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Water Table Contribution to Faba Bean Water Use

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LYSIMETER experiment on sandy loam soil was conducted to estimate the contribution of water table to meet the water requirements of Faba bean (*Vicia faba* L.). The lysimeters were connected to a tank with Marriotte siphon and a piezometer to maintain the water table level (WT) at the desired depths, which consisted of 50, 70 and 90 cm from the soil surface. The results of this study showed that there is no high difference between the values of actual evapotranspiration (Et_a) for this crop under the three levels of WT. It slightly increased with increasing water table depth. As well as, 70 cm WT treatment showed that it can be consider suitable conditions. At this level, the amount of water was meet the requirements of crop which cause a significant high values of its water use efficiency (WUE) and water economy (WE) and also a maximum grain yield. Compared to a high WT level 50 cm or a deep WT level 90 cm where, the crop depends basically on the water irrigation requirements.

Keywords: Water table contribution, Crop water requirements, Faba bean.

Faba bean (*Vicia faba* L.) is one of the most important pulse crops grown for seed in Egypt, being cultivated from the North to the Deep South. Due its high nutritive value, it is a primary source of protein in the diet of masses. The average cultivated areas are 69720 ha, with an average yield of 1896 kg/ha (AOAD, 2007). On the other side, seed yield and biomass of faba bean were highly dependent on the amount of water availability and its use efficiency (Mohamad and Dennet, 2010). Along with this fact, shallow water table areas in Egypt are likely to increase which created by indiscriminate use of irrigation water. Non functional drainage systems and also seepage from rice fields thus can result in further water table rise leading to water logging and secondary salinity problems, which are the potentially serious problems for the agricultural industry. Because of the negative impact of water table on crop yield and long-term impact on agricultural productivity; they can reduce the potential yield by 30-80 percent for many crops (McFarlane and Williamson, 2002).

On the other hand, upflow from shallow water tables can be a significant component in the root zone water balance of cropping systems and has been a topic of extensive research in the last few decades. Groundwater can contribute significantly to crop water needs and therefore reduce applied irrigation. It could also be used as sub-irrigation by adopting proper irrigation scheduling to help bridge the gap between water demand and supply (Kahlown *et al.*, 2005). Reduced irrigation above shallow water tables not only results in more efficient use of water resources, but also lowers the risk of water logging and nutrient losses below the root zone. Therefore the aim of this experiment was to investigate the optimum utilization of water for faba bean crop under different three water table levels using lysimeter experiment.

Material and Methods

A lysimeter experiment was carried out in eighteen double walls concrete lysimeters of the size 1.25 m × 1.25 m in area and 1.25 m depth using the cultivar Faba bean (*Vicia faba* L.) as test plant. Each lysimeter consisted of a drain and a water feeding tubes from the bottom of the lysimeter to control the WT depths through a daily supplying of a tap water to saturate the soil up to the agreement levels under low pressure. A tank with Marriotte siphons and piezometer were connected to each lysimeter to maintain the WT at the desired levels where represent, 50, 70 and 90 cm from the soil surface. The amount of water used to raise a water table were monitored by the daily loss of water from the Marriotte siphon which, measured by water flow meters. In the same time, the excess amount of water percolated into the WT was measured through storage bottles attached to the bottom of each lysimeter, and the difference between them represent a water use from the water table. The soil and that the different lysimeters had similar properties of sandy loam texture extending from surface to 60 cm depth. Some physical and chemical properties of the investigated soil are shown in Tables 1 and 2.

TABLE 1. Some physical properties of the soil .

Sampling depth (cm)	Bulk Density (g/cm^3)	Soil moisture constants: Field * Capacity (%)	Wilting** Point (%)	Available water (%)	Particle-size distribution: Sand (%)	Silt (%)	Clay (%)
00 – 20	1.33	38.04	15.27	22.77	51.90	22.30	20.80
20 – 40	1.41	33.65	13.26	20.39	48.70	30.30	16.33
40 – 60	1.30	31.07	12.04	19.03	50.50	30.10	14.70

TABLE 2. Some chemical properties of the soil .

Sampling depth (cm)	Organic matter (%)	$CaCO_3$ (%)	ECe ds/m	Soil pH	Available N (%)	Available P (%)	Available K (%)	Total N (%)	Total P (%)	Total K (%)
00 – 20	2.40	1.27	2.40	7.50	0.28	0.001	0.04	2.70	0.16	0.40
20 – 40	1.50	1.40	1.50	7.70	0.25	0.001	0.04	2.25	0.13	0.11
40 – 60	1.80	1.81	1.80	7.50	0.24	0.001	0.03	1.02	0.14	0.30

* At 0.33 mbar .
** At 15 mbar .

Faba bean (*Vicia faba* L.) variety Giza 843 was cultivated in 17th Nov., 2010 with 20 cm planting distances and 30 cm between rows, so, there were 24 plants in each lysimeter to record its relative dry grain yield as (g/plant). The experimental plants were fertilized before sowing according to the recommendation of the Ministry of Agriculture, and irrigated by drip irrigation system to meet the field capacity of the crop for each treatment (liter/period) by using graduated cylinder. At the cultivate site, the meteorological data were recorded regularly to calculate the Et_o by modified penman equation (mm/day). In the same time, The TDR was used to measure water content after and before irrigation from 00-20, 20-40 and 40-60cm depths of the surface to calculate the water use from irrigation. A summation of water use from water table and water use from irrigation take as an actual evapotranspiration (Et_a). The treatments were arranged in a complete randomized plot design with three replicates and the results were statistically analyzed using F-value test and the means were compared by the L.S.D at the level of 5% probability. MSTATC was the computer program that used to calculate the obtained results and statistical analysis.

Results and Discution

Climatic conditions and reference evapotranspiration (Et_o)

Values of (Et_o) were fluctuated following the changes in the climatologically norms during the growth season as shown in Table 3. Generally, they increased at the end of the growth season at the period (09 Apr. to 15 May, 2010). This finding is mainly due to the relatively high temperature, average of wind (km/d), the gradually increase of sun shine and the low relative humidity at the end of the season. These results confirmed with the findings of Abo-Hadid *et al.* (1988) and El-Naggar (1997).

TABLE 3. Weekly meteorological data and reference evapotranspiration (Et_o) in Faculty of Agriculture, Ain Shams University site during faba bean season of 2009-2010.

Period	Air Temp C°			Ave. Rh %	Ave. Wind (km/d)	Sun Shine (h)	Et_o mm/day
	Max.	Min.	Ave.				
21 Nov. - 28 Nov.	23.0	10.7	16.9	71.1	157.7	10.3	2.8
29 Nov. - 05 Dec.	22.3	11.1	16.7	75.1	147.4	10.2	2.2
06 Dec. - 12 Dec.	21.4	10.4	15.9	61.1	229.7	10.1	2.7
13 Dec. - 19 Dec.	20.3	10.1	15.2	64.0	267.4	10.0	3.0
20 Dec. - 26 Dec.	22.6	10.9	16.7	57.3	435.4	10.0	4.0
27 Dec. - 02 Jan.	20.7	8.4	14.6	76.1	157.7	10.0	2.0
03 Jan. - 09 Jan.	18.5	9.8	14.2	66.9	186.1	10.1	2.4
10 Jan. - 16 Jan.	19.6	10.0	14.8	56.6	154.3	10.1	2.2
17 Jan. - 23 Jan.	21.0	11.3	16.1	55.4	174.9	10.2	2.9
24 Jan. - 30 Jan.	20.6	12.6	16.6	49.9	212.6	10.3	2.8
31 Jan. - 06 Feb.	20.1	12.7	16.4	43.6	260.6	10.4	4.0
07 Feb. - 13 Feb.	23.9	11.9	17.9	49.4	168.0	10.6	3.2
14 Feb. - 20 Feb.	21.4	13.4	17.4	42.3	346.3	10.8	5.1
21 Feb. - 27 Feb.	19.3	11.6	15.4	47.3	305.1	11.0	4.3
28 Feb. - 06 Mar.	19.1	11.0	15.1	48.0	329.1	11.2	4.2
07 Mar. - 13 Mar.	25.4	14.4	19.9	37.6	246.9	11.4	5.7
14 Mar. - 20 Mar.	25.4	14.4	19.9	37.6	246.9	11.4	4.6
21 Mar. - 27 Mar.	21.3	10.9	16.1	52.4	253.7	11.9	4.6
28 Mar. - 03 Apr.	22.0	12.3	17.1	47.3	264.0	12.1	5.1
04 Apr. - 10 Apr.	26.6	14.9	20.7	51.9	164.6	12.3	5.1
11 Apr. - 17 Apr.	26.0	15.6	20.8	50.3	243.4	12.6	5.6
18 Apr. - 24 Apr.	28.4	16.3	22.4	45.9	298.3	12.8	6.8
25 Apr. - 01 May.	28.4	16.7	22.6	50.3	318.3	13.0	7.4
02 Apr. - 08 May.	27.9	16.9	22.4	46.1	336.0	13.2	7.0
09 Apr. - 15 May.	26.4	14.0	20.2	48.6	356.6	13.4	7.8

Water use from water table

The water use from WT showed that, the highest WT contribution was under the shallowest water table, which gradually reduced with increasing water table depth (Fig.1). This result is confirmed with (Kahlown *et al.,* 2005).

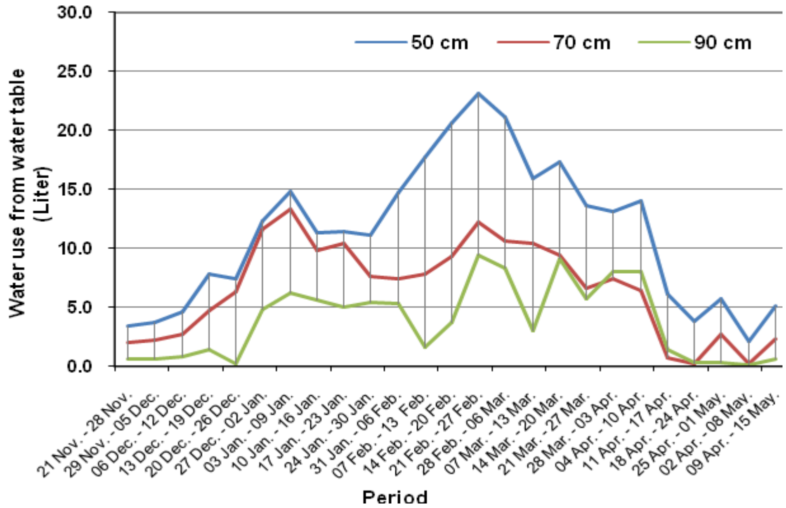

Fig. 1 . Water use from water table (liter/period) for Faba Bean crop under different WT levels.

Water use from irrigation water

The irrigation requirements are minimum at 50 cm WT and increase with increasing the water table depth to meet the field capacity of the soil (Fig.2). This is mainly due to the fact that, water table contributions are higher with decreasing WT depth, which consequently reduces the irrigation requirements. These results are consistent with the finding of Kahlown *et al.* (2005).

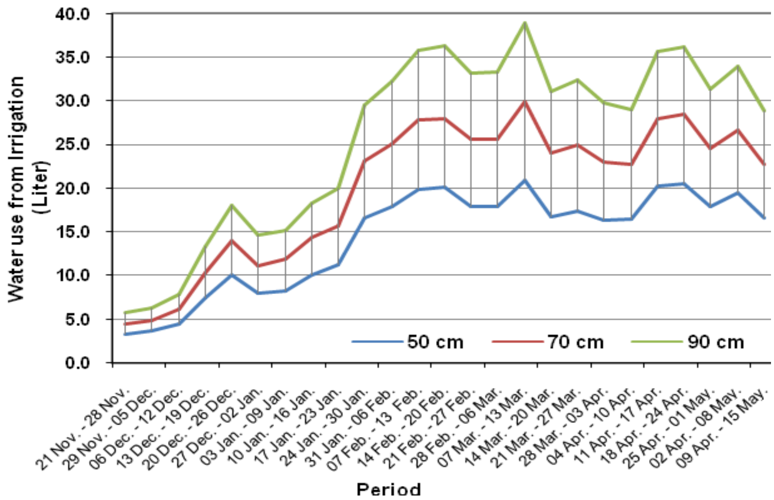

Fig. 2. Water use from irrigation water (liter/period) for Faba Bean crop under different WT levels.

Actual evapotranspiration (Et_a)

It is clear to notice that the trend of (Et_a) for the three WT levelis is varied from period to another depending on the change in climatic conditions (air temperature, relative humidity and solar radiation) and plant growth stage (Fig. 3). Generally, the values at the initial stage are low, because the growth of the plants is still small and it doesn't cover most of soil surface, so most of irrigation water evaporated from the soil surface only. The evaporation represents 90% of the consumptive use in this stage (Allen *et al.,* 1998). Values of Et_a increase at the late stage where the plants are developed and reach their maximum peak at April and May because the plants in this stage reach their maximum height, leaf area, number of leaves and number of branches. Then Et_a values decline as the crop becomes mature this is mainly due to the fall down of most leaves of the plants which cause reduction of water transpiration. This trend is in agreement the results obtained by Doorenbous and Pruitt (1984) and El-Nagar (1997). On the other hand, the variation in the climatic conditions during the season affects either the transpiration or the duration of the total growing period and the various growth stages during the growth season. In a cool climate a certain crop will grow slower than in a warm climate.

Effect of water table levels on actual evapotranspiration (Et_a)

The obtained results of Et_a (Fig.3) show that, there is no high difference in Et_a values between the levels of WT. It slightly increases with increasing water table depth. The highest Et_a value is obtained at 90 cm WT depth, where the water table is supplying little water and the crop depends basically on the water irrigation requirements. This result probably is due to that, the crop was irrigated more frequently. Consequently, a wet surface evaporates water rapidly and a high consumption of water by crop because of an overestimation of water transpired by the crop. These due to that, under high soil water conditions the water used by the crop exceeds the need of the crop itself ('luxury consumption'). These finding agrees with that obtained by Kahlown *et al.* (2005) and Cosentino *et al.* (2007). Comparatively with WT levels (50 and 70 cm WT), the evaporation from the soil surface decreases slightly and ET deceases consequently. Concerning the trend of slightly higher ET from 50 cm to 70 cm water tables, may be due to the highly development of vegetative growth of faba bean plants under 70 cm WT treatment which reflects their high transpiration and consumptive use of water.

Crop coefficient (K_c) of faba bean plant

One should bear in mind, that the values of K_c are a result of dividing the weekly value of (Et_a) under different WT levels by the value of the weekly reference evapotranspiration (Et_o) calculated by modified penman equation as shown in Fig.4. The expected values of K_c would follow the same behavior of Et_a accordance for the different WT. It varies with crop characteristics and with only limit extent with climate. It generally, are low in the initial stage of the plant, and then increases as the plant age progressed to reach their maximum in the mid-season, then decreases again in the end stage of the growth under the three levels of water table.

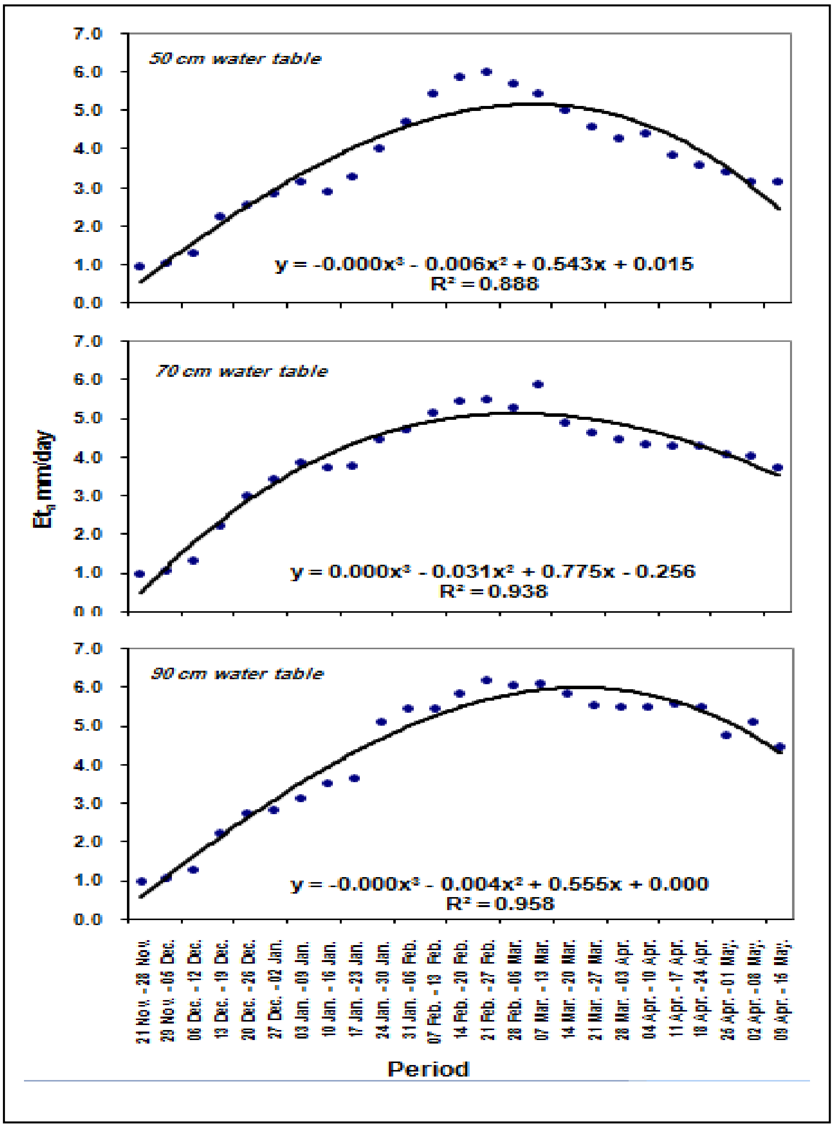

Fig. 3. Actual evapotranspiration (Et_a) for Faba Bean crop under different levels of WT.

Effect of water table levels on the (K_c) values

The values of K_c for faba bean are increased with increasing water table depth (Fig.4). On the other hand, the highest values of K_c are observed at the level of 90 cm water table followed by 70 cm and the lowest ones are found at 50 cm WT level. These results may be due to the increase of actual evapotraspiration with increasing water table level which reflects on the values of crop coefficient. Whereas, the maximum rates of water consumed were found at 90 cm water table levels followed by 70 cm and 50 cm, respectively. These results are in agreement with the findings of Sammis *et al. (*1982) and El-Naggar (1997). In other words, the crop coefficient values are highly affected by soil water stress, where the values of crop coefficient are decreased with increasing soil water stress. These are mainly due to the effect of soil water stress on plant physiological state.

Considering is the effect of plant growth stages on crop coefficient, data illustrated in Fig. 4 represent the third order polynomial regression equations and the coefficients of determination (R^2) to describe the relation between the values of crop coefficient and different periods through the growth stage. It is observed that the obtained regression equations can be used to predict the crop coefficient values at any period of growth stage and in the regions having similar climatic conditions. Moreover, we can predict K_c values under different levels water table by using modified penman equation. In other words, these equations could be used in irrigation scheduling programs under the similar conditions.

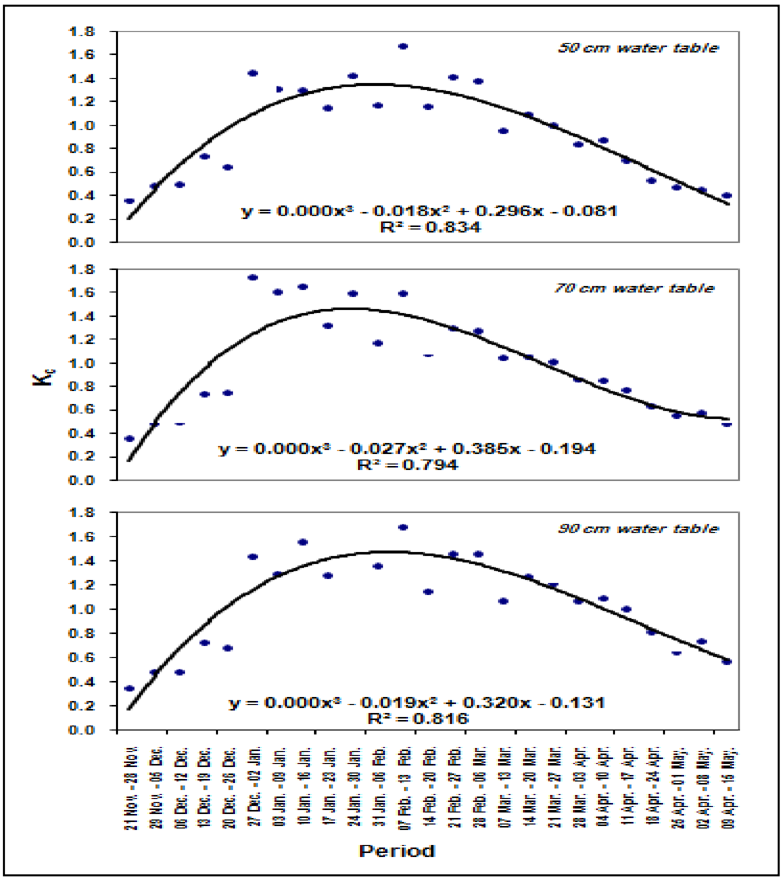

Fig. 4. Crop coefficient (K_c) for faba bean crop under different WT levels .

Data illustrated in Fig. 5 show that, there are significant differences in the grain yield of faba bean crop in the WT levels under studying. The highest value is found at 70 cm WT followed by 50 cm WT then 90cm WT. It is clear that supplying faba bean crop with adequate water accelerate the physiological processes and favors the mineral uptake and translocation of metabolizes, which in turn increases the total grain yield. As well as, increasing the water causes unsuitable conditions of aeration to the respiration of plant root. On the other hand, the insufficient water supply to a crop during critical stages of growth causes substantial yield loss. (Attia, 2013) reported that, pod development and seed filling stages were the most droughts sensitive. These results are agreed with Kamal *et al.* (2012) who indicated that Faba bean is more sensitive to drought than some other seed legumes and the physiological processes associated with drought tolerance are less understood than for other crop species .

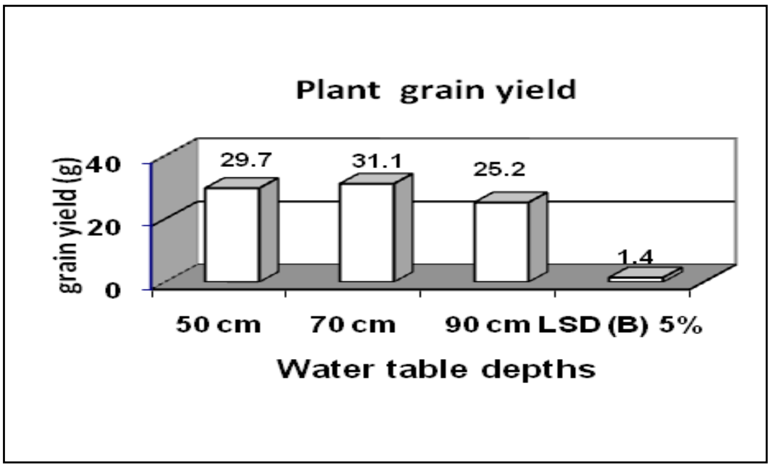

Fig. 5. Grain yield of faba bean crop under different water table levels treatments.

Water use efficiency (WUE) of faba bean crop

Efficient use of water is becoming increasingly important, and using a suitable amount of water may contribute substantially to the best use of water for crops and improving irrigation efficiency. This improving is attributed to consumption adequate and suitable amount of water to meet a high production. Data in Fig. 6 show a significant differences between the values of water use efficiency under different WT levels. The highest value of water use efficiency is obtained under 70 cm WT, while the lowest one are found at 90 cm WT level, while 50 cm WT is in between of them. The lowest value of WUE is considered at 90 cm WT, where the crop depends basically on the water irrigation requirements. Under high soil water conditions, the water used by the crop exceeds the need of the crop itself (‘luxury consumption’), but it doesn’t give the maximum yield. And this could explain the corresponding WUE. This result agrees with that obtained by Cosentino *et al.* (2007). However, the highest WUE at 70 cm WT may be due to that, crop consumed a little amount of water due to stomata which control plant gas exchange and transpiration water loss reduce their opening according to the available amount of water in the soil (Davies and Zhang, 1991 and Tardieu & Davies, 1993**).** On the other hand, 50 cm WT gives low WUE and this is probably due to the crop yield is reduced.

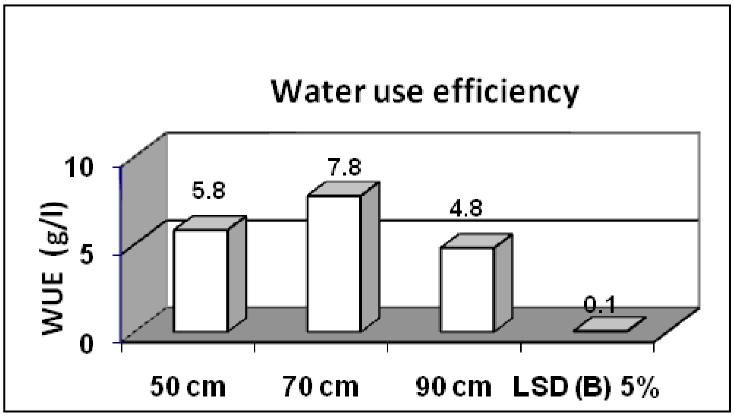

Fig. 6. Water use efficiency (WUE) of faba bean crop under different WT levels.

Water economy (WE) for of faba bean

The national aim in old or in new lands in Egypt is increasing the yield per unit of consumed water. Economy of water is used to evaluate the economy of irrigation practices for maximum utilization of water supplies. Data show a significant effect of contribution of WT levels on WE for crop (Fig.7). The highest value is obtained at 70 cm WT; this may be due to that, suitable amount of water added can gain a maximum grain yield automatically increases crop production per unit of water used.

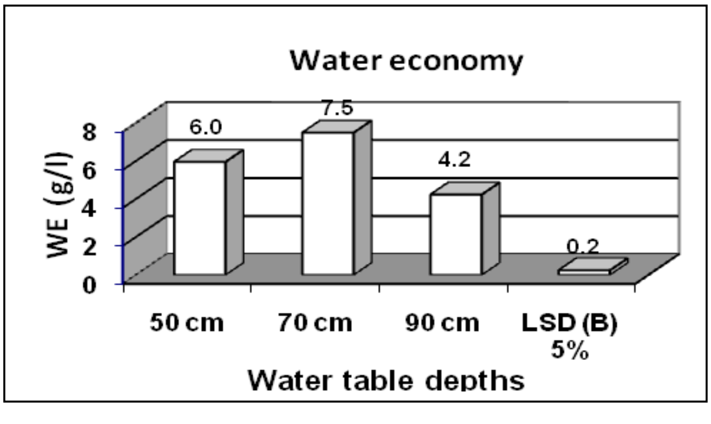

Fig. 7. Water economy (WE) of faba bean crop under different WT levels.

Conclusion

Water table contribution is a significant component of water balance and should be recognized as providing part of the water needed by the crop for evapotranspiration. This will save water and energy and will also reduce the drainage effluent and help to keep the water table at the desired depth**.**

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مدى مساهمة الماء الأرضى للأستهلاك المائى الفعلى لمحصول الفول البلدى

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أقيمت تجربة ليزومتر فى أرض رمليه طمييه لتقدير مدى مساهمة الماء الأرضى لسد احتياجات الفول البلدى من الماء. وقد تم توصيل اليزومتر بخزان يحتوى على نظام سيفون واتصل أيضا ببيزومتر للحفاظ على مستوى الماء الأرضى للمستوى المطلوب وهو 50 و70 و90 سم من سطح التربة . وقد أظهرت النتائج انه لم يكن هناك أختلاف كبير بين قيم الاستهلاك المائى لهذا المحصول تحت تأثير الثلاث مستويات من الماء الارضى. وكان هناك زياده طفيفه فى قيم الاستهلاك المائى مع زيادة عمق الماء الأرضى. وعلى الرغم من ذلك يمكن القول ان ظروف معاملة عمق 70 سم من الماء الأرضى كانت أكثر ملائمة واكثر مساهمه لسد احتياجات الفول البلدى من الماء. وقد أعطت هذه المعامله أعلى قيم بالنسبة لكفاءة أستخدام الماء وايضا لاقتصاديات المياه بالاضافة الى أعلى محصول حبوب مقارنة بالمستويات الاخرى سواء أعلى مستوى ماء أرضى 50 سم أو أقل مستوى ماء أرضى 90 سم التى يعتمد عندها المحصول نسبيا على ماء الرى.