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ROLE OF IRRIGATION SCHEDULING AND POTASSIUM FERTILIZATION ON SOIL MOISTURE DEPLETION AND DISTRIBUTION OF QUINOA ROOT (IRRIGATION SCHEDULING FERTILIZATION AND THEIR EFFECT ON MOISTURE DEPLETION AND YIELD)

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Abstract

A field experiment was carried out during the spring season 2017 in the fields of College of Agriculture, University of Baghdad in Abu Ghraib (25 km west of Baghdad), to study the role of irrigation scheduling and potassium fertilization on the moisture depletion and distribution of quinoa roots with four irrigation treatments (0.8, 1.0, 1.2 and 1.4) PEF and four levels of Potassium fertilization (0, 60, 120 and 180 kg $K_2O.ha^{-1}$).

Results showed the effect of irrigation treatments on the water depth applied during quinoa growing season. It was noticed that the lowest value of water used was 302.9 $mm.season^{-1}$ which was obtained at 0.8 PEF, while the highest seasonal water consumptive use was 325.5 mm $season^{-1}$ for the treatment 1.4 PEF. The best value of water use efficiency was 1.63 kg m^{-3} was for 1.2PEF irrigation treatment with seasonal water consumptive use was 323.0 mm and highest grain yield 5.13 ton ha^{-1} at potassium fertilization level of 120 $kg.ha^{-1}$. The values of monthly plant factor (Kc) were 0.67, 0.41, 0.70 and 0.55 on February, March, April and May respectively depending on the date of 1.2 PEF treatment.

Results also showed the highest distribution percentage of quinoa roots was found at the upper depth of soil (0.00- 0.30 m) and increased with increasing in values of PEF, the same results was found for the moisture depletion for all irrigation treatments approximately, 5.25 ton ha^{-1} were obtained and consider as the highest yield of quinoa grain for treatment PEF 1.2 at the level of fertilization of 120 kg ha^{-1}.

Key word: Quinoa, Fertilization, root, moisture depletion

Introduction

Irrigation scheduling is a water management strategy and aims to add irrigation water in the right quantity at the right time (Hillel, 1880). Irrigation scheduling provides information that can be used to develop irrigation strategies for different crops and different soil and climatic conditions. This scheduling can be determined using long-term data that represent the average of conditions or immediate seasonal information based on real-time information and short-term forecasts (Martin *et al.,* 1990).

Drought and salinity are common negative environmental factors affecting plant growth, the global distribution of vegetation cover and the restriction of crop yield in agriculture (Gregory, 2006), Crop production in arid and semi-arid regions, including Iraq, can be improved by diversifying crop production and introducing new crops and cultivars, such as the *Chenopodium quinoa* Willd, a tolerant plant with the potential to become an important crop in arid and saline areas and to satisfy a growing global market (Jacobsen and Shabala, 2013). The broad genetic variation in salinity tolerance in quinoa provides an excellent source of choice and breeding for high tolerance (Ruiz-Carrasco, 2011).

The amount of plant response to fertilizer additives indicate of chemical and physical changes in soil and plant as

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well as other associated factors. To obtain the highest response to fertilizer by the plant, it depends on the appropriate fertilizer recommendation and the required area with knowledge of the actually fertilizer content found in the soil. Potassium is an important component of the plant, responsible for regulating more than 80 enzymes in the plant, and its presence reduces the effect of toxic amines and increases plant resistance to lesions, diseases and fungi (IPI, 2000). Potassium found in cytoplasm cells cannot replace any other positive ion, and the least potassium deficiency in the cytoplasm of the cell will affect certain activities of the plant, especially in relation to a large number of enzyme reactions that depend on or stimulate potassium ion as well as potassium stimulate CO_2 absorption by leaf Stoma and the synthesis of ATP which is essential in filling the sieve tubes with the materials produced by photosynthesis.

Quinoa belongs to the Chenopodiaceae family, an Andean treasure. It has recently been introduced in the United States of America, Canada and Europe, as it consider a candidate for agricultural diversification for its ability to adapt to various environmental conditions, such as drought resistance, frost tolerance, saline soils, diseases and lesions (Jacobsen *et al.,* 2005).

The quinoa is an excellent health food because of the richness of its grains with natural nutrients, vitamins, fiber, unsaturated fats, and minerals such as phosphorus, calcium, zinc, magnesium and iron. It contains a very high digestible protein, which is the eight essential amino acids for the growth of children and adults. Quinoa is characterized as gluten free and suitable for people, who suffer from the sensitivity of lactose in milk and vary the need of this plant for water depending on the climate and the period of plant growth,

When it is grown as a winter crop, it is possible to rely only on rainwater, while cultivating it as a summer crop, irrigation is light and close, and salt water can be used. The aim of the experiment is to calculate the amount of water needed and the level of potassium fertilization to obtain the highest yield and highest water use efficiency of quinoa.

Materials and methods

An experiment was carried out during the spring season of 2017 in the fields of the College of Agriculture University of Baghdad, The soil texture was classified as a clay loam. The location lies on longitude 44^0 16' 36'' east and latitude 33^0 18' 23'' north, and 34 m above sea level. The texture of soil was silt clay loam (123 sand), (391 clay), and (486 silt), the field capacity and wilting point was 31.3 and 13.5%, respectively, having pH value of 7.8 in soil paste and EC value of 1.87 dS. m^{-1} in soil paste extract. Soil bulk density was 1.32 g. cm^{-3}, The values of cumulative pan (CPE) was obtained from Al-Raed-meteorological Station Abu-Graib, The irrigation interval per each treatment is the number of days in which the cumulative pan evaporation (CPE) should be approximately equals the estimated water amount of the considered treatment. The equivalent amount of cumulative pan evaporation (CPE) that can occur while this amount of moisture is being used i.e. usable CPE must be determined from meteorological data. Then the corresponding CPE for each pan factor (PEF) could be computed, which is resulting in identifying the number of days at which irrigation event should be executed. The amount of applied irrigation water during the irrigation treatments was according to crop evapotranspiration (ETc), The total depth of water applied was computed according the treatments which were arranged in a split-split plot design with three replicates. The collected data were subjected to the statistical analysis (by using Mstat-C software), using the analysis of variance (ANOVA). Experimental factors included two factors, Irrigation treatments included irrigation scheduling based on IW: CPE (accumulative evaporation from pan evaporation: irrigation requirements) as follows:

a. Irrigation treatments (main plot)

1. Irrigation depending on the percentage (PEF) 0.8 IW:CPE
2. Irrigation depending on the percentage (PEF) 1.0 IW:CPE
3. Irrigation depending on the percentage (PEF) 1.2 IW:CPE
4. Irrigation depending on the percentage (PEF) 1.4 IW:CPE

b. Potassium fertilization (Sub Plot treatments)

Potassium Sulphate Fertilizer (K_2O 45%) was used in this experiment at the following levels:

1. 0.0 kg / h^{-1}
2. 60 kg / h^{-1}
3. 120 kg / h^{-1}
4. 180 kg / h^{-1}

The field was watered (73.3mm) at level approach to field capacity, before planting date on 15/1/2017, and then irrigated with water depth equal to 42mm for seed growing. Irrigation water treatments were started after the complete emergence corresponding to 23/2/2017 and stopped depending upon irrigation treatments at maturity stage. The amount of irrigation water applied during the irrigation treatments was according to crop evapotranspiration (ETc), and the total water depth applied was computed according the treatments Table 1, and the quantities of water added during the growing season were calculated according to experimental treatments (PEF) as well as calculate the distribution of moisture and the total water depth according to the treatments. The water consumption was calculated in four ways by water balance method, evaporation from the evaporation pan, Class A, Dorenbos and Pruitt, and the FAO Penman-Monteith method, Plant characteristic, yield for quinoa and water use efficiency also computed.

Table 1: CPE values for each irrigation treatment (PEF)*

Factors (PEF)	CPE mm
0.8	33.3
1.0	26.6
1.2	22.2
1.4	19

*CPE=IW/PEF

Phosphate fertilizer was added in the form of TSP (46% $P2O_5$) at 60kg before second irrigation, the potassium fertilizer (K_2O 48%) was added in one step immediately prior to the second irrigation. According to the study treatments, nitrogen fertilizer was added in the form of urea (N 46.5%) as recommended by 200 kg h^{-1} N (Food and Agriculture Organization of the United Nations, 2017). at two steps, the first after planting and the second before flowering.

Results and Discussion

Water requirements for quinoa yield and yield response for the irrigation scheduling.

Table 2 showed the irrigation intervals (day) and depth of irrigation water (mm) under different empirical pan factors (PEF). The amount of water applied was varied between all treatments according to the irrigation treatments and the growth months of the quinoa crop. It could be resulted from different maturity stage dates which differ between treatments according to water stress which occur due to elongate the irrigation interval thought the studied treatments. It has noticed as the growth season progressed, the irrigation interval for February, March, April and May was 10, 9, 6 and 5 days for PEF 0.8. The shortest irrigation interval was PEF 1.4 for the same months 7, 5, 4 and 3 days respectively. The same table indicated that irrigation interval decreased by increasing in IW: CPE ratio and with progress of growing season. The irrigation interval value for treatment of 0.6 PEF was 10, 9, 6 and 5 d in February, March, April and May July respectively. On the other hand, irrigation interval was 6, 4, 3, 3 and 2 for 1.6 PEF treatments. The higher value of irrigation interval was 10 d for 0.8 PEF treatments in February, while the lowest value was 3 d for PEF 1.2 and 1.4 treatment in May. The increase of the irrigation interval reduces the number of irrigation (irrigation frequency), which is positively reflected in the maintenance of energy and the work cost. The reduction of the irrigation interval is compatible with the concept of

Table 2: Irrigation intervals (day) and depth of irrigation water (mm) under different empirical pan factors (PEF).

PEF	Months	Irrigation No.	Irrigation interval (day)	Water depth add in one irrigation (mm)	Water depth add in month (mm)	Total irrigation number	Total water depth ($mm/season^{-1}$)
0.8	February	3	10	2.66	18.64	17	285.02
	March	3	9	13.32	39.96		
	April	5	6	21.31	98.56		
	May	6	5	21.31	127.86		
0.1	February	3	9	2.18	15.00	21	289.46
	March	4	8	10.64	42.56		
	April	7	4	17.02	112.76		
	May	7	4	17.02	119.14		
1.2	February	4	7	1.87	14.49	26	292.73
	March	5	6	8.88	44.40		
	April	8	4	14.06	107.30		
	May	9	3	14.06	126.54		
1.4	February	4	7	1.80	13.00	29	285.44
	March	6	5	7.60	45.60		
	April	8	4	12.18	92.86		
	May	11	3	12.18	133.98		

• The first date of all irrigation treatments was 1/2, while the last date of irrigation according to irrigation interval was 22/5, 25/5 and 31/5 for the treatments 0.8, 1.0, 1.2 and 1.4, Respectively.

drip irrigation. This occurred when the irrigation interval 3, 3 and 4 days was suitable period, which was reflected in the number of irrigation's for every treatment. The highest number of irrigation was 29 irrigation at PEF 1.4, followed by 26, 21 and 17, irrigation at PEF 1.2, 1.0 and 0.8, respectively, the results harmony with (Hadithi, 2002), who indicated that the actual water consumptive use was decreased with plant progress growth and lower water consumption at maturity stage.

The amount of water applied was varied between all treatments. It could be resulted from different maturity stage dates which differ between treatments according to water stress occurred due to elongate the irrigation interval thought the studied treatments (Table 2). The table reveal that the heights amount of water added was 292.73 mm in season^{-1} corresponded to PEF 1.2, while the water consumptive use was 289.46, for 1.0 PEF treatment followed by 285.44 and 285.02 mm season^{-1} for the treatments, 1.4 and 0.8 PEF, respectively, although the differences were very limited, this difference is due to the variable of the water amount added to each irrigation and the irrigation interval, when treatments changes and progress of plant growth (Saifulldeen and *et al.,* 2018).

Daily evapotranspiration calculated by water balance equation.

Table 3 showed the effect of irrigation scheduling on daily actual evapotranspiration (ET_a) for quinoa crop, which was calculated by using water balance equation during the growing season. The increases of PEF coefficient from 0.8 to 1.4 lead to increased ETa, respect to the irrigation treatment 0.8, the actual water consumption was 302.9, 323.3, 323 and 325.5 mm season^{-1} of treatments 0.8, 1.0, 1.2 and 1.4 PEF, respectively.

The highest value of interaction between the growth months and the PEF coefficient was 133.2 mm month $^{-1}$ during May and at PEF 1.4, on the other hand, the lowest value was 40.2 mm month^{-1} during February at PEF 1.4. This is because of the plant at the beginning of its growing stage is accompanied by a decrease in temperature which reduces the evaporation requirements and these agree with (Al-Obeidi, 2013) The increase in actual water consumption by the quinoa plant is attributed to the increase of the ready water in the root area of the plant.

Table 3: Effect of irrigation scheduling on actual monthly and seasonal evapotranspiration used during the growth season of quinoa plant.

Irrigation scheduling treatments	February	March	April	May	Seasonal actual water consumption
0.8 PEF	52.5	44.2	98.0	108.2	302.9
1.0 PEF	45.1	50.5	116.5	111.2	323.3
1.2 PEF	44.8	45.7	120.8	111.7	323.0
1.4 PEF	40.2	51.4	100.7	133.2	325.5

Under the same irrigation system, which is accompanied by increasing the absorption rate of plant roots for water under conditions of increasing evaporation rates from soil surface these results agreed with (Hadithi, 2002), (Adeniran *et al.,* 2010) and (Jensen and Allen, 1989) who indicated that soil available water depends on each type of soil, depth of roots, amount of available water, and the requirements for daily evaporation or potential evaporation ET as the potential evapotranspiration will govern the higher limit requirements for moisture extraction from the soil.

3. Comparison of the daily reference evapotranspiration (ET_o) estimated by three deferent methods with the daily actual evapotranspiration (ETa) estimated at 1.2 pan evaporation coefficient (PEC) during the growth seasons.

The results in Table 4 show the comparison of reference evapotranspiration (ETo) that estimated by three methods and actual evapotranspiration (ETa) estimated at PEF 1.2, noting that the evaporation rate values of evaporation pan class A, Dorenbos and Pruitt, and the FAO- Penman-Monteith 4.81, 4.36 and 6.14mm/Day^{-1}, respectively, compared to actual water consumption estimated in the water balance method (ETa) which was 2.8mm/day^{-1} These results were agree with (Al-Obeidi, 2013) and (Dulaimi, 2016), which adopted the FAO-Penman-Monteith method and the A-Class evaporation pan method in central Iraq.

Table 4 shows that evaporation values from the class-A pan (EP) are significantly higher than the actual evapotranspiration values (ETa), reference evaporation (ET_o) and evapotranspiration calculated by (pan class A, Dorenbos and Pruitt, and the FAO- Penman-Monteith), with a difference in primary values. This difference increases as the growth stage progresses. The values for no stress treatment were 5.43 mm for E_{pan}, 3.57 mm ET_o and 4.91 mm, respectively. The high values of Ep are due to the calculated values of the metrological data that the evaporation process can occur without interruption during daylight hours and night due to the effects of weather condition like solar radiation, which equip the water molecules with the energy needed to convert the liquid to vapor and wind, which removes the saturated layer and replace dry layer. As well as sensitive heat, relative humidity and heat transfer across the sides of

Table 4: daily reference evapotranspiration rate (ET_o) in three methods during the growing season

Season months of the year	Daily evapotranspiration ET_a (mm day^{-1})	Daily reference evapotranspiration [ETo (mm/day]) estimated by three different methods			ETo / ETaratio
		Pan evaporation method	Doorenbos and Pruitt (1977) method	FAO Penman-Monteith method	
February	1.6	2.4	2.47	3.26	2.8
March	1.5	3.62	3.63	4.82	1.72
April	4	5.69	3.75	5.75	0.64
May	4.1	7.52	7.57	10.71	2.19
Mean	2.8	4.81	4.36	6.14	

* Actual evapotranspiration estimated depends on evaporation pan coefficient = 1.2

the pan that affect the energy balance (12 and 42). The values of ETD and ET_o are related to temperature as well as light hours as the process of transpiration during daylight hours is under the influence of solar radiation at night, the stomata of the plant are closed, reducing water consumption or stopping it. The ET_o values of the Penman-Montieth equation have similarly to the actual evapotranspiration values of the quinoa yield, although they were slightly higher than the actual evaporation values Fig. 1. ET_o increased with the growth stages and approached to ETa at flowering and maturity stages was higher in the early stages.

This may be due to the low values of aerodynamic resistance (ra) and rc resistance values during these stages in the modified Penman-Montieth equation (2 and 3 Allen). The values of PEF 1.2 was superior to irrigation treatments in terms of yield and water use efficiency as will be shown later, so it can be said that this treatment is the most appropriate treatment under the conditions of central Iraq.

The monthly yield coefficient (Kc) of quinoa plant.

The monthly and seasonal corn crop coefficient (Kc) estimated at 1.2 pan evaporation coefficient during the growth seasons is illustrated in Table 5 and Fig. 1. In this Table, the monthly corn crop coefficient (Kc) estimated at 1.2 pan evaporation coefficient (PEC) was calculated by dividing the daily actual evapotranspiration estimated at 1.2 PEC by the daily reference evapotranspiration estimated by the pan evaporation method. The value of the seasonal corn crop coefficient (Kc) estimated at 1.2 PEC is the average of values of the monthly corn crop coefficient (Kc) estimated at 1.2 PEC during the five months of growth season. The heights value of the crop coefficient (K_c) was 0.70 during April month, compared to other growth months. This is due to increasing of ET_a values for this month during the entire season. This result is harmony with (Hadithi, 2002 and Jubouri, 2002) result, who noted an increasing in the value of the crop coefficient under water stress condition subjected to plant, The high crop coefficient (Kc) was observed with the development of the stages of growth to maturity, the result showed there was reduction in kc value approached to 0.55, this was due to a reduction in actual water consumptive use value, There was a reduction in crop coefficient values in the latter stages of the plant life cycle due to the completion of its growth and maturity. Water stress has also reduced crop coefficient values. It is noted that the crop coefficient decreases more when plants are exposed

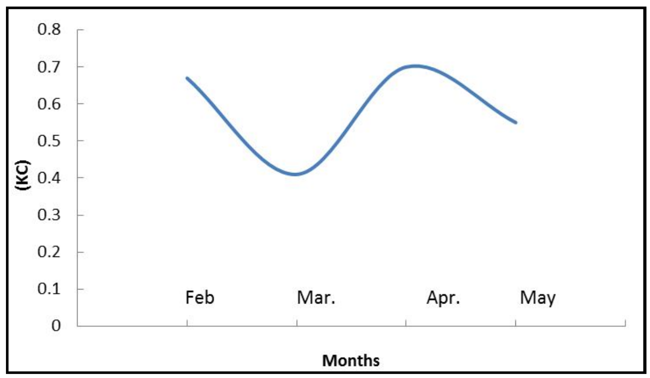

Fig. 1. Crop coefficient (K_c) for quinoa with growth months.

Table 5: Crop coefficient (Kc) per month of quinoa yield estimated by pan coefficient 1.2 during the growing season.

Treatment	Daily reference evapotranspiration ET_a (mm\day)*	Daily actual evapotranspiration ET_a(mm\day)**	Monthly crop coefficient ***(Kc)
February	2.4	1.6	0.67
March	3.62	1.5	0.41
April	5.69	4.02	0.70
May	7.52	4.1	0.55
(K_c)*** seasonal			
crop coefficient	4.81	2.8	0.58

*Daily evapotranspiration ET_a (mm\day) estimated by pan evaporation
** Daily actual evapotranspiration ETa (mm\day) estimated at pan coefficient 1.2 *** pan coefficient estimated at 1.2 by ET_o/ET_a

to water stress and as the stages of growth progress.

Doorenbos and Pruitt (1992) pointed out that the kc value relates to evapotranspiration of disease-free crop grown in large fields under optimum soil water and fertility condition, and achieving full production potential under given growing environment.

Effect of irrigation scheduling on root distribution of quinoa plant.

Fig. 2 shows the distribution of the root weights at different PEF treatments, respect to the depth of 0 – 0.60 m. It was noted that the total root mean weight of the plant was increased at 1.4 PEF, with values of 47.75, 33.75, 12.50, for the depths 0 .0 -0.15, 0.15-0.30, -0.30-0.45, 0.45 - 0.60 m, respectively. It was noted that all root weight for all treatments was concentrate in 0.0, -0.15 and the ratio of root weight density was in this layer comparing to the soil layers of 0.15 - 0.60 m, 0.33, 0.37, 0.41, 0.47 for PEF 0.8, 1.0, 1.2 and 1.4, respectively. while the lowest distribution of root lengths was at 0.45-0.65 m. These results are agree with the findings of (Zartman and Woyewodzic, 1979) who mentioned that the 70% of the total root weight of cron was concentrated in the top of 0.10 m of soil layer, this due to the continuous wetting of soil surface layer during the growing season which lead to keep the water easily available close to the roots zone region.

The percentage of lengths were 0.17, 0.14, 0.10 and 0.06 corresponding to PEF 0.8, 1.0, 1.2 and 1.4, respectively, availability water in the upper layers encouraged the roots to concentrate through who. Jensen (1989) noted that the availability of soil water depends on the type of soil, the amount of water available and the requirements of daily evaporation or evaporation effort, which controls the maximum rate of water extraction found (Klepper *et al.,* 1973 and Rowse, 1974), mentioned that frequent irrigation causes the distribution of plant roots closer to soil surface than the dry conditions (drought conditions).

Effect of irrigation scheduling in the moisture extraction pattern of quinoa plant

Fig. 3 shows the effect of irrigation scheduling on the quinoa moisture extraction pattern during its growing season. Increasing of PEF coefficient from 0.8 to 1.4 resulted in a gradual increase in the moisture extraction pattern (SMEP) by the quinoa plant corresponding to depth of 0.0 - 0.15 m 35.50, 39.75, 41.25, 50% for depth of 0.15-0.30m, 27.00, 29.75, 29.75 and 33.75% respectively. There was a gradual decreases in the extraction pattern of the quinoa plant at the rest of the depth. The results agreed with (El-Bably, 2007), which noted that most of the moisture extraction pattern was

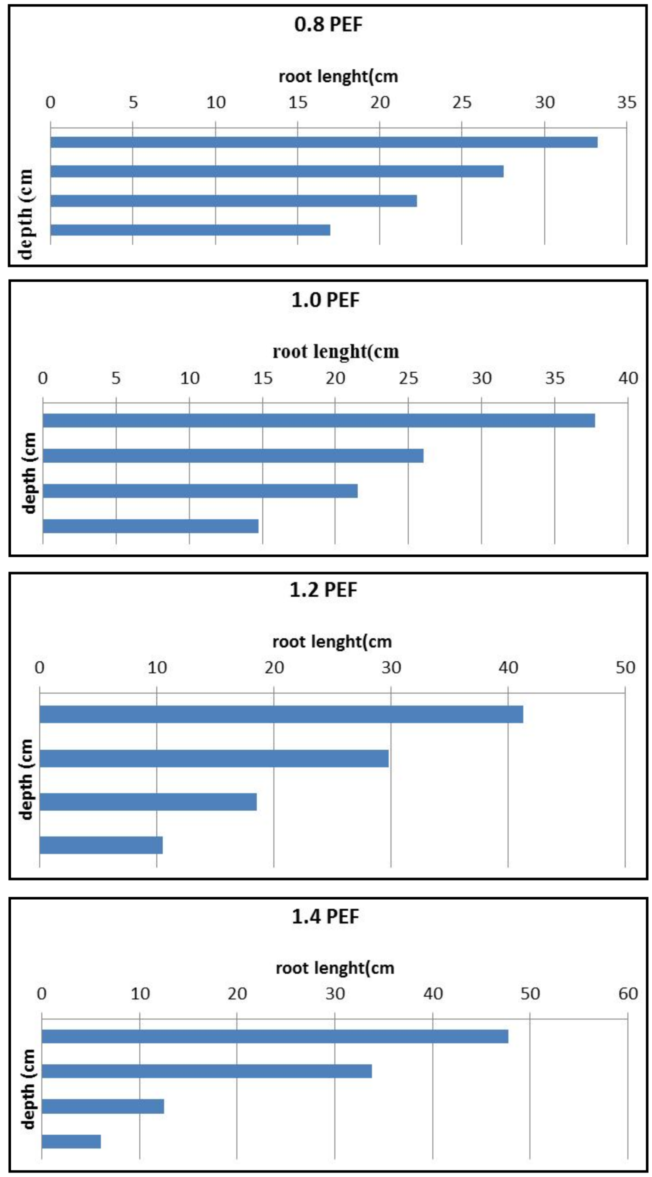

Fig. 2: Root distribution patterns of quinoa by irrigation treatments PEF

from the top 30 cm of the soil layer and also noted that the corn plant extracted about 76.14, 71.22 and 64.24% of soil moisture from 30 cm when the irrigation was done at PEF 1.2, 1.0 and 0.8 of the accumulative pan evaporation respectively. On the other hand, the moisture content of 0.30-0.60m was 23.86, 28.78 and 35.76%.

These values indicate that, when soil moisture is maintained as a result of irrigation frequent, most of the withdrawn water is from the top 30cm of the soil layer. When the moisture content of the surface layers is subject to irrigation deficiency, as in PEF 0.8, the quinoa extracts its water requirements from the deepest layers in order to meet their needs. Furthermore, Israelsen and Hansen (1962) revealed that when the upper portion of the root zone is kept moist, most of water used consumptively by the plant will be removed from the soil near the surface. However, when infrequent irrigations are applied, and essentially no rainfall occurs, less water may be used from the surface foot than from the succeeding depths. Again, Ainer (1983) indicated that the increasing depletion of the available soil moisture caused reduction in the rate of moisture depletion from the upper soil layer and more moisture might be extracted from the lower depths.

Effect of Irrigation Scheduling and Potassium Fertilization in the Quinoa Grain.

Table 6 shows the effect of irrigation scheduling and potash fertilization on quinoa grain crop. The grain increased significantly ($P \leq 0.05$) as a result of the increase of PEF coefficient from 0.8 to 1.4 compared to the those that were irrigated at PEF 0.8. The highest grain yield, was 4.65 tons h^{-1}, while the lowest grain yield 3.33 tons h^{-1} was found when the plant was irrigated at PEF 1.4, the results were agreement with (Dulaimi, 2016 and El-Marsafawy (1995) found that irrigation regime had a significant effect on yield and yield components of maize. Grain yield and ear yield/fed were significantly increased under irrigation at 1.0 or 1.4 accumulative pan evaporation. Moreover, Khalil *et al.,* (2002) indicated that irrigation regime [0.7, 1.0 and 1.3 evaporation pan coefficient (EPC)] significantly affected the grain yield. The superiority of this character for maize plants was obtained by irrigation using 1.0 evaporation pan coefficient (EPC). It could be concluded that grain yield was increased with increasing available water. This increase can be attributed to the significant role of available water in affecting 100 grain weight.

It is concluded that the grain yield increases with the increase of ready water in the soil. This increase can be attributed to the important role of available water in influencing the weight of grain. Furthermore El-Bably (2007) revealed that a higher grain yield for irrigated maize cultivars at 1.2 of accumulative pan evaporation (A.P.E.) owing to the higher yield components such as ear length, number of rows/ear, number of grains/row, 100-grain weight, and yield of plant. He concluded that irrigation scheduling in maize based on 1.2 accumulative pan evaporation produced high yield in North Delta, Egypt.

It is evident from Table 14 that the grain yield of corn was significantly increased ($p = 0.05$) by increasing the potassium fertilization level from 0.00.0 to 180kg K_2O h^{-1} was achieved when the comparison compared to that of the control treatment 1.9 tons.h^{-1}, The significant increase in the grain yield of quinoa when 120kg h^{-1} of fertilization was used, The average grain yield was 4.68 ton. h^{-1}. While grain yield decreased when 180kg h^{-1} was used, an slight increasing by 4.3 ton.h^{-1} was noted, this agrees with Abdel-Nasser and Hussein (2001) showed that the highest values of corn grain yield, weight of 100 kernel and grain protein content were attained at the

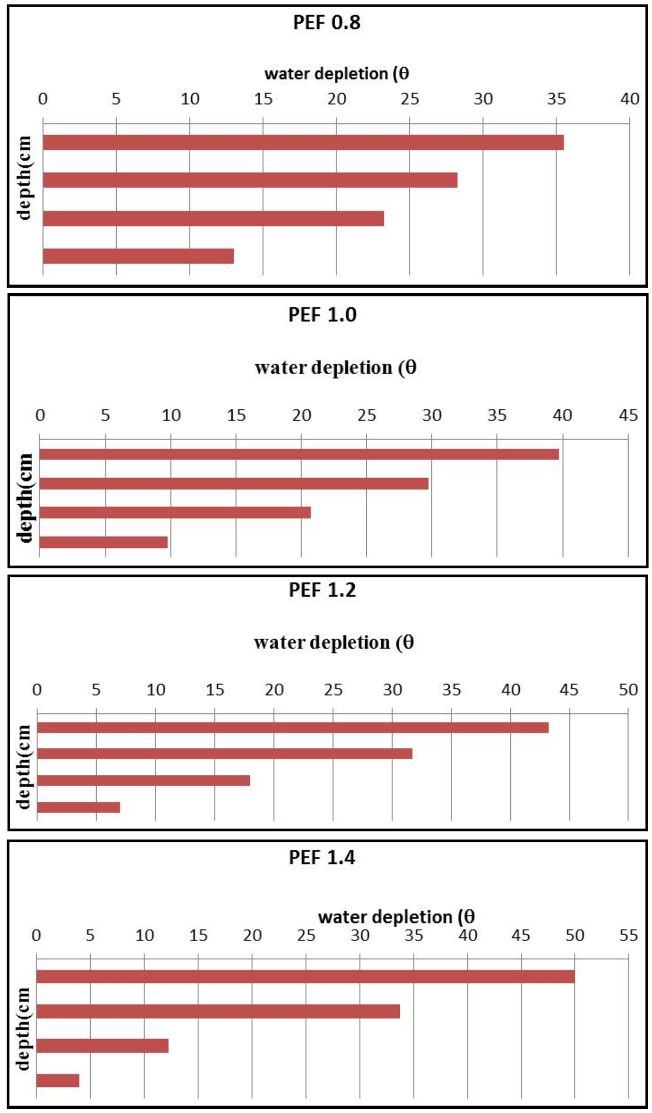

Fig. 3. Extraction of moisture from the roots of the quinoa plant with PEF irrigation.

Table 6: Effect of the irrigation scheduling and potassium fertilization on the grain yield of Quinoa during growth seasons.

Irrigation treatments	Level of potassium fertilizer (kg K_2O. h^{-1})				
	0	60	120	180	Mean
0.8 PEF	2.73	2.36	4.48	4.67	3.56
1.0 PEF	1.56	4.21	4.79	4.19	3.68
1.2 PEF	3.46	4.79	5.25	5.13	4.65
1.4 PEF	1.90	3.98	4.23	3.21	3.33
Mean	2.41	3.83	4.68	4.3	3.80
$L.S.D_{0.05}$	Irrigation treatments A=0.0814 Level of potassium fertilizer B = 0.0.814 AB=0.1628				

highest level of K-fertilization (60 kg K2O/fed).

These results were agree with (Dulaimi, 2016) who indicated that the effect of irrigating treatments on cowpea seed yield and its components showed that treatment Ef 1.2 was superior in fresh seed yield by 5.13 ton.hec.-1, weight of 100 seeds by 31.88 gm. A significant difference in the number of grains in the pod was noted, the highest value was 9.34 for PEF 1.2, while, the lowest value 4.81 ton. h^{-1} was obtained for the wet grain yield for the PEF 0.6 treatment, a significant differences the highest value of 5.13 ton.h^{-1} for PEF 1.2 has noticed. It is evident that prolonging irrigation interval might have decreased soil moisture availability and hence might have reduced metabolites translocation to the developing grains.

Effect of irrigation scheduling and potassium Fertilization Level on the water use efficiency of Quinoa during the growth season.

The data in table 7 show the effect of irrigation scheduling and the level of potassium fertilization on the water efficiency of quinoa grains. The increase of the PEF coefficient of 0.8 to 1.4 led to a decrease in water use efficiency, except for irrigation treatment at 1.2 PEF, with a value of 1.44 kg.m^{-3} with an increase of 22% compared with those irrigated at 0.8 PEF, water use efficiency was 0.8 PEF (1.175kg.m^{-3}). This may be due to the superiority of the treatment of 1.2 PEF to the rest of the treatments as they have already surpassed the value of the grain. The same results were obtained (El-Bably, 2007), who found the water efficiency increased with moisture-deficit irrigation at 0.8, 1.0 and 1.4 PEF from accumulative pan evaporation (A.P.E)

Frequent irrigation reduction due to irrigation at 0.8 resulted in increased water use efficiency compared with the other 0.8, 1.0 and 1.4 PEF of accumulative pan evaporation (APE). (Hadithi, 2002) and (El-Marsafawy, 1995) concluded that water use efficiency increased when the ready soil moisture was reduced at the time of irrigation (eg APE 0.6). Dulaimi (2016) studied the irrigation interval and water requirements on water productivity and found that the EF 1.2 treatment changed from the rest of the treatments and give the best water productivity, with a grain yield rate of 5.02 ton. h^{-1}. Water use efficiency [W.U.E. (kg/m3)] determines the capability of the plants to convert the water consumed to an economical crop yield. The data in table 12 illustrates the effect of the irrigation scheduling and potassium fertilization on the water use efficiency for the quinoa grains. Increasing the pan evaporation coefficient from 0.8 up to 1.4 PEC decreased the water use efficiency for the quinoa grains compared to that when the quinoa plants were irrigated at 0.8 PEC. The water use efficiency for the quinoa grains was increased when the pan evaporation coefficient was increased from 0.8 to 1.0 PEC, than, it was decreased when the pan evaporation coefficient was increased from 1.0 up to 1.4 PEC compared to that when the quinoa plants were irrigated at 0.8 PEC. Similar results were reported by several authors. El-Bably (2007) found that water use efficiency (WUE) was increased as the soil moisture deficit [Irrigation water was applied at 1.2, 1.0 and 0.8 of accumulative pan evaporation (A.P.E.)] was increased. The low frequent irrigation due to irrigation at 0.8 of accumulative pan evaporation (A.P.E.) resulted in a significantly high water use efficiencies compared to the other two irrigation treatments (1.2 A.P.E).

Table 7 shows that the increasing the level of Potassium fertilization from 0.0 to 180kg K_2O h^{-1} has led to increase water use efficiency with the highest increasing was obtain at 120kg $K_2O.h^{-1}$, of 95.83, 22.14 and 9.1 compared to the control l (0.0), 60 and 180kg K_2O h^{-1}, respectively, these findings agree with many researchers (Hadithi, 2002 and El-Hamdi, Knany, 2000) who indicated that improve any growth factor will improves seed production and water use efficiency. These factors include tillage, species, and distance between plants, control of pests, time of planting and plant nutrient supply, (Mengel and Foster, 1973) showed that it is well established that the plants abundantly supplied with K can utilize the soil moisture more efficiently than the K-deficient plants. Thus the high-K plants need less water to produce a given yield than the plants undersupplied with K. Abedel-Nasser and Hussein (2001) indicated that the potassium fertilization (0, 15, 30, and 60kg K2O/fad.) significantly increased the water use efficiency (WUE) by the corn plants from 0.703 to 0.833kg grain/m^3 consumed water as the K level was increased from 0.0 to 60kg K_2O/fad.

Table 7: Effect of Irrigation scheduling and potassium fertilizer level on the water use efficiency of Quinoa plant during the growth season.

Irrigation treatments	Water use efficiency for the quinoa grains (kg grains/m3 consumed water)				
	Level of potassium fertilizer (kg K_2O. h^{-1})				
	0	60	120	180	Mean
0.8 PEF	0.90	0.77	1.48	1.54	1.17
1.0 PEF	0.48	1.30	1.48	1.30	1.14
1.2 PEF	1.07	1.48	1.63	1.59	1.44
1.4 PEF	0.58	1.22	1.30	0.99	1.02
Mean	0.75	1.19	1.47	1.35	1.19
L.S.D	Irrigation treatments A=0.0764 Level of potassium fertilizer B = 0.0.764 AB=0.1528				

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