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EFFECT OF SOIL MOISTURE STRESS ON APPLE TREES

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Abstract

Seasonal rates of water consumptive use by apple trees ranged from 85.58 to 120.18cm under differentt soil moisture levels. The values of water consumption was increased as soil moisture maintained high by frequent irrigation. Monthly water use was found to be low after dormancy, then increased gradually to reach a maximum during July andAugust. Thereafter, the rates started to decline to reach its minimum during November when the trees were going to dormant period. Apple roots extract 70% of their moisture need from the first foot of soil profile. Seasonal crop coefficient was found to be 0.66. Results showed that the moist treatment (40% of availble soil moisture is depleted) had the highest water use efficiency (1.00 kg fruit/m3 ET) compared with other soil moisture levels. Water deficit enhanced bud development. However, keeping the soil moisture at a high level delayed bud burst process. Bud burst percentage increased as soil moisture stress increased. However, fruit setting showed a reverse trend to that observed with bud burst. Adequate water supply at the root zone of apple trees is important in reducing the percentage of fruit shedding or fruit drop. The moist soil moistre level out-yielded the other irrigation treatments. The highest values of fruit characters i.e. fruit weight, fruit diameter or length and volume was gained from the moist treatment. However fruit quality i.e. firmness, total soluble solids and acidity showed a reverse trend to that observed with other fruit charcters. Also, moist soil moisture level led to high concentrations of leaf mineral content than other treatments.

INTRODUCTION

Apple (Malus sylvestris cv. Anna) is a deciduous tree introduced to Egypt since 1980. The area being cultivated is 75566 feddans (Department of Economic and Statistics, Ministry of Agriculture, Giza, A.R.E. 1995). This area is concentrated mainly in the newly reclaimed land. A great success was gained in the newly reclaimed areas under drip irrigation. There is a lack of information about the response of apple trees to water deficit. Such deciduous trees are without leaves during the period from late November to February and they use less water through this period. Growth response of several peach, pear and apple cultivars and rootstocks, to soil water, showed that the high available water treatments produced longer shoots than those obtained from the low ones (Proebsting and Middleton, 1980). Apple trees are grown when soil moisture is maintained at 75-85% (wet), 60-70% (semi wet), 45-55% (dry) of the water holding capacity from June to late November, tree growth was limited as shoot elongation ceased in late July (Kuroda et al, 1985). In trials with mature peach trees subjected to 3 levels of moisture, wet treatment (irrigated at 3 weeks intervals) medium (received one irrigation) versus dry treatment (non irrigated), no significant differences among treatments for fruit yield or fruit size were indicated, but fruit maturity was slightly delayed in the dry treatment (Larson et al, 1988). The amount of water applied is important for determining the cropping potential on apricot cv. cafona trees (Ruggiero, 1991). The sensitivity of plum trees to water deprivation at various fruit growth stages was studied. Water deprivation caused the most severe reduction in tree water status when it was imposed over longer periods of time and during periods of high evaporative demand and had more severe effects under shallow soil conditions. Compared to the fully irrigated control, deprivation during all stages of fruit development (most severe deprivation treatment) was associated with increased flowering, reduced fruit hydration ratio and smaller fruit size under all soil conditions (Lampinen et al., 1995). Irrigation of apple trees by drip irrgation system in a 3-day cycle induced higher vegetative growth rates, but lower average yield compared with subsoil microirrigation system. (Gospodinova and Dotchey, 1996). The aim of this study is to determine the effect of soil moisture stress on water consumption, water use efficiency, stages of bud and flower development, yield, fruit quality and leaf minerals content of Anna apple trees.

MATERIALS AND METHODS

The present investigation was carried out at Elkanater Horticultural Research Station, (soil type is silty-loam) during the two successive seasons namely 1995 and 1996 using Anna apple budded on M.M. 106 rootstock. The experimental design was a randomized complete block with four replications. The irrigation treatments were as follow:

A : Irrigation when 20% of available soil moisture is depleted (wet).
B : Irrigation when 40% of available soil moisture is depleted (moist).
C: Irrigation when 60% of available soil moisture is depleted (medium).
D : Irrigation when 80% of available soil moisture is depleted (dry).

Irrigation treatments had started after the trees receiving the winter irrigation at February, i.e. from swelling stage. Irrigation water was practiced when the moisture content reached the desired soil moistur level in each treatment. Soil samples were taken from each treatment 5 days after irrigation to determine the available soil water retained in the soil. Field capacity, witing and bulk density of the experimental site were determined and presented in Table 1. Soil moisture was determined gravemetrically on oven dry basis in soil samples taken to a depth of 15 cm up to 60cm. Water consumptive use was computed as the differences in soil moisture content in soil samples taken prior to and 48 h after irrigation. Water consumptive use was calculated according to the following formula: [Cu = D X AD x (e2-e1)/100] where, Cu = water consumptive use in mm., D = soil depth in cm., AD = Bulk density g/cm3., e1= soil moisture percentage before irrigation and e2=Soil moisture percentage after irrigation. The sum of the measured consumptive use in each month is the monthly water use from which seasonal water consumption was obtained. For calculating crop coefficient (Kc), potential Evapotranspiration was estimated by Modified Penman (Doorenbos and Pruitt, 1984) using records of Meteorological data. Penman formula is as follows: (ETp = W.Rn + (1-W) Fu (ea-ed)] where, ETp= potential evapotranspiration in mm/day, W = weighting factor depending on mean air temperature and altitude, Rn = net radiation expressed as mm/day, fu = 0.27 (1+ul/100), u = wind speed Km/day and ea-ed = vapor pressure deficit /mm bar.

Table 1. Soil moisture constant from the epperimental site.

Depths (cm.)	Field capacity (F.C.)%	Welting point (F.C.)%	Available water % (A.W.)%	Bulk density g/cm3
0-15	35-83	18.79	17.04	1.30
15-30	33.44	17.34	16.10	1.35
30-45	29.64	15.1	14.54	1.35
45-60	31.74	16.86	14.88	1.37

Data recorded in this study are:1) stages of flower bud burst process, 2) bud burst%, fruit set %, yield kg /tree and yield efficiency, 3) retained fruit, 4) fruit characters (weight, dimensions and volume) and fruit quality (firmness, total acidity and T.S.S. %) and 5) leaf minerals content [N%, in distillation in a micro-kjeldahl apparatus, after Black (1965), P% according to John (1970), K% using the flame photometer (Dewis and Freitas, 1972), and (Fe, Zn and Mn) were determined directly in the diluted digested solution using atomic absorption spectrophotometer (Perkin

Elmer 3300)]. All leaves samples were collected at the mid of July in the two seasons. All the data were subjected to statistical analysis and the mean values were compared using the method proposed by Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

1. Water Relations:

1.1. Water consumptive use:

1.1.1. Seasonal Rates:

Seasonal rates of water consumptive use by apple trees under different soil moisture stress treatments are presented in Table 2. The values of water use in the first season ranged from 83.51 to 117.83 cm depending on the level of soil moisture depletion before irrigation. However, in the second season, it ranged from 87.64 to 122.53cm. The values showed that seasonal water use by the studied trees irrespective of irrigation treatments are higher in the second year than in the first season. Such results is mainly due to differences in climatic factors. in this connection (Pruitt, 1960 and Change, 1971) concluded that the rate of evapotranspiration depends on the evaporate power of air. Most studies showed a very close correlation of water consumptive use and climate.

Table 2. Water consumptive use (cm. and m.3/fed.), yield (kg./fed.) and water use efficiency (Kg./fed./m.3) for apple trees as affected by water stress.

Treat.	ET. (cm.)	ET. (m3/fed.)	Yield (Kg./fed.)	W.U.E. (Kg./fed./m.3
		1995		
A	117.83	4949.00	2475.40	0.50
B	108.43	4554.00	3808.90	0.84
C	92.31	3877.00	3073.90	0.79
D	83.51	3507.00	2000.30	0.57
		1996		
A	122.53	5146.00	3042.40	0.59
B	112.07	4707.00	5433.80	1.15
C	95.64	4028.00	3803.60	0.94
D	87.64	3681.00	1947.80	0.53
		Mean of two seaons		
A	120.18	5048.00	2758.90	0.55
B	110.25	4631.00	4621.40	1.00
C	94.11	3952.00	3438.80	0.87
D	85.58	3594.00	1974.10	0.55

Data in Table 2 indicate that seasonal water consumptive use increased as soil moisture was maintained high by frequent irrigation. The higher water use was attained under wet treatment followed by moist and medium level, where the lowest values were found to be from the dry treatment which received irrigation when 80% available soil moisture was consumed. In other words, the rate of evaportanspiration increased in an ascending order. dry (D) < medium (C)< moist (B)< wet (A) moisture level.

The probable explanation of these results can be attributed to the availability of soil water to apple trees in addition to the higher evaporation rate from wet soil surface than a dry one. In this respect, Doorenbos and pruitt (1984) concluded that after irrgation the soil water content will be reduced primarily by evapotranspiration. As the soil dries, the rate of water transmitted through the soil will be reduced. At the stage when the rate of flow falls below the rate needed to meet ET. crop, it will fall below its predicted level. Unger and Stewart (1983) pointed out that soil water evaporation occurs in three stages. In the first stage, water loss is rapid and steady, it depends on the net effects of water transmission to the surface and on environmental conditions such as wind speed, temperature, relative humidity and radiant and energy radiant. During the second stage, the loss rate decreases rapidly as the soil water supply is depleted. Soil factors control the rate of water movement to the surface and above ground. Evaporation during the third stage is extremely slow and is controlled by absorptive factor's at the liquid-solid interface.

1.1.2. Monthly Rates:

As a general trend, monthly water Consumption (Fig. 1) was found to be low at the beginning of the growth season of apple trees (after dormancy). Such pattern can be related to less transpiring surface (leaves) during the period of blooming. Also, the potential evapotranspiration was found to be low through this period (Table 2). Then water use values increased gradually as the green cover of trees increased and the increase in air temperature and solar radiation. Monthly water consumption recorded its maximum rates during June and July may be due to : a) leaf system on the tree is fully expanded, b) growth of fruit on a volume basis is in an almost uniform rate until maturity, c) higher solar radiation and air temperature (potential evapotranspiration recorded its maximum values during these months). Thereafter, evaportanspiration rates started to decline to reach its minimum value during November as the trees were goining to dormant period. The previous results can be discussed on the basis that evaporation was greater than transpiration early in the

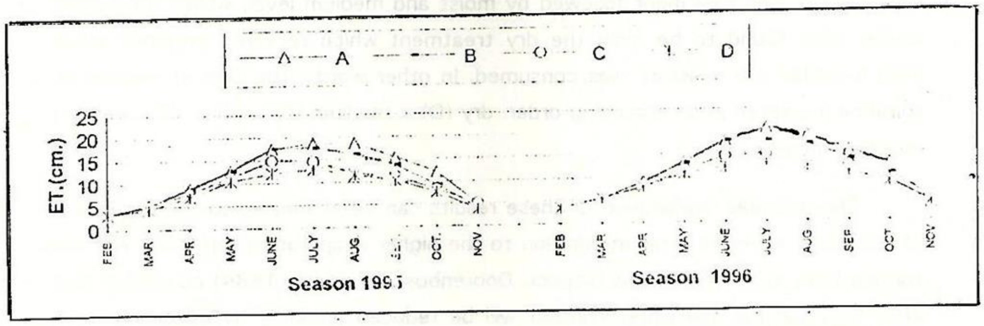

Fig.1. Monthly ET. (cm.) for apple trees under different water stress treatments.

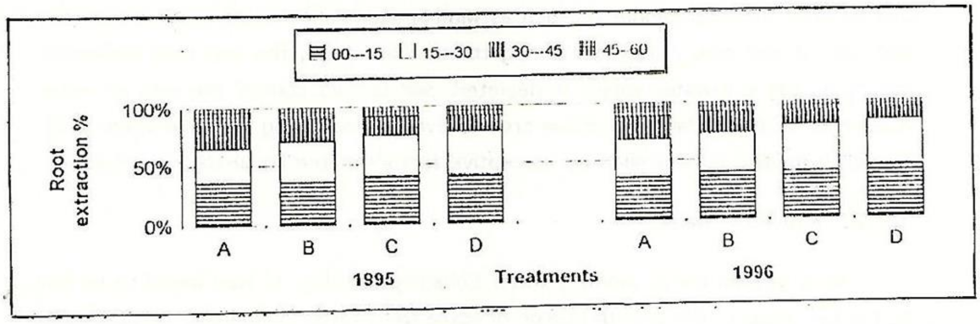

Fig.2. Water extraction % by apple roots under different soil moisture stress treatments.

season (blooming period) as the plants intercept little of the net radiation. Later on, as the extend of green cover increased by the expansion of leaves, transpiration was greater than evaporation. Thus, the gradual increase in evapotranspiration from the beginning of the growth season till fruit maturity can be explained on the basis of percent cover. In the light of the previous results, it can be concluded that soil moisture stress has a direct effect on monthly evaportranspiration of apple trees. As soil moisture stress increased by prolonged irrigation intervals, monthly water use decreased. The drier soil, the lesser is the water consumption by apple trees.

In this connection Weagand (1962) pointed out that the drying rate of a bare soil is proportional to the water content and inversely to time, and a drying front advances into the soil linearly. Ibrahim (1981) concluded that the increase in evaportanspiration rate by maintaining soil moisture at a high level can be attributed to excess available water that found in the root zone to be consumed by plants.

1.2. Water Uptake:

Water uptake by apple tree roots under different soil moisture stress is illustrated in Fig. 2. Results clearly indicate that 'apple roots extract about 70% of their moisture needs from the first foot of soil profile. The rest of their moisture needed are extracted from the second foot. These results showed that the bulk of the roots are usually concentrated in the upper soil layer. Such pattern of results may indicate the important of irrigating apple trees frequently to compensate the moisture consumed from the first foot. Prolonged irrigation intervals may cause an injury to the root hairs of such trees. This may be reflected on the growth of such deciduous trees thereby reducing their production. Increasing soil moisture strees did result in decreasing the amount of water absorbed from lower soil depths. Such pattern of findings can be attributed to that water deficit restrict the growth of root hairs of apple trees. Uriu and Magness (1967) concluded that growth of apple roots decreased as soil water suction reached 0.4 - 0.5 bar. Johnson et al. (1992) pointed out that soil moisture determination indicated that water use by the control occurred mainly in the upper soil profile.

1.3. Crop Coefficient (Kc):

Most crops do not require much water during the season as would be needed to meet the potential evapotranspiration, even though adequate soil moisture can be provided (Jensen, 1968). Thus, the term crop coefficient is being used to differentiate water requirements of crops. For the determination of crop coefficeint, both actual and potential evalpotraspiration are measured concurrently. Crop coefficient calculated as the ratio of the previous two measurements throughout its growth cycle is presented in Table 3. The values were calculated according to the daily potential evapotranspiration estimated by Penman's method and water consumptive use obtained from the moist treatment. Crop coefficient was low at the beginning of the blooming period, due to relatively large diffusive resistance of the soil. Thereafter, crop coefficient increased as the green cover increased due to the increase in leaves regrowth and expansion. This means that the diffusive resistance decreased as a result of the increase in leaf area through the period of leaf expansion. The value of crop coefficient reached its maximum value during June and July (0.75) which is the period of fruiting. This pattern may demonstrate that such period is considered the peak period of water demand by apple trees. Then crop coefficient decreased again during the late season of growth to reach a minimum when plants are going to dormancy period. It is worthy to mention that seasonal crop coefficient of apple trees was found to be (0.66).

Table 3. Actual and potential evapotranspiration ET. (mm/day) during two seasons.

Actual ET. mm/day	Season	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.
	1995	1.20	1.65	2.90	4.11	5.83	5.74	5.25	4.57	2.97	1.35
	1996	1.24	1.77	2.94	4.22	5.97	5.77	5.50	4.57	3.39	1.37
	mean	1.22	1.71	2.92	4.17	5.90	5.75	5.37	4.57	3.18	1.36
Potenlial ET. mm/day	Season	2.82	2.70	4.18	5.75	7.83	7.28	7.06	6.30	4.84	2.72
	1995	2.82	3.07	4.50	6.25	7.90	7.98	7.48	6.96	4.50	2.87
	1996	2.82	2.89	4.34	6.00	7.87	7.63	7.27	6.63	4.67	2.80
Kc		0.43	0.59	0.67	0.69	0.75	0.75	0.74	0.69	0.68	0.48

1.4. Water Use Efficiency:

In arid regions, water supplies is more limited and water cost increases. The management objectives may shift to optimizing production per unit of applied water. Water use efficiency is defined as the quotient of crop yield produced per unit area over the volume of water required in evaportanspiration to produce the crop. Water use efficiency by apple trees expressed as Kg. fruit yield/feedan/unit of water (m.3) consumed in complete evapotranspiration is presented in Table 2. Results showed that the values of water use efficiency were higher in the second season than in the first. These results are mainly due to higher yield production in the second season compared with the first one. The decrease in yield production observed in the first year was much more than the decrease in water consumption. Those two factors are responsible for lower water use efficiency values observed in the first year of the study. Regarding the effect of moisture stress on water use efficiency, results in table 2 showed that the moist treatment had the highest water use efficiency (1.00 Kg. fruit/m2 ET.). The least water use efficiency values was found to be from either wet or dry soil moister stresses. These results may show that irrigating apple trees either frequently or by prolonged intervals result in a sharp reduction of water use efficiency values. It can be concluded that for maximizing the values of water use efficiency by apple trees, irrigation water should be practiced at moderate soil moisture strees i.e. 40% depletion in available water. In this connection, Ritchie (1974) pointed out that some water conservation benefits can be obtained from allowing plants to experience moderate water stress. It is well known that plant roots when were subjected to soil moisture strees, extract soil water from greater depths than plants kept irrigated to optimum levels. Thus, water stored in the profile is used more efficiently.

2. Apple yield and Related measurments:

2.1. Flower Bud burst:

Flower Bud burst process could be classified to the following stages: 1) dormant stage 2) swelling stage 3) bud burst stage 4) green cluster stage 5) full flower opening stage. Results concerning the effect of soil moisture stress on flower bud burst process is illustrated in Fig.3. The data showed that the dry treatment accelerated development of flower buds compared with the other irrigation treatments. However, other soil moisture levels i.e. wet, moist and medium soil moisture were found to be less with respect to bud burst process. In otherwords, increasing the amount of retained soil moisture prior to irrigation did result in retarding the development of flower buds. On the contrary keeping the soil moisture at a higher level (wet or moist) by frequent irrigation delayed bud burst process. The higher soil moisture is the less flower buds burst process. In this connection, Uriu and Magness (1967) pointed out that water shortage during the period of bud development in deciducus fruits tend to increase bud development. Moreover, Johnson et al., (1992) cocluded that flower and fruit density were greater in dry treatment.

2.2. Fruit Set and drop:

The percentage of bud burst and fruit setting of apple trees under various levels of irrigation treatments is presented in Table 4. In general, burst percentage increased as soil moisture stress increased. Thus, bud burst percentage can be arranged in an ascending order as follows: Wet<Moist<Medium <Dry. This pattern was

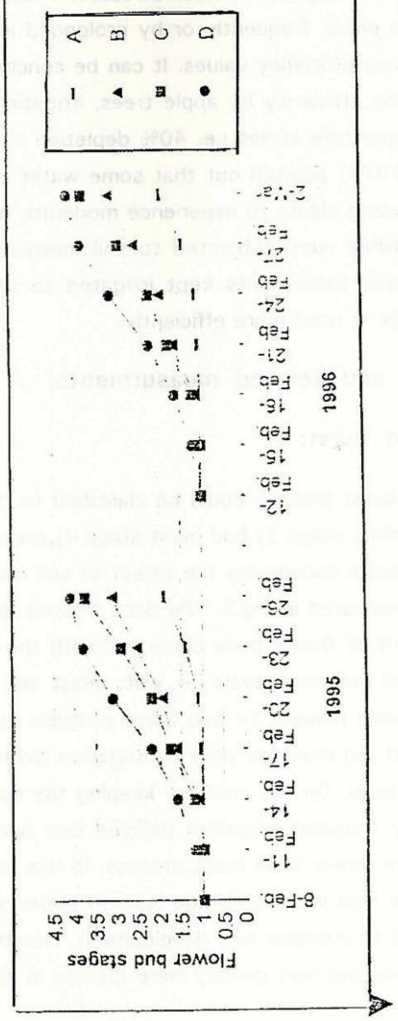

Fig.3. Stages of flower bud burst process during 1995 and 1996 seasons.

found to be true in both seasons. As for fruit setting results (Table 4), a reverse trend with bud burst was observed. In other words, increasing soil moisture stress resulted in a significant decrease in fruit setting. However, maintaining soil moisture at a high level by frequent irrigation (wet treatment) resulted in a significant decrease in fruit setting compared with either moist or medium soil moisture stress. Such trend may prove that adequate soil moisture is very important in increasing fruit setting by apple trees. These results indicate that deficit during blooming period reduce fruit setting. At the same time, more water stored in the root zone of apple trees may cause a reduction in fruit setting due to their effect either on aeration or on the growth of roots (wet treatment). In this respect Skepper and Vircent (1962) reported that 4 to 5 weeks water storage before blooming resulted in a reduction in fruit setting by deciduous trees. Also George and Nissen (1988) found that soil moisture strees reduced fruit set in apple trees. Following up the retained fruits on apple trees at various periods of fruit devlopment (Table, 5) results showed a similar trend to that observed with fruit setting. Such type of findings may prove the importance of maintaining soil moisture at an optimum level (40% depletion moist treatment) for increasing the retained fruits on apple trees. In other words, adequate water supply at the root zone of apple trees is very important in reducing the percentage of fruit shedding or fruit drop. Results of Table 5 showed that fruit drop increased gradually to reach a maximum through late June (expressed as percentaged of retained fruit). Such problem can be controlled by adequate water supply and preventing water deficit through such period. An increase in fruits drop had been observed in trees under stress following an irrigation close to harvest. Thus, maintaining soil water at moist level is very important during the period of pre harvest. In this respect, Simons (1963) made an anatomical studies of apple fruit abscission and found that lack of soil water accompanied with high temperatue hastened the abscission zone development in all the varieties experimented. Also George and Nissen (1988) found that soil moisture stress reduced flowering and fruit set on apple trees.

Table 4. Bud burst, fruit set, yield/tree and yield efficiency of apple trees as affected by water stress.

Treat.	Bud burst %		Fruit set %		Yield (Kg./tree %		Yield efficiency	
	1995	1996	1995	1996	1995	1996	1995	1996
A	56.36	58.31	24.78	25.77	9.43	11.59	0.09	0.10
B	63.46	61.39	28.58	29.39	14.51	20.70	0.14	0.20
C	67.30	65.15	26.69	27.58	11.71	14.49	0.11	0.14
D	71.35	70.58	20.08	16.75	7.62	7.42	0.07	0.07
L.S.D. 5%	1.55	1.46	0.53	1.03	1.52	2.23	0.01	0.02

2.3. Yield/tree and Yield Efficiency:

Apple fruit yield i.e. yield / tree or yield efficiency as affected by soil moisture stress in the two successive seasons is presented in Table 4. Statistical analysis showed that water deficit had a significant effect on productivity of apple trees. The maximum fruit yield and yield efficiency were scored from the moist treatment followed by medium soil moisture level and the wet treatment. The lowest production was obtained from the dry soil moisture level (severe soil moisture stress). The moist condition out-yielded the other irrigation treatments. The increase in yield gained from such treatment was found to be significant over the other levels of soil moisture. Such finding may prove that adequate water supply for apple trees is an important factor for maximizing its production. Kramer (1977) stated that water stress reduced photosynthesis by closure of stomata which decrease the supply of CO_2. Also, water stress reduces the capacity of the protoplasm to carry on photosynthesis, Cepicka and Novotny (1991) revealed that irrigation increasing average yield over the three years by 76.8% on peach trees. Benporatll and Greenblat (1994) found that increased yield of apple trees was indicated by irrigation at the high level of water.

It is worthy to mention that maintaining soil moisture at a high level (wet treatment) by frequent irrigation decreased slightly the yield of apple trees. Such pattern can be attributed to the leaching of nutrients and or low aeration in wet soil which may affect the growth of root hairs. Marangoni and Rossi-pisa (1986) found that apple fruit weight was 10% lower than on irrigated plots. Johnson et al. (1992) found that radial growth was poorest in the dry treatment on peach trees. Lampine et al. (1995) showed an optimal level of tree water stress was required to give high fruit high production in French prune.

2.4. Fresh Characteristics and Fruit Quality :

Fruit characters of apple tree (fruit weight, diameter, length and volume) as affected by soil moisture stress in the two seasons is presented in Table 6. Results showed that all the fruit characters was significantly affected by water deficit. The highest values of fruit characters was gained from the moist treatment followed by the medium level of soil moisture and the wet treatment. However, the least values were found to be from the severe soil moisture stress. Such results indicate that water deficit affect greatly the fruit size which was reflected on the final tree yield. It can be concluded that irrigating apple trees when 40% of available water is depleted can be recommended for higher fruit yield and better fruit size.

Table 5. Effect of water stress on retained fruit % of apple during 1995 and 1996 seasons.

Seasons Treat.	1995 18-Apr.	1996 20-Apr.	1995 1-May.	1995 3-May.	1995 4-May.	1995 16-May.	1995 27-May.	1996 29-May	1995 10-Jun	1995 11-Jun.	1995 23-Jun.	1995 24-Jun
A	62.07	59.98	44.42	49.65	31.20	36.40	26.00	28.23	19.25	21.25	14.14	12.98
B	95.73	87.86	75.31	66.06	76.83	50.50	52.90	44.12	39.58	31.97	28.08	22.32
C	46.93	74.60	40.02	57.63	35.02	39.43	28.17	31.88	23.30	24.47	18.88	14.63
D	51.25	64.35	35.83	46.23	29.92	33.13	22.48	22.64	17.17	16.25	12.11	9.88
L.S.D. 5%	1.86	2.88	3.32	3.07	3.58	1.56	4.51	2.06	4.68	2.01	3.18	2.27

Table 6. Fruit characteristics and quality of apple trees as affectedby water stress.

Seasons Treat.	Fruit weight (gm.)		Fruit diameter (cm)		Fruit length (cm)		Fruit volume (cm3.)		Firmness		Total acidity %		T.S.S. %	
	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996
A	100.45	102.93	5.67	6.02	6.19	6.38	109.80	111.52	10.56	10.06	0.48	0.40	11.02	11.05
B	117.59	108.21	6.25	6.22	6.72	6.52	130.52	121.04	12.13	12.21	0.51	0.44	12.00	11.19
C	106.56	104.65	5.37	6.17	6.37	6.41	117.32	114.60	12.63	12.33	0.55	0.46	12.07	11.39
D	94.36	98.91	5.44	5.93	6.17	6.13	102.62	106.42	15.17	14.03	0.64	0.53	12.20	12.09
L.S.D. 5%	3.99	1.85	0.29	0.27	0.40	0.32	2.66	2.22	0.65	0.14	0.07	0.02	0.93	0.23

As for fruit quality (firmness pound /Cm2, acidity and total soluble solids), results of Table 6 showed that under dry condition, apple fruit quality was found to be better than under moderate water supply. Fruits produced from trees grown under dry conditions was higher in the values of fimness, acidity and total soluble solids. In this connection, Marangoni and Rossi-pisa (1986) found that the fruit weight was 10% lower than in irrigated plots in apple trees. Crisosto et al. (1994) found that the deficit irrigation treatment induced higher T.S.S. concentration than with excess or optimum irrigation in peaches. Ramos et al. (1994) in their study of the effect of water stress on pears found that both fruit size decreased with water stress whereas soluble solids (T.S.S) and acidity increased.

2.5. Leaf mineral contents:

To study the effect of water stress on leaf minerals content, samples of treated plants were taken and subjected to chemical analysis. Data obtained are presented in Fig.4 (a & b). It is clear that water stress at the moist treatment had led to a highly significant increase in N, Zn, and Mn in treated plants compared to the other treatments in the two seasons. On the other hand, all water stress treatments did not affect P, F, Ca, Mg, and Fe as leaf contents in treated plants. These results agree with Draz (1986). Oiszewski et al. (1995) obtained nearly simillar results on bitter almond and apple, respectively.

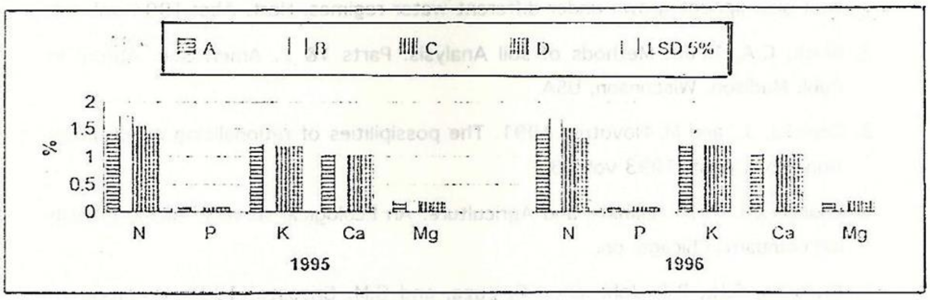

Fig.4a. Leaf macro elements content as affected by water stress.

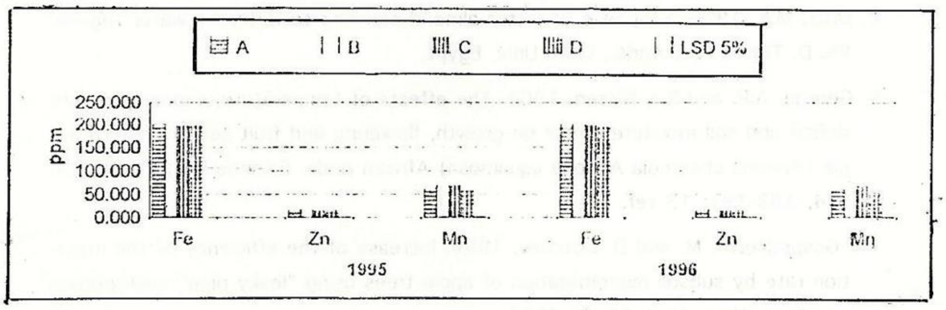

Fig.4b. Leaf micro elements content as affected by water stress.

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تأثير الإجهاد المائى على أشجار التفاح

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تراوح معدل الاستهلاك المائى الموسمى للتفاح بين ٥٨, ٨٥، ١٨, ١٢٠. سم تحت مستويات الرطوبة المختلفة وقد تزايد قيم الاستهلاك المائى بزيادة الرطوبة الارضية وقد وجد أن الاستهلاك المائى الشهرى بدأ منخفضا بعد فترة السكون ثم تزايد تدريجيا ليصل إلى أعلى معدل له خلال شهرى يونيو ويوليو ثم بدء يتناقص ليصل إلى أدنى مستوى له خلال شهر نوفمبر حيث بدأت الأشجار الدخول فى فترة السكون وقد لوحظ أن جذور أشجار التفاح تستفيد ٧٠٪ من احتياجات الرطوبة من القدم الأول كما وجد أن ثابت المحصول الموسمى للتفاح هو ٠,٦٦ . وقد أوضحت النتائج أن المعاملة الرطبة التى تروى عند فقد ٤٠ ٪ من الماء الميسر هى أعلى المعاملات فى كفاءة استخدام المياه حيث بلغت ١,٠٠ كجم ثمار/م٣ ماء مستهلك. لوحظ أن نقص الرطوبة فى مستوى الجذور يشجع تطور البراعم وتفتحها، بينما كان عقد الثمار على عكس ذلك تماما اذ أن المحافظة على رطوبة التربة حول جذور أشجار يشجع تطور البراعم وتفتحها، بينما كان عقد الثمار على عكس ذلك تماما اذا ان المحافظة على رطوبة التربة حول جذور أشجار التفاح أدت الى زيادة العقد وقد أعطت المعاملة الرطبة أعلى محصولا بفرق معنوى عن باقى المعاملات وكذلك بالنسبة لصفات الثمار. أما صفات جودة الثمار (الصلابة ، الحموضة ، المواد الصلبة الذائبة الكلية) فكانت علي عكس ذلك. أيضا أعطت المعاملة الرطبة أعلى تركيزات لمحتوى الأوراق من العناصر بالمقارنة بالمعاملات الآخرى.