**Journal of Soil Sciences and Agricultural Engineering**

**Journal homepage: www.jssae.mans.edu.eg**
**Available online at: www.jssae.journals.ekb.eg**

# Effect of Water Regimes and Polyvinyl Alcohol on Faba Bean Yield, Chemical Composition and Water Use Efficiency

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## ABSTRACT

Quantifying local crop response to irrigation is important for establishing proper irrigation management approaches.To apply that, a field experiment was carried out to evaluate the effect of three available soil moisture depletion(ASMD) levels, 25 %, 50 %, and 75% applied using solid set sprinkler irrigation system in combination with four concentrations (0.00%, 0.05%, 0.1% and 0.2 %)of poly vinyl alcohol soil conditioner. The combined effect of water regimes and different concentrations of soil conditioner was studied on faba bean (*Vicia faba* cv Giza 843), The experiment was carried out in the semiarid climate of northeast Farm of El-Ismailia Agricultural Research Station, El-Ismailia Governorate Egypt during two successive seasons(2012/2013 and 2013/2014).Evapotranspiration ($ET_a$), yield productivity of faba bean, water use efficiency and macronutrients uptake were also evaluated. Results showed that the actual seasonal crop evapotranspiration ($ET_a$) for ASMD treatments varied between (1605.36 –2482.45$m^3$ $fed^{-1}$.) in the first season (2012/2013) and (1439.26 – 2457.01$m^3$ $fed^{-1}$.) in the second season (2013/2014). There are three options to calculate seasonal $ET_c$ for faba bean crop in Ismailia condition. So, it can be use FAO-24RD, PMd or Droogers and Allen (2002)methods. Moreover,obtained data reveal that application of polyvinyl alcohol(PVA)synthetic soil conditioners (with high concentration), decreased available soil moisture depletion (ASMD) in sandy soil and caused a significant increase in faba bean yield, water use efficiency (WUE) and improved the macronutrient uptake by faba bean yield. Finally, the results clearly showed that the significant effect of PVA at (0.1or 0.2 %) concentration was most observed at 50% ASMD.

***Keywords:*** irrigation regime, ASMD, polyvinyl alcohol (PVA), faba bean, sandy soil.

## INTRODUCTION

Irrigation is one of the most important inputs in agricultural practices for all crops cultivation to increase crop productivity. Crop water management and crop yield in different environments are very important concern in irrigation planning. This is considered important for irrigation policy makers and for farmers to maximize crop yield.

Furthermore, faba bean is considered the most important winter legume crop in Egypt. Seed of faba bean contain high protein percent (28%) which gave the crop great importance as a cheap protein source for human consumption. Also, faba bean crop has an important role in improving soil characteristics after harvesting. This is mainly because it increases soil fertility due to nitrogen fixation by root nodules leaving about 20-25 units of N/fed. This is usually beneficial for the next cultivated crop. So, water stress significantly decreases faba bean seed yield (Ahmed *et al.* ,2000 and Atta *et al.* , 2002). Al-Naeem (2008) added that faba bean yield and its components were reduced with increasing the depletion percent of available soil water. Ghassemi-Golezani *et al*. (2009) investigated the effects of different irrigation regimes on growth and grain yield for three faba bean cultivars. The results revealed that water limitation reduced grains per plant, grain filling duration, and grain weight. Consequently, grain yield per unit area under limited irrigation was considerably lowered than that under well-watering. Al-Suhaibani (2009) added that influences of drought at the lowest level of applied water which was less than 4000 $m^3$/ha severely retards faba bean seed yield, whereas water supply at 7000 $m^3$/ha could be conserved for growing faba bean under arid environment of Saudi Arabia. Moreover, Mohammad (2014) showed that water stress at 75% available water depletion significantly decreased plant height and seed yield $ha^{-1}$,while it increased seed protein content of faba bean. El-Harty (2015) showed that drought had pronounced negative effects on yield and its components for all faba bean yield characters. El-Harty, (2016) identified a decrease in Faba bean traits with water deficit except WUE which was highest under moderate stress.

Later on, El-Gindy *et al*. (2003) concluded that faba bean seed yield increased gradually as water requirements increased from 50% to 125% of ETc. Rizk and Sherif (2014) showed that faba bean seasonal consumptive use increased by decreasing available soil moisture depletion (ASMD).

On the other hand, soil conditioners such as superabsorbent polymer (SAP) have a great possibility to enhance the water use efficiency in crops. Hydrogel is increasingly being seen as a potential technology for enhancing the water and nutrient use efficiencies in plants, creating a pleasant and nourishing rhizospheric micro-environment for better plant growth and yield. Such polymeric substances also improve the soil physical properties, water holding volume, permeability and permeation; especially in structure-less and drought affected soils. Poly vinyl alcohol (PVA) has been widely used as

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**DOI: 10.21608/jssae.2020.160915**

hydrogel precursor through co-polymerization with other polymer compounds, due to its hydrophilic character. PVA is a synthetic polymer which is soluble in water because of its hydroxyl groups and can be absorb large volume of water, thus is a potential water retention material that increases plant growth (Chiellini *et al*., 2003 and Chandrika *et al*., 2014). Kukal *et al.* (2007) observed that very low concentration (0.1% PVA) significantly increases the aggregate stability. Hossein Nazarli *et al.* (2010) suggested that application of polymers could be advantageous against drought stress and could protect plants in drought stress conditions. In this way, it has the ability to increase the efficiency of water use and to overcome drought events by reducing water stress.

Recently, Jiang *et al.* (2016) and Yin *et al.* (2016) indicated that poly vinyl alcohol (PVA) could effectively enhance the water retention capacity of sandy soil and the plant growth. Abobatta (2018) and Özen *et al.*, (2019) indicated that high molecular weight PVA can improve soil characters, can increase nutrient use efficiency, and can help in the management of irrigation to reduce water consumption and conservation.

From the previously stated information, the goal of this experiment is to evaluate the effect of irrigation regime using different levels of available soil moisture depleted (ASMD) in combination with synthetic soil conditioners (PVA) on faba bean yield, macronutrients total content along with water use efficiency under the climatic conditions of Ismailia Governorate.

## MATERIALS AND METHODS

The present investigation was carried out at the farm of Ismailia Agricultural Research Station in Ismailia Governorate, Egypt, during the two winter seasons (2012/2013) and (2013/2014). The research farm is located at 30 35, 41.9" N latitude and 32 16 45.8" E longitude. Some physical and chemical characteristics of the experimental soil sites were determined according to Jackson (1973) and Klute (1986) the results are presented in Tables (1-2).

**Table 1. Physical analysis and moisture constants of the investigated soil.**

| Soil depth cm | Particle size distribution | | | | Texture | Bulk density g/cm3 | Retained moisture at field capacity,v /v | | Retained moisture at permanent wilting point ,v/v | | Available moisture mm/soil depth | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coarse sand% | Fine sand % | Silt % | Clay % | | | % | mm/15cm | % | mm/15cm | % | mm/15cm |
| 0-15 | 68.42 | 25.86 | 3.77 | 1.95 | Sandy | 1.66 | 12.21 | 18.32 | 2.24 | 3.36 | 9.97 | 14.96 |
| 15-30 | 73.85 | 21.86 | 2.94 | 1.35 | Sandy | 1.64 | 10.92 | 16.38 | 1.98 | 2.98 | 8.94 | 13.40 |
| 15-30 | 75.45 | 21.01 | 2.87 | 0.67 | Sandy | 1.66 | 10.25 | 15.38 | 2.52 | 3.78 | 7.73 | 11.60 |
| 45-60 | 87.74 | 8.36 | 3.5 | 0.40 | Sandy | 1.67 | 7.97 | 11.95 | 2.61 | 3.91 | 5.36 | 8.04 |
| Total | | | | | | | | | | | | 48.00 |

**Table 2. Chemical analysis of the investigated soil.**

| Parameters | Values | Parameters | Values |
|---|---|---|---|
| pH(1.2.5 soil water susp). | 8.12 | OM % | 0.23 |
| EC dS $m^{-1}$ | 0.50 | $CaCO_3$ % | 0.53 |
| Soluble anions in soil paste extract (meq $L^{-1}$) | | Soluble cations in soil paste extract (meq $L^{-1}$) | |
| $CO^{-2}$ | - | $Ca^{+2}$ | 1.20 |
| $HCO_3$ | 1.50 | $Mg^{+2}$ | 0.50 |
| $Cl^-$ | 2.01 | $Na^+$ | 2.80 |
| $SO_4$ | 1.20 | $K^+$ | 0.21 |
| Macronutrients in soil | | | |
| Total N % | 0.06 | Total P % | 0.04 |
| Available N (mg $Kg^{-1}$) | 21.6 | Available P mg $kg^{-1}$ | 2.85 |

The main objective of this study was to determine the effect of irrigation regime and applied polyvinyl alcohol (PVA) as hydrophilic soil conditioner with different concentrations on faba bean crop yield and nutrients total content as well as to study some plant water relationships.

**Climatic condition:**

The meteorological data ,air temperature ($C^o$), relative humidity (%), actual and possible sunshine (hour), solar and extraterrestrial radiation ($MJm^{-2}$ $day^{-1}$) and wind speed (m/sec) had been daily recorded (Table 3) at Ismailia Station , Egypt and their monthly mean values were calculated during the last ten years period .

**Table 3. The meteorological data of Ismailia Station during the last ten years period.**

| Month | Parameters | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $T_{max.}$ $^oC$ | $T_{min.}$ $^oC$ | $T_{mean}$ $^oC$ | $RH_{max.}$ % | $RH_{min.}$ % | $RH_{mean}$ % | W.S m/sec | N hour | N hour | Rs $MJm^{-2}$ $day^{-1}$ | Ra $MJm^{-2}$ $day^{-1}$ |
| Nov | 25.9 | 13.6 | 19.4 | 78.5 | 36.9 | 57.7 | 2.17 | 8.80 | 10.43 | 14.67 | 21.83 |
| Dec | 22.0 | 9.8 | 15.4 | 73.30 | 38.5 | 55.4 | 2.37 | 7.30 | 10.03 | 11.89 | 19.37 |
| Jan | 20.0 | 8.1 | 13.60 | 78.5 | 31.9 | 55.20 | 2.56 | 7.60 | 10.23 | 12.86 | 20.7 |
| Feb | 21.4 | 9.3 | 15.10 | 70.60 | 30.8 | 50.70 | 2.91 | 8.30 | 10.97 | 16.02 | 25.5 |
| Mar | 24.4 | 11.4 | 17.7 | 66.5 | 26.5 | 46.5 | 3.23 | 9.1 | 11.8 | 19.83 | 31.2 |
| Apr | 28.4 | 14.2 | 21.0 | 61.4 | 21.8 | 41.6 | 3.23 | 10.20 | 12.73 | 23.87 | 36.7 |

**Irrigation system:**

The experiment was irrigated by a solid set triangle sprinkler system. The laterals were spaced 12 m apart. The sprinklers were spaced 10 meters lateral. Each two laterals and sprinklers have a control valve to adjust the quantity of applied water. The rate of water application was 45.5 $m^3$ $fed^{-1}$/hr (sprinkler discharge 1.3 $m^3$/ hr at 2.5 bar ). The quantity of applied water was exactly controlled with excellent uniform distribution of water. The number of sprinkler per fed. was 35. The application rate (A) is calculated as follows:-

$$A = K\frac{Qs}{LS}$$

**Where:**

**A= Application rate [mm/hr], Qs = Discharge of sprinkler [L/min], L= The distance between lateral [m], S= The distance between sprinklers on lateral [m], K= Fraction equal 60**

**Experimental layout:**

Faba bean (*Vicia faba*, cv. Giza 843) was cultivated at 25/11/2012 and 27/11/2013 for the first and second seasons, respectively. The seeds were placed in holes 25 cm. apart on rows 300 cm long and 60 cm between the rows. All cultural practices were the same as recommended. Mineral fertilizers, also, were applied at recommend dose; superphosphate (15 %$P_2O_5$) at rate of 200 kg $fed^{-1}$ and half does of potassium sulfate (50Kg $K_2O$) were applied before cultivation. Nitrogen fertilizer as ammonium nitrate (33%) at rate of 100kg $fed^{-1}$ and second dose of potassium were added to soil after 35 day of sowing date. The irrigation treatments applied at end of initial stage. Also, the different concentrations (0.0, 0.05, 0.1and 0.2%) of polyvinyl alcohol (PVA) were applied before cultivation. The harvest dates of faba bean were 14/4/2013 and 20/4/2014 for first and second seasons, respectively.

The experiment was carried out in split plot design with three replicates. The main plot was assigned to irrigation treatments while the sub plots to polyvinyl alcohol soil conditioner concentration. Each plot was 3.5m in length and 3.0 m in width.

**The main plots consisted of:**

Irrigation treatments: Irrigation practiced included three treatments, 25%, 50% and 75% of available soil moisture depletion (ASMD).

**The subplots consisted of:**

Polyvinyl alcohol soil conditioner included four concentrations (C0=zero %., C1=0.05 %., C2=0.1 %. and C3=0.2 %) were applied before the soil tillage.

**Water management:**

The water management required at the field level determine by the depth and the interval of irrigation. The required net application depth per irrigation taken to be a function of a management allowed deficit (percent), the soil water-holding capacity (v/v divided by 100), and the crop root depth (mm). whereas, the interval of irrigation the net application depth per irrigation and crop evapotranspiration, $ET_c$ .Faba bean evapotranspiration ($ET_C$) calculated by multiplying the Potential evapotranspiration ($ET_o$) and adjusted faba bean crop coefficient (Kc) according to the Penman Monteith daily ($PM_d$) equation (Allen *et al*., 1998).

**The studied characters:**

**1- Water relations:**

**Calculation of water consumptive use (Cu) or actual evapotranspiration ($ET_a$):**

Water consumptive use (Cu) was determined according to the equation given by Israelsen and Hansen ( 1962) as follow:

$$WCU = \sum_{i=1}^{n=4} \frac{(\theta_2 - \theta_1)}{100} X\ Bd\ X\ D$$

**Where:**

**WCU = Water consumptive use [mm],**
**D = depth of soil layer (15mm each) [mm],**
**Bd = Soil bulk density [g /$cm^3$],**
**$e_1$= Soil moisture content before irrigation, [w/w],**
**$e_2$ = soil moisture content after irrigation, [w/w].**
**n = number of soil layer.**

**Reference evapotranspiration ($ET_o$) :** The ETo alculated using five methods. These are: FAO form of radiation method (24RD) given by Jensen *et al.* (1990), modified Penman- Montieth method (PMd) presented by Allen *et al.* (1998), the Droogers and Allen (2002), Valiantzas (2006) and Tabari *et al*.(2013)

**Crop Coefficient (Kc):**

Five different approaches are used to estimation of kc values for faba bean by from actual evapotranspiration ($ET_a$) values and reference evapotranspiration ($ET_o$) values calculated as follows: -.

$$Kc = ET_a / ET_o$$

**Kc: crop coefficient**
**ETa: crop evapotranspiration (mm $day^{-1}$)**
**$ET_o$: reference crop evapotranspiration (mm $day^{-1}$)**

**Water use efficiency:**

Water use efficiency (WUE) in $kg/m^3$ was calculated for the deferent treatments, using the following formulae of Vites (1965):

$$W.U.E = \frac{\text{Seed yield in kg / fed}}{\text{Actual evapotranspiration in } m^3\ fed^{-1}}$$

**2- Yield and yield chemical compositions:**

Faba been yield (straw and seeds) for both first and second seasons were collected from each plot, samples were weighed and oven dried at 70°C for 48 h up to a constant dry weight, ground and prepared for digestion as described by Page *et al.* (1982). The digests was then subjected to the determination of nutrients (N, P and K) according to Procedures described by (Cottenie *et al*., 1982).

Total uptake of N/P/K was calculated separately by the following formula:

$$\text{Uptake of N/P/K(kg } fad^{-1}) = \frac{N\%\ P\%K\%\ x \text{ dry matter (kg } fad^{-1})}{100}$$

**Soil analysis:**

Particle size distribution was conducted using the pipette method according to Klute (1986). Soil moisture constants were determined using the pressure membrane apparatus (Stackman 1966). Soil pH, electric conductivity (EC) and cationic and anionic compositions of the saturation extract of the soil were determined according to the standard methods described by Jackson (1973).

**3- Statistical analysis:**

All the data collected for the yield, water use efficiency and chemical composition were subjected to the statistical analysis according to Snedecor and Cochran (1980) and the mean values were compared by LSD.

## RESULTS AND DISCUSSION

**Water relations of faba bean crop:**

**Faba bean actual evaopotranspiration ($ET_a$) affected by different water regimes and poly vinyl alcohol concentrations as soil condition.**

Results in Table 4-5 and Figs.1 indicated that increasing available soil moisture depletion from 25% to 50% reduced actual evapotranspiration, ($ET_a$) by 14.75% and 16.02% during first and second season, respectively. On the other hand, 50% depletion treatment increased actual evapotranspiration by 31.82% and 43.35% compared to 75% depletion treatment in the first and second season, respectively. Results clearly indicated that water consumption by faba bean plants was higher in first season than in the second one. Such trend is mainly due to the differences in climatic conditions and sowing date between both seasons of study. Similar conclusion was reached by Mohammad (2014), Moursi *et al.* (2014) and Jabow *et al.* (2015). Appropriate frequency of irrigation can be

determined from the available soil moisture retaining capacity and the rate of faba bean evapotranspiration taking into consideration that it better replenish the soil moisture when about 50% of the total available soil water is exhausted (Allen *et al*.,1998)

With respect to, the effect of applied different concentrations (0.2, 0.1, 0.05 and zero %) of polyvinyl alcohol as soil conditioner on total mean actual faba bean evapotranspiration ($ET_a$) results illustrated in Table 3& Table 4 and Figure1. Mean values of total $ET_a$ for PVA concentration 0.2% treatment were 456.67 and 437.82 mm in first and second seasons, respectively. These values increased to 480.39 and 465.47 mm, 505.17 and 486.04 mm as result of applied 0.1 and 0.05 % concentration PVA in first and second seasons, respectively. Hence, the average increased in $ET_a$ compared to zero concentration PVA treatment reached 527.18 and 502.39 mm in first and second season, respectively. These results were in agreement with those obtained by Jiang *et al.* (2016), Yin *et al*. (2016) and Abobatta (2018) who observed that the density of chain cross linking creates an expressive amount of free volume between the polymer network. This in turn, combined to the presence of huge number of hydrophilic groups, has the ability of water absorption and retention for large amounts of water, on the order of 10 to 1000 g/g (1.000-100.000%). Hydrogel polymers may be used to increase the efficiencies of water and fertilizers use.

**Table 4. faba bean daily, monthly and total actual evapotranspiration ($ET_a$) affected by soil moisture depletion treatments and poly vinyl alcohol levels in seasons2012/2013.**

| months | | Nov.* | | Dec. | | Jan. | | Feb. | | Mar. | | Apr.** | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Irr. | PVA | Daily | monthly | Daily | monthly | Daily | monthly | Daily | monthly | Daily | monthly | Daily | monthly | | |
| Treat. | level | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | $m^3$/f. |
| | 0.2% | 2.74 | 13.7 | 2.60 | 80.72 | 3.70 | 114.70 | 5.32 | 148.96 | 5.31 | 164.61 | 1.35 | 18.90 | 541.59 | 2274.69 |
| 25% | 0.1% | 2.74 | 13.7 | 2.75 | 85.19 | 4.00 | 124.00 | 5.66 | 158.48 | 5.59 | 173.29 | 1.45 | 20.30 | 574.96 | 2414.82 |
| A.S.M..D | 0.05% | 2.74 | 13.7 | 2.83 | 87.79 | 4.37 | 135.47 | 5.97 | 167.16 | 5.97 | 185.07 | 1.5 | 21.00 | 610.19 | 2562.80 |
| | Zero% | 2.74 | 13.7 | 2.92 | 90.39 | 4.55 | 141.05 | 6.28 | 175.84 | 6.23 | 193.13 | 1.67 | 23.38 | 637.49 | 2677.48 |
| mean | | 2.74 | 13.7 | 2.77 | 86.02 | 4.15 | 128.80 | 5.81 | 162.61 | 5.77 | 179.02 | 1.49 | 20.90 | 591.06 | 2482.45 |
| | 0.2% | 2.74 | 13.7 | 2.62 | 81.32 | 2.71 | 84.01 | 4.82 | 134.90 | 4.39 | 136.09 | 1.26 | 17.64 | 467.67 | 1964.23 |
| 50% | 0.1% | 2.74 | 13.7 | 2.67 | 82.86 | 2.92 | 90.52 | 5.08 | 142.39 | 4.63 | 143.65 | 1.31 | 18.34 | 491.47 | 2064.19 |
| A.S.M..D | 0.05% | 2.74 | 13.7 | 2.77 | 85.93 | 3.05 | 94.55 | 5.37 | 150.30 | 4.89 | 151.64 | 1.49 | 20.86 | 516.98 | 2171.33 |
| | Zero% | 2.74 | 13.7 | 2.89 | 89.51 | 3.23 | 100.13 | 5.57 | 156.13 | 5.08 | 157.52 | 1.59 | 22.26 | 539.25 | 2264.87 |
| mean | | 2.74 | 13.7 | 2.74 | 84.90 | 2.98 | 92.30 | 5.21 | 145.93 | 4.75 | 147.23 | 1.41 | 19.77 | 503.84 | 2116.15 |
| | 0.2% | 2.74 | 13.7 | 2.31 | 71.61 | 2.36 | 73.16 | 3.42 | 95.76 | 2.87 | 89.05 | 1.25 | 17.5 | 360.78 | 1515.28 |
| 75% | 0.1% | 2.74 | 13.7 | 2.37 | 73.65 | 2.39 | 74.09 | 3.63 | 101.59 | 3.02 | 93.67 | 1.31 | 18.34 | 375.05 | 1575.20 |
| A.S.M..D | 0.05% | 2.74 | 13.7 | 2.46 | 76.21 | 2.47 | 76.57 | 3.73 | 104.50 | 3.13 | 97.03 | 1.45 | 20.3 | 388.32 | 1630.94 |
| | Zero% | 2.74 | 13.7 | 2.49 | 77.23 | 2.53 | 78.43 | 3.81 | 106.58 | 3.45 | 107.11 | 1.55 | 21.7 | 404.76 | 1700.07 |
| mean | | 2.74 | 13.7 | 2.41 | 74.68 | 2.43 | 75.56 | 3.64 | 102.11 | 3.12 | 96.71 | 1.39 | 19.46 | 382.23 | 1605.36 |
| | 0.2% | 2.74 | 13.7 | 2.51 | 77.89 | 2.92 | 90.613 | 4.52 | 126.54 | 4.19 | 129.91 | 1.29 | 18.0 | 456.67 | 1918.02 |
| Mean overall of PVA | 0.1% | 2.74 | 13.7 | 2.60 | 80.57 | 3.10 | 96.1 | 4.79 | 134.15 | 4.41 | 136.87 | 1.36 | 18.99 | 480.39 | 2017.63 |
| | 0.05% | 2.74 | 13.7 | 2.68 | 83.31 | 3.30 | 102.207 | 5.02 | 140.65 | 4.66 | 144.58 | 1.48 | 20.72 | 505.17 | 2121.73 |
| | Zero% | 2.74 | 13.7 | 2.76 | 85.71 | 3.44 | 106.547 | 5.22 | 146.18 | 4.92 | 152.59 | 1.60 | 22.45 | 527.18 | 2214.14 |

***Sowing dates at first was 25/11/2012 ** Harvest date was 14/4/2013**

**Table 5. faba bean daily, monthly and total actual evapotranspiration ($ET_a$) affected by soil moisture depletion treatments and poly vinyl alcohol levels in seasons2013/2014.**

| Months | | November* | | December | | January | | February | | March | | April** | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Irr.treat. | PVA level | daily | monthly | daily | monthly | daily | monthly | daily | monthly | daily | monthly | daily | monthly | | |
| | | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | $m^3$/f./ |
| | 0.2% | 2.46 | 7.38 | 2.28 | 70.587 | 3.63 | 112.53 | 4.99 | 139.65 | 5.69 | 176.29 | 1.49 | 23.84 | 530.28 | 2227.19 |
| 25% | 0.1% | 2.46 | 7.38 | 2.42 | 75.02 | 3.93 | 121.83 | 5.55 | 155.526 | 6.04 | 187.21 | 1.55 | 24.80 | 571.76 | 2401.41 |
| A.S.M..D | 0.05% | 2.46 | 7.38 | 2.52 | 78.089 | 4.26 | 132.06 | 5.93 | 166.11 | 6.31 | 195.73 | 1.60 | 25.60 | 604.97 | 2540.89 |
| | Zero% | 2.46 | 7.38 | 2.68 | 83.204 | 4.62 | 143.22 | 6.15 | 172.28 | 6.47 | 200.51 | 1.65 | 26.40 | 632.99 | 2658.58 |
| mean | | 2.46 | 7.38 | 2.47 | 76.72 | 4.11 | 127.41 | 5.66 | 158.39 | 6.13 | 189.94 | 1.57 | 25.16 | 585.00 | 2457.01 |
| | 0.2% | 2.46 | 7.38 | 2.22 | 68.69 | 2.95 | 91.45 | 4.09 | 114.59 | 5.04 | 156.24 | 1.40 | 22.40 | 460.74 | 1935.13 |
| 50% | 0.1% | 2.46 | 7.38 | 2.37 | 73.51 | 2.95 | 91.45 | 4.37 | 122.43 | 5.40 | 167.40 | 1.44 | 23.04 | 485.22 | 2037.92 |
| A.S.M..D | 0.05% | 2.46 | 7.38 | 2.49 | 77.27 | 3.03 | 93.93 | 4.62 | 129.25 | 5.58 | 172.98 | 1.47 | 23.52 | 504.33 | 2118.21 |
| | Zero% | 2.46 | 7.38 | 2.53 | 78.34 | 3.13 | 97.03 | 4.63 | 129.59 | 5.71 | 177.07 | 1.58 | 25.28 | 514.70 | 2161.75 |
| mean | | 2.46 | 7.38 | 2.40 | 74.45 | 3.01 | 93.46 | 4.43 | 123.97 | 5.4 | 168.42 | 1.47 | 23.56 | 491.25 | 2063.25 |
| | 0.2% | 2.46 | 7.38 | 2.02 | 62.78 | 2.02 | 62.62 | 3.02 | 84.58 | 2.72 | 84.44 | 1.29 | 20.64 | 322.44 | 1354.27 |
| 75% | 0.1% | 2.46 | 7.38 | 2.09 | 64.93 | 2.17 | 67.27 | 3.18 | 89.01 | 2.88 | 89.28 | 1.35 | 21.60 | 339.47 | 1425.78 |
| A.S.M..D | 0.05% | 2.46 | 7.38 | 2.13 | 66.00 | 2.27 | 70.37 | 3.26 | 91.40 | 2.96 | 91.88 | 1.39 | 22.24 | 349.27 | 1466.96 |
| | Zero% | 2.46 | 7.38 | 2.15 | 66.54 | 2.41 | 74.71 | 3.30 | 92.42 | 3.05 | 94.49 | 1.50 | 24.00 | 359.54 | 1510.06 |
| mean | | 2.46 | 7.38 | 2.1 | 65.06 | 2.22 | 68.74 | 3.19 | 89.35 | 2.90 | 90.02 | 1.38 | 22.12 | 342.68 | 1439.26 |
| | 0.2% | 2.46 | 7.38 | 2.17 | 67.35 | 2.87 | 88.87 | 4.03 | 112.94 | 4.48 | 138.99 | 1.39 | 22.29 | 437.82 | 1838.86 |
| Mean overall of PVA | 0.1% | 2.46 | 7.38 | 2.29 | 71.15 | 3.02 | 93.52 | 4.37 | 122.32 | 4.773 | 147.96 | 1.45 | 23.14 | 465.47 | 1955.04 |
| | 0.05% | 2.46 | 7.38 | 2.38 | 73.79 | 3.19 | 98.79 | 4.60 | 128.92 | 4.95 | 153.53 | 1.48 | 23.63 | 486.04 | 2042.02 |
| | Zero% | 2.46 | 7.38 | 2.45 | 76.03 | 3.38 | 104.97 | 4.69 | 131.43 | 5.08 | 157.35 | 1.58 | 25.23 | 502.39 | 2110.13 |

***Sowing dates at second season was 27/11/2013 **Harvest was 16/4/2014**

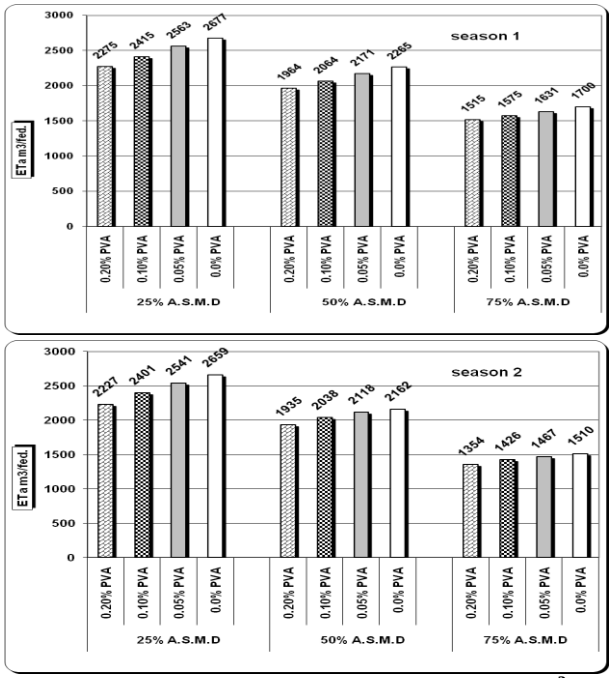


**Fig. 1. Total actual faba bean evapotranspiration ($m^3$ $fad^{-1}$) at different available soil moisture depletion levels and PVA concentration at the first season (2012/2013) and the second season (2013/2014)**

**Experimental crop coefficients ($k_c$)**

Monthly experimental crop coefficient values were obtained for the 50% ASMD treatment from $ET_a$ values and the $ET_o$ calculated using five methods. These are: FAO form of radiation method (24RD) given by Jensen *et al.* (1990), modified Penman- Montieth method (PMd) presented by Allen *et al.* (1998), the, Droogers and Allen (2002), Valiantzas (2006) and Tabari *et al.*(2013) are in (Table, 6).

The results showed that Kc values obtained from the FAO form of radiation method (24RD) and $PM_d$ were close to medium water deletion and, it's followed by Droogers and Allen (2002). Water consumptive use of faba bean at 50% ASMD was generally higher than those obtained from Valiantzas (2006) and Tabari *et al.* (2013). Obtained results may be due to an empirical equations having been developed to adequate different climate.The previous discussion we have three choices to calculated seasonal $ET_c$ of faba bean crop in Ismailia condition. So, we can use FAO -24RD, $PM_d$ or Droogers and Allen (2002) methods.

**Faba bean yield response to various available soil moisture depletion and polyvinyl alcohol concentrations treatments:**

Results presented in (Table 7) showed that faba bean yield (straw and seeds) were significantly affected by increasing ASMD from 25% to 75%.The maximum (straw and seed) yield was obtained at 25% ASMD treatment followed by 50% ASMD treatment. Consequently, the least yield was obtained at 75% ASMD treatment. These results indicate the importance of maintaining soil moisture at the highest level to maximize (straw and seed) yield. These results were in agreement with those reported by El-Gindy *et al.* (2003) and Al-Naeem (2008).

**Table 6. Estimation of $k_c$ values of faba bean as affected by different methods:-**

| Equation | $ET_a$ | FAO-(24RD) | | PMd | | Droogers and Allen | | Valintazs equ. | | Tabari equ. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | monthly | monthly | $K_c$ | monthly | Kc | monthly | Kc | monthly | Kc | monthly | Kc |
| Months | mm | mm | | mm | | mm | | mm | | mm | |
| **First season (2012/2013)** | | | | | | | | | | | |
| November* | 13.7 | 17.8 | 0.77 | 16.85 | 0.813 | 14.15 | 0.97 | 6.75 | 2.03 | 12.6 | 1.09 |
| December | 84.91 | 82.15 | 1.03 | 84.63 | 1.00 | 68.82 | 1.23 | 18.6 | 4.56 | 57.35 | 1.48 |
| January | 92.3 | 86.18 | 1.07 | 92.38 | 0.999 | 68.51 | 1.35 | 26.35 | 3.50 | 58.84 | 1.57 |
| February | 145.93 | 106.4 | 1.37 | 107.8 | 1.353 | 80.92 | 1.80 | 52.92 | 2.76 | 68.96 | 2.11 |
| March | 147.23 | 161.82 | 0.91 | 155.62 | 0.94 | 122.76 | 1.20 | 101.06 | 1.45 | 98.58 | 1.49 |
| April** | 19.78 | 96.6 | 0.20 | 90.86 | 0.22 | 74.62 | 0.26 | 66.22 | 0.30 | 55.58 | 0.35 |
| Average Kc | | | 0.89 | | 0.89 | | 1.13 | | 2.43 | | 1.35 |
| Second season (2013/2014) | | | | | | | | | | | |
| November* | 7.38 | 10.68 | 0.69 | 10.11 | 0.73 | 8.49 | 0.87 | 4.05 | 1.82 | 7.56 | 0.98 |
| December | 74.45 | 82.15 | 0.91 | 84.63 | 0.88 | 68.82 | 1.08 | 18.6 | 4.00 | 57.35 | 1.30 |
| January | 93.47 | 86.18 | 1.08 | 92.38 | 1.01 | 68.51 | 1.36 | 26.35 | 3.55 | 58.84 | 1.59 |
| February | 123.97 | 106.4 | 1.165 | 107.8 | 1.15 | 80.92 | 1.53 | 52.92 | 2.34 | 68.96 | 1.80 |
| March | 168.42 | 161.82 | 1.04 | 155.62 | 1.08 | 122.76 | 1.37 | 101.06 | 1.66 | 98.58 | 1.71 |
| April** | 23.56 | 110.4 | 0.21 | 103.84 | 0.23 | 85.28 | 0.27 | 75.68 | 0.31 | 63.52 | 0.37 |
| Average Kc | | | 0.85 | | 0.85 | | 1.08 | | 2.28 | | 1.29 |

***sowing dates at first and at second season were 25/11/2012 and 27/11/2013, respectively.**

****harvest dates at first and at second season were 14/4/2013 and 16/4/2014, respectively.**

Also, results in (Table, 7) show that the effect of various concentrations of polyvinyl alcohol soil conditioner on yield production. Faba bean straw and seed yields increased with increasing PVA level. Results reveal that significant effects for adding polyvinyl alcohol soil conditioner (PVA) on faba bean straw yield (ton fed.$^{-1}$) in both seasons. While, the effect of PVA concentration on faba bean seed (kg fed.$^{-1}$) was insignificant except when applied at 0.2% concentration, the effect was significant in first season. The difference between applied 0.1% and 0.2% concentration of PVA were insignificant, but, it had significant effect with applied 0.0 % and 0.05 % on faba bean seed kg fed$^{-1}$., in second season. These results are in agreement with those obtained by Kukal *et al.* (2007), Chandrika *et al.* (2014), Jiang *et al.* (2016) and Yin *et al.* (2016).

The interaction differences among different concentrations of PVA at various ASMD show a significant effect on faba bean straw yield in both seasons.

The interaction differences between the levels of PVA at 25% ASMD were insignificant, except when 0.2% concentration is used on Faba bean seed yield kg/fad. There was observed statistically significant difference at irrigation

level 50% ASMD between 0.2%, concentration and each of 0.1%, 0.05% and zero% concentrations. However, no significant difference was observed between 0.2% and 0.1%. Similarly, no significant difference was observed between 0.1%, 0.05% and zero%. At irrigation level 75%, no statistical significance was observed among all treatments. The results clearly showed that the best effect was most observed at 50% ASMD and 0.1% or 0.2% PVA concentrations.

**Table 7. Effect of soil moisture depletion and poly vinyl alcohol soil condition on Faba bean straw and seed yields.**

| Irrigation rate | PVA concentration | Season 2012-2013 | | Season 2013-2014 | |
|---|---|---|---|---|---|
| | | Straw(ton fed$^{-1}$) | Seed(Kg fed$^{-1}$) | Straw(ton fed$^{-1}$) | Seed(Kg fed$^{-1}$) |
| | C3 | 2.383 | 1439.14 | 2.338 | 1424.06 |
| 25% | C2 | 2.329 | 1370.22 | 2.305 | 1325.71 |
| ASMD | C1 | 2.147 | 1313.60 | 2.150 | 1260.54 |
| | C0 | 2.014 | 1210.58 | 2.005 | 1204.57 |
| Mean for irrigation (I1) | | 2.218 | 1333.38 | 2.1995 | 1303.72 |
| | C3 | 1.905 | 1262.31 | 1.891 | 1241.30 |
| 50% | C2 | 1.418 | 996.16 | 1.535 | 990.18 |
| ASMD | C1 | 1.265 | 804.11 | 1.300 | 843.07 |
| | C0 | 1.187 | 767.27 | 1.157 | 735.47 |
| Mean for irrigation (I2) | | 1.444 | 957.46 | 1.471 | 952.50 |
| | C3 | 1.230 | 654.89 | 1.189 | 637.99 |
| 75% | C2 | 1.085 | 605.08 | 1.035 | 599.83 |
| ASMD | C1 | 1.008 | 537.06 | 1.019 | 520.73 |
| | C0 | 0.981 | 522.76 | 0.967 | 490.40 |
| Mean for irrigation (I3) | | 1.076 | 579.94 | 1.052 | 562.23 |
| | | Mean for soil conditioners | | | |
| C3 | | 1.839 | 1118.78 | 1.806 | 1101.12 |
| C2 | | 1.611 | 990.49 | 1.625 | 971.91 |
| C1 | | 1.473 | 884.92 | 1.490 | 874.78 |
| C0 | | 1.394 | 833.53 | 1.376 | 810.15 |
| | | L.S.D. at 0.5% for | | | |
| irrigation (A) | | 0.05 | 190 | 0.07 | 84.2 |
| Soil conditioners (B) | | 0.05 | 139 | 0.04 | 74.2 |
| A*B | | 0.09 | 241 | 0.08 | 129 |

**Water use efficiency of faba bean.**

Water use efficiency, (WUE) has been used to evaluate different agronomic practices in relation to water use. It can be increased by increasing crop production or by decreasing water consumption. Water use efficiency by faba bean expressed as kg faba bean seeds per $m^3$ water consumed in complete evapotranspiration in two seasons is presented in Table 8.

All variables significantly affected on faba bean water use efficiency in two seasons. The results showed that the maximum water use efficiency obtained at 50%

ASMD and 25% ASMD treatments in first and second seasons, respectively. The lowest WUE was obtained at 75% ASMD and adding zero% polyvinyl alcohol concentration. The differences between the three (ASMD) treatments on WUE were significant in both seasons. The obtained results are in full agreement with those reported by Ekebafe *et al.*(2011), Chandrika *et al.* (2014) and El-Harty (2016).

Water use efficiency values were significantly affected by adding the polyvinyl alcohol soil conditioner. The best response to poly vinyl alcohol condition on WUE was the application of 0.2% concentration. These results were in good line with those obtained by Hossein Nazarli *et al.* (2010) and Chandrika *et al.* (2014).

The effects of interaction between the soil moisture depletion and vinyl alcohol soil condition on water use efficiency were significant for both seasons.

**Effect of various available soil moisture depletion and polyvinyl alcohol soil conditioner treatments on nutrients uptake by faba bean crop.**

Nitrogen, phosphorus and potassium (NPK) uptake by faba bean straw and seeds as affected by available soil moisture depletion and different concentrations of polyvinyl alcohol treatments were shown in Table 9-10.

**Table 8. Water use efficiency (WUE) as affected by the different treatments**

| Irrigation rate | PVA concentration | Water use efficiency, kg/m$^3$ | |
|---|---|---|---|
| | | 2012- 2013 | 2013-2014 |
| | C3 | 0.63 | 0.64 |
| 25% | C2 | 0.57 | 0.55 |
| ASMD | C1 | 0.51 | 0.50 |
| | C0 | 0.45 | 0.45 |
| Mean for irrigation (I1) | | 0.54 | 0.53 |
| | C3 | 0.64 | 0.64 |
| 50% | C2 | 0.48 | 0.49 |
| ASMD | C1 | 0.37 | 0.40 |
| | C0 | 0.34 | 0.34 |
| Mean for irrigation (I2) | | ٠,٤٥ | 0.46 |
| | C3 | 0.43 | 0.47 |
| 75% | C2 | 0.38 | 0.42 |
| ASMD | C1 | 0.33 | 0.35 |
| | C0 | 0.31 | 0.32 |
| Mean for irrigation (I3) | | ٠,٣٦ | 0.39 |
| | Mean for soil conditioners | | |
| C3 | | 0.58 | 0.60 |
| C2 | | 0.49 | 0.50 |
| C1 | | 0.42 | 0.43 |
| C0 | | 0.38 | 0.38 |
| | L.S.D. at 0.5% for | | |
| irrigation (A) | | 0.01 | 0.023 |
| Soil conditioners (B) | | 0.031 | 0.009 |
| A*B | | 0.05 | 0.017 |

**Table 9. Effect of available soil moisture depletion rates and polyvinyl alcohol concentrations on nutrients uptake by faba bean in season 2012/2013.**

| Irrigation rates | PVA concentration | Nutrients uptake in straw (Kg Fed. $^{-1}$) | | | Nutrients uptake in seeds (Kg Fed. $^{-1}$) | | |
|---|---|---|---|---|---|---|---|
| | | N | P | K | N | P | K |
| | C3 | 34.23 | 13.09 | 36.87 | 25.46 | 8.65 | 19.96 |
| 25% | C2 | 34.13 | 9.55 | 34.98 | 24.66 | 8.99 | 18.25 |
| ASMD | C1 | 31.49 | 7.16 | 34.49 | 24.53 | 7.75 | 17.91 |
| | C0 | 28.83 | 5.87 | 30.67 | 22.99 | 7.18 | 17.19 |
| Mean | | 31.98 | 8.86 | 34.18 | 24.42 | 8.14 | 18.32 |
| | C3 | 27.30 | 8.48 | 29.73 | 21.45 | 9.21 | 18.68 |
| 50% | C2 | 20.78 | 7.08 | 22.60 | 17.59 | 6.11 | 13.72 |
| ASMD | C1 | 18.06 | 6.53 | 20.17 | 14.52 | 5.16 | 10.33 |
| | C0 | 17.08 | 3.60 | 18.70 | 13.74 | 4.91 | 9.07 |
| Mean | | 20.92 | 6.45 | 22.89 | 16.84 | 6.35 | 12.96 |
| | C3 | 18.07 | 7.78 | 20.88 | 11.60 | 4.78 | 7.82 |
| 75% | C2 | 15.49 | 6.38 | 18.11 | 11.48 | 4.57 | 7.72 |
| ASMD | C1 | 14.52 | 5.82 | 14.85 | 11.36 | 3.55 | 6.82 |
| | C0 | 14.13 | 5.28 | 14.34 | 9.50 | 3.32 | 6.26 |
| Mean | | 15.18 | 6.16 | 16.63 | 11.0 | 4.05 | 7.16 |
| | Mean of soil conditioners | | | | | | |
| C3 | | 26.53 | 9.78 | 29.16 | 19.50 | 7.55 | 15.49 |
| C2 | | 23.47 | 7.67 | 25.23 | 17.91 | 6.56 | 13.23 |
| C1 | | 21.36 | 6.50 | 23.17 | 16.80 | 5.49 | 11.69 |
| C0 | | 20.01 | 4.92 | 21.24 | 15.41 | 5.14 | 10.84 |
| | LSD at 0.5 for | | | | | | |
| Irrigation (A) | | 1.46 | 0.93 | 2.69 | 0.93 | 2.33 | 1.55 |
| Soil conditioners (B) | | 1.23 | 2.37 | 1.89 | 1.16 | 1.39 | 0.76 |
| A*B | | 2.13 | 2.10 | 3.27 | 2.00 | 2.42 | 1.31 |

**Table 10. Effect of available soil moisture depletion rates and polyvinyl alcohol concentrations on nutrients uptake by faba bean in season 2013/2014.**

| Irrigation rates | PVA concentration | Nutrients uptake in straw (Kg Fed. $^{-1}$) | | | Nutrients uptake in seeds (Kg Fed. $^{-1}$) | | |
|---|---|---|---|---|---|---|---|
| | | N | P | K | N | P | K |
| | C3 | 33.54 | 12.66 | 34.79 | 25.07 | 8.61 | 19.72 |
| 25% | C2 | 33.73 | 9.44 | 36.62 | 23.89 | 8.70 | 17.65 |
| ASMD | C1 | 31.47 | 7.17 | 34.47 | 23.62 | 7.72 | 17.22 |
| | C0 | 28.69 | 5.91 | 30.61 | 22.91 | 6.96 | 17.15 |
| Mean | | 31.81 | 8.88 | 34.17 | 23.83 | 8.00 | 17.97 |
| | C3 | 27.11 | 9.62 | 29.61 | 21.10 | 9.05 | 18.32 |
| 50% | C2 | 22.55 | 7.09 | 24.59 | 17.52 | 6.06 | 13.71 |
| ASMD | C1 | 18.68 | 6.28 | 20.82 | 14.41 | 5.42 | 10.85 |
| | C0 | 16.54 | 3.51 | 18.04 | 13.92 | 4.59 | 8.72 |
| Mean | | 21.20 | 6.60 | 23.32 | 16.79 | 6.25 | 12.85 |
| | C3 | 17.49 | 7.53 | 20.22 | 11.45 | 4.70 | 7.60 |
| 75% | C2 | 14.82 | 6.08 | 17.38 | 11.21 | 4.40 | 7.67 |
| ASMD | C1 | 14.54 | 5.80 | 14.94 | 10.62 | 3.34 | 6.62 |
| | C0 | 13.76 | 5.12 | 14.03 | 9.23 | 3.23 | 5.87 |
| Mean | | 15.24 | 6.16 | 16.72 | 10.66 | 3.93 | 6.96 |
| | Mean of soil conditioners | | | | | | |
| C3 | | 26.08 | 9.11 | 28.10 | 19.20 | 7.30 | 15.17 |
| C2 | | 23.74 | 7.51 | 26.14 | 17.57 | 6.48 | 13.00 |
| C1 | | 21.53 | 7.16 | 23.41 | 15.86 | 5.24 | 11.55 |
| C0 | | 19.71 | 4.77 | 20.95 | 15.72 | 5.18 | 10.58 |
| | LSD at 0.5 for | | | | | | |
| Irrigation (A) | | 1.42 | 0.84 | 2.04 | 0.92 | 2.01 | 1.01 |
| Soil conditioners (B) | | 1.04 | 1.99 | 1.78 | 0.88 | 1.16 | 0.83 |
| A*B | | 1.79 | 3.45 | 3.08 | 1.52 | 2.30 | 1.44 |

Results show that, during the two seasons of study, there were significant effects due to the irrigation regime on nitrogen, phosphorus and potassium uptake by faba bean in straw and seed. The highest values recorded by 25% followed by 50 %( ASMD), while 75 %( ASMD) treatment achieved the lowest ones in both seasons. Similar results were reported by Siam *et al.* (2017)

Also, for PVA concentrations, results revealed that increasing concentrations increased NPK uptake in faba bean straw and seed. Furthermore, values of nutrients uptake were more enhanced with application of 0.1% and 0.2% concentrations compared to other concentrations. These results were agreement with those obtained by Youssef *et al.* (2014), Siam *et al.* (2017) and Abobatta (2018).

The interaction differences between 25% ASMD and levels of PVA were observed statistically significant between 0.2%, concentration and each of 0.05% and zero%. Also, similar trend was observed with P uptake in straw faba bean. However, all variables showed insignificant effect on P uptake in seed faba bean in both season at 25% ASMD. There was often observed a statistically significant difference at irrigation level 50% ASMD between 0.2%, concentration and other concentrations on NPK faba bean straw and seed uptake. However, no significant difference was often observed between 0.05% and zero%. At irrigation level 75%, no statistical significance was observed among all treatments. Except at irrigation level 75%, a statistical significance was observed at 0.2% concentration and other concentrations of N uptake for faba bean straw, in both season. The values of nutrients uptake were more enhanced at 50% A.S.M.D with application of the 0.1% and 0.2% of concentrations compared to other concentrations.

## CONCLUSION

Application of synthetic soil conditioners (polyvinyl alcohol with high concentration) under decreasing available soil moisture depletion in sandy soil caused a significant increase in faba bean yield and, it improved the total content of macronutrient in faba bean yield. The results clearly showed that the best effect was most observed at 50% ASMD and 0.1or 0.2 % PVA concentration.

## ACKNOWLEDGMENT

The authoresses wish to express their sincere gratitude and appreciation to the Development of Soil Conditioners Project, Dept. of Physics and Chemistry of Soil, Soils, Water and Environ. Res. Inst., Agric. Res. Center (ARC), Giza, Egypt, for introducing all facilities needed to accomplish this study.

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## تأثير معاملات الري وبولي فنيل الكحول على انتاجية و كفاءة استخدام المياه والتحليل الكيميائي لمحصول الفول البلدي

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يعد التقدير الكمي لاستجابة المحصول الحقلية للري من الأهمية بمكان لانشاء توجهات جيدة لادارة الري. لتطبيق ذلك تم اجراء تجربة حقلية لتقييم تأثير ثلاث مستويات استنفاذ الرطوبي من ماء التربة الميسر(٢٥%و٥٠%و٧٥%) تحت نظام الري بالرش بالتداخل مع أربع تركيزات (٠,٠%و ٠,٠٥%و٠,١%و٠,٢%) من محسن البولي فنيل الكحول. تم دراسة التأثير المشترك لمعاملات الري و التركيزات المختلفة لمحسن التربة على محصول الفول البلدي صنف جيزة ٨٤٣ و التي تم اجراؤها في محطة البحوث الزراعية بالاسماعيلية و الواقعة شمال شرق مصر في منطقة ذات مناخ شبه جاف أثناء موسمين شتوي ٢٠١٢/٢٠١٣ و ٢٠١٣/٢٠١٤ . و قد تم تقدير معدل البخر نتح، انتاجية المحصول، كفاءة استخدام المياه، و معدل امتصاص العناصر الغذائية الكبرى لمحصول الفول البلدي. تراوح البخر نتح الفعلي تحت معاملات الري ما بين (1605.36 _ 2482.45) م$^3$ /فدان و ما بين (1439.26_ 2457.01) م$^3$ /فدان خلال موسمي الزراعة٢٠١٢/٢٠١٣ و ٢٠١٣/٢٠١٤ على الترتيب. و قد تبين أنه يمكن استخدام أي من المعادلات الآتية : معادلة الفاو الأشعاعية أو بنمان مونتيث اليومية أو دروجرس_آلان ٢٠٠٢ لحساب الاستهلاك المائي لمحصول الفول البلدي. تبين أيضا أن اضافة محسن التربة الصناعي (البولي فنيل الكحول بتركيزاته ٠,١%أو٠,٢%) مع نقص الاستنفاذ الرطوبي بالتربة الرملية أدى إلى زيادة محصول و كفاءة استخدام المياه و تحسين معدل امتصاص العناصر الغذائية لمحصول الفول البلدي. كما أوضحت النتائج جليا الحصول على أفضل النتائج للفروق المعنوية عند تركيزات ٠,١% أو٠,٢% لمحسن البولي فنيل الكحول و معاملة الري ٥٠% استنفاذ رطوبة التربة الميسرة.