى من خلال الطرق (أ) ، (ب) ، (ج) تقريبا 1.6 ، 6.4 و 100 % من المساحة المتاحة للشجرة ، على الترتيب. كانت إستجابة نمو الشجرة ، نمو الأفرع ، المحتوى المائى للورقة ، ومحصول الشجرة إيجابية لكمية مساحة المنطقة المبتلة . لوحظ أعلى و أقل كفاءة محصولية للشجرة تحت الطريقة (أ) و (ج) ، على الترتيب . كانت إستجابة الأشجار لمستوى إضافة ماء الرى ضعيفة. لذلك فإن إضافة 80 لتر /شجرة/ يوم مثلت أفضل معدل يمكن تطبيقه خلال الفترة من مارس وحتى أكتوبر . لم تتأثر صفات الثمار بشكل محدد لأى من معاملات الرى . كانت ثمار أشجار الطريقة (ج) أكثر عصيرية . إقترح تقليل مسافة الزراعة مع إتباع نظام الزراعة فى أسوار لطريقة الرى بالتنقيط لزيادة المحصول فى وحدة المساحة وكفاءة إستخدام ماء الرى . كما إقترح اجراء دراسات مكملة لتضبيط جدولة الرى تعتمد على كمية فقد الماء من منطقة إنتشار الجذور والمساحة الخضراء للأشجار .

المجلة العلمية لكلية الزراعة – جامعة القاهرة – المجلد (52) العدد الأول (يناير 2001): -151- 166.