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IRRIGATION SCHEDULING FOR PEA USING EVAPORATION PAN UNDER DRIP IRRIGATION AT NORTH NILE DELTA REGION.

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ABSTRACT

The aim of this study which was carried out at Sakha Agricultural Research Station, Kafr el-Shiekh Governorate is to determine the most suitable irrigation frequencies for pea grown under drip irrigation system. The irrigation treatments were based on cumulative pan evaporation (CPE) at different empirical pan factors (0.6, 0.8, 1.0, 1.2, 1.4 and 1.6 of CPE. Irrigation interval was based on available water = Ef * CPE.

Results indicated that reducing the irrigation interval through increasing empirical pan factor (Ef) value from 0.6 to 1.6 has a highly significant effect on fresh seed yield. The highest mean fresh seed yield in the two seasons (1066.5 kg/fed.) was obtained when irrigation was done at Ef 1.6 and the lowest fresh seed yield (507.5 kg/fed.) was obtained when we use Ef 0.6. The highest value of crop water productivity CWP (0.93 kg/m^3) was obtained by using Ef 1.6 and the lowest CWP (0.45 kg/m^3) was obtained by using Ef 0.6 . The highest value of biological yield (7.67 ton/fed.) was get with the treatment of Ef 1.4, where the lowest value (5.16 ton/fed.) was resulted from the treatment irrigation at Ef 0.8. Studied treatments have highly significant effects on fresh pod yields. The highest fresh pod yield (2.98 ton/fed.) was produced from treatment irrigation at Ef 1.6, where the lowest value (1.94 ton/fed.) was obtained by using Ef 1.0.

Insignificant differences were found between the studied treatment means regarding to weight of 100 seeds and percentage of moisture in seeds. Number of seeds/pod was high significantly influenced by studied treatments. The number of seeds/pod (9.0) resulted from 1.6 as Ef treatment. While, the lowest number of seeds/pod (7.2) was obtained from Ef 0.6 treatment. The highest value of netting percentage 36.1% was obtained from irrigation at Ef 1.2 and 1.6 treatments, while the lowest 21.2% was obtained from irrigation at Ef 0.6 treatment. The highest mean value of pod filling (0.86) was resulted from irrigation at Ef 1.0, 1.2 and 1.6 treatments. On the other hand the lowest value (0.76) of the pod filling was obtained from irrigation at Ef 1.4. So, it is useful to recommend that the proper irrigation interval could be   scheduled according to CPE.

Keywords: irrigation scheduling – drip irrigation – pea – pan evaporation.

INTRODUCTION

At present, Egypt is facing two main problems, increasing population and water shortage. So, less water is available for agricultural production. Increasing water use efficiency should be one of the major goals maximizing the production of vegetable as well as field crops from the water unit. Vegetable crops require more water and more frequent irrigations than the most of field crops. Little activities could be done to reduce water needs for any given vegetable. Pea (*Pisum sativum L.*) is one of the main legumes grown in Egypt. It is grown for green pods and dry seeds. It considered as a good source of protein, energy and other nutrients. It can be grown in a wide range of soils.

The total volume of water supplied to meet crop needs is influenced by water delivery systems and cultural practices. So, timing of each watering event plays a vital role on effective farm irrigation. In irrigated agriculture, it is necessary to optimize water management and increase the efficiency of water use by group of technical procedures providing the information needed to irrigate at the optimum frequency and time (Singh and Chauman, 1996). For this reason, it is necessary to have information about biotic factors inherent to the plant, physical and hydraulic properties of the soil and atmospheric demand (Maldonado *et al*., 2006).

Irrigation scheduling is one of the most effective tools to preserve water (Fereres, 1996). Furthermore, it allows the increase of crop yield, water economy for a better adjustment to the crop requirements during the growth season and energy savings by avoiding excessive water application. Finally, the use of this methodology improves general farm management (Werner,1996). There are three ways to irrigation program: 1. Analysis of the soil water status (tensiometers, dielectrical sensors and neutron probes), 2. Measurement of the plant water status (xylematic hydric potential, diffusive resistance, foliar temperature) and 3. The water balance method (Howell, 1996 and Werner, 1996). The latter way considered the continuous soil-plant-atmosphere system to generate information about the frequency and time of irrigation (Salazar and Thompson, 1996). A fundamental parameter in the water balance method is the determination of crop demand. Therefore, finding a method to adequately predict crop evapotranspiration has been a goal of researchers for years (Allen *et al*., 1989 and Singh and Chauman, 1996).

Drip or trickle systems are most efficient and are the best adapted to high value vegetable crops. There are many advantages to drip but ability to place a precise quantity in the exact place where the need is the biggest. This ability enables drip system to waste less water in the delivery process compared to surface irrigation system which use ditches, furrows and /or pipes as a delivery vehicle and sprinklers which apply water above the crop.

The drip irrigation system conserved about 30 % of water as compared with surface irrigation (Cetin *et al*., 2002), as it allows small but frequent application of water with minimum losses. In addition, it does not increase air humidity above crop canopy, as much as sprinkler irrigation. Hanson and Bendixen (2004) in an evaluation study of drip irrigation showed that a trickle irrigation system gives 35% higher water use efficiency and 32% lower salt accumulation than surface irrigation. Beck *et al*., (1998) studied ecological and economical control of drip irrigation. They indicated that more than one parameter must be used to get satisfactory correlations between water consumption and the environmental conditions. They also said that evapotranspiration was reduced by using a drip [trickle] irrigation system. Simsek *et al*. (2005) studied the effects of different irrigation regimes, 50, 75,100 and 125% of cumulative pan evaporation, on cucumber (*Cucumis sativus*, L.) under drip irrigation system, open field condition and three days period. Their results demonstrated that application of 100 % of cumulative pan evaporation by drip system in a three day irrigation frequency would be optimal for growth in semi arid regions.

So, the main objectives of the present study are: Obtain the most suitable irrigation interval for pea under drip irrigation system using class A pan evaporation and achieve the best crop water productivity at north Nile delta region.

MATERIALS AND METHODS

Two field experiments were carried out during the two winter seasons of 2008- 2009 and 2009-2010 at Sakha Agricultural Research Station (30° 57̀ N – 31° 07̀ E) and altitude of 6 m above mean sea level, Kafr El-Sheikh Governorate, North Nile Delta region. These experiments were conducted to find out the most suitable irrigation interval under drip irrigation for pea crop (*Pisum sativum L.*) var. Master B. production as well as their water relations. The experimental soil is heavy in texture (59.6% clay), having pH value of 7.8 in soil paste and EC value of 1.87 dS/m in soil paste extract. Field capacity was also determined to be 40.79% as well as permanent wilting point percentage was measured (21.17%). Soil bulk density 1.2 $g.cm^{-3}$.

Climatic data were obtained from Sakha Agro-meteorological Station. The experimental field was ploughed twice by using chisel plougher. A disk harrow was also used to find suitable seed-bed size aggregates and then, the soil was leveled. Seeds were sown on 25th November 2008 and 5th December 2009 in the 1st and 2nd season, respectively. Sowing was done with planting space of 0.15 x 0.8m on two sides of ridges. Irrigation water treatments were started after the complete emergence and conducted according to treatments till maturity stage then irrigation stopped as shown in Table (1). Nitrogen, phosphorus, and potassium fertilizers were applied as recommended through fertigation technique. The treatments were arranged in randomized complete plot design with three replicates. The plots (84 m^2) were randomly assigned to six irrigation scheduling which are;

1. rrigation at 60% of class A pan evaporation (Ef 0.6).
2. rrigation at 80% of class A pan evaporation (Ef 0.8).
3. rrigation at 100% of class A pan evaporation (Ef 1.0).
4. rrigation at 120% of class A pan evaporation (Ef 1.2).
5. rrigation at 140% of class A pan evaporation (Ef 1.4).
6. rrigation at 160% of class A pan evaporation (Ef 1.6).

Table (1): The maturity stage dates for different empirical pan factors treatments in both seasons.

Treatments (Ef)	2008/2009	2009/2010
0.6	22/2/2009	28/2/2010
0.8	18/2/2009	24/2/2010
1.0	26/2/2009	3/3/2010
1.2	22/2/2009	2/3/2010
1.4	28/2/2009	26/2/2010
1.6	25/2/2009	2/3/2010

- Scheduling irrigation using cumulative pan evaporation (CPE) as following steps:

1. Usable capacity of the soil moisture reservoir for a field and crop must be determined. The soil moisture reservoir capacity is limited by soil depth from which the crop extracts appreciable amount of water. The upper 45 cm depth of the soil surface were used in estimating the soil moisture reservoir in the present study.
2. Soil available water (AW) for 45 cm depth was 106 mm. multiply this result by 30% (allowable moisture depletion AMD for pea) to get 32 mm which is the usable moisture at every irrigation.
3. Divide the usable moisture 32 by the studied empirical factors (Ef 0.6, 0.8, 1.0, 1.2, 1.4, and 1.6). The usable moisture values at every irrigation for each treatment in Table (2).
4. 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.
5. Determine the irrigation interval by setting the cumulative pan evaporation (CPE) to be equal to the usable moisture at every irrigation for each treatment as following equation:

$$CPE = \frac{A.w * AMD}{Ef}$$

Where: CPE= cumulative pan evaporation, Ef= Empirical pan factor (0.6, 0.8, 1.0, 1.2, 1.4&1.6), AW= Available water (mm) for the soil for effective root zone depth, and AMD= Allowable moisture depletion by setting lower limit 30%.

Then, it could identify the number of days should be irrigated depends upon the CPE values.

Table (2): CPE values for each studied empirical pan factors (Ef).

Treatments (Ef)	**CPE, mm**
0.6	53
0.8	40
1.0	32
1.2	27
1.4	23
1.6	20

- The amount of applied irrigation water during the irrigation treatments was determined according to crop evapotranspiration (ETc) :

$$ET_{\circ} = EP * K_p$$ and

$$ETc = ET_{\circ} * K_c$$

Where, ET_O = potential evapotranspiration in mm/day, Ep= evaporation from pan evaporation, mm., K_p =Pan coefficient which was considered as 0.85 for pan evaporation and K_c = crop coefficient.

$$IW = \frac{ET_c * A}{Ea}$$

Where: IW equals amount of irrigation water (L); ET_c equals crop evapotranspiratin ,mm; A equals plot area (m^2). and application efficiency E_a (85%).

- Crop water productivity (CWP), Kg m^{-3} which defined as water utilization efficiency was calculated according to Doorenbos and Pruitt (1977) as follow:

$$CWP = \frac{Yield\ (\text{kg/fed.})}{Irrigation\quad water\ applied\ (m^3 / fed.)}$$

- Yield and its components were recorded such as;
  1. Biological yield, (ton/fed.).
  2. Fresh pod yield, (ton/fed.).
  3. Fresh seed yield, (ton/fed.).
  4. Weight of fresh 100 seeds,(gm).
  5. Number of seeds/pod.
  6. Netting percentage (%);

$$Netting\ \% = \frac{Weight\ \ of\ \ green\ seed\ (g)}{Weight\ \ of\ \ green\ pod\ (g)} \times 100$$

  7. Pod filling;

$$Pod\quad filling = \frac{Number\quad of\quad seeds / pod}{Pod\ \ length\ \ (cm)}$$

  8. Percentage of moisture in seeds.

The collected data were subjected to the statistical analysis, using the analysis of variance (ANOVA). The Duncan's multiple range test was used to compare between the means (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Data in Table (3) show that the irrigation interval is decreased by increasing Ef value from 0.6 to 1.6. The longest interval (8 days in Dec., Feb. and March and 9 days in Jan.) was obtained when Ef 0.6 was used and the shortest irrigation interval (4 days in Dec. and Jan. - 3 days in Feb. and March) was obtained by using Ef 1.6. Tabulated data in Table (3) also show the mean irrigation interval for each Ef value and in each growing month.

Table (3): Average of irrigation intervals (day) during growing months under different empirical pan factors.

Treatments (Ef)	Dec.	Jan.	Feb.	March
0.6	8	9	8	8
0.8	7	7	6	8
1.0	6	6	5	5
1.2	5	6	4	4
1.4	5	5	4	4
1.6	4	4	3	3

The amount of seasonal applied irrigation water (IW) including rainfall, fresh seed yield and crop water productivity (CWP) for different treatments are tabulated in Table (4). Results indicate that reducing the irrigation interval through empirical factor (Ef) 0.6 to 1.6 has a highly significant effect on amount of applied water. The amount of water applied was varied between all treatments at both seasons. It could be resulted from different maturity stage dates (Table, 1) which differ between treatments according to water stress which occur due to elongate the irrigation interval thought the studied treatments. High significant effects also resulted between treatments on fresh seed yield. The highest mean fresh seed yield in the two seasons (1066.5 kg fed^{-1}.) was obtained when we irrigate at Ef 1.6 and the lowest fresh seed yield (507.5 kg/fed.) was obtained when Ef 0.6 was used. Thus, it can be lead that the yield not only function of amount of applied water but it is a function also of time of watering. Regarding crop water productivity, data in Table (4) reveal that the highest value of CWP (0.93 kg m^{-3}) was resulted from using Ef 1.6 and the lowest CWP (0.45 kg m^{-3}) was obtained by using Ef 0.6. These results agreed with Martin and Jamieson (1996) and El-Mansi *et al*. (1999)

Table (4): Seasonal water applied m^3, fresh seed yield kg $fed._{}^{-3}$ and crop water productivity, kg m^{-3}. for different treatments in both seasons.

Treat. Ef	1st season 2008/2009				2nd season 2009/2010				Mean of both seasons		
	IW, m^3/fed.	Rainfall, m^3/fed.	Total, m^3/fed.	Fresh seed yield, Kg/fed.	IW, m^3/fed.	Rainfall, m^3/fed.	Total, m^3/fed.	Fresh seed yield, Kg/fed.	Total of IW, m^3/fed.	Seed yield, kg/fed.	CWP, Kg/$m^{3.}$
0.6	974.03	154.98	1129.01 d	526.0 d	1028.88	108.36	1137.24 c	489.0f	1133.13	507.5	0.45
0.8	938.73		1093.71 f	601.0 cd	993.58		1101.94 f	633.0d	1097.83	617.0	0.56
1.0	997.53		1152.51 b	559.0 d	1052.38		1160.74 a	509.0e	1156.63	534.0	0.46
1.2	972.33		1127.31 e	753.0 bc	1027.18		1135.54 d	827.0c	1131.43	790.0	0.70
1.4	1018.53		1173.51 a	907.0 ab	1010.38		1118.74 e	1034.0b	1146.13	970.5	0.85
1.6	993.33		1148.31 c	1039.0 a	1048.18		1156.54 b	1094.0a	1152.43	1066.5	0.93

Data in Table (5) presents the biological yield, fresh pod yield and its components as affected by different treatments. Regarding biological yield there is highly significant differences between the studied treatment means.

The highest value (7.67 ton/fed.) was obtained with the treatment of Ef 1.4, where the lowest value (5.16 ton/fed.) was obtained with the treatment irrigated at Ef 0.8. Data revealed also that the studied treatments have highly significant effects on fresh pod yields. The highest fresh pod yield (2.98 ton/fed.) was obtained from treatment irrigated at Ef 1.6, where the lowest value (1.94 ton/fed.) was obtained by using Ef 1.0. Similar results were found by Sawan (2001).

Non significant differences were found regarding to weight of 100 seeds and percentage of moisture in seeds. So, it can be stated that the studied treatments haven't any significant effects on weight of 100 seeds. Because the moisture in seed considers the main component of about 70.9-72.5% of seed weight. Number of seeds /pod was high significantly influenced by studied treatments. The number of seeds/pod (9.0) resulted from Ef 1.6 treatment. While, the lowest number of seeds/pod (7.2) was obtained from Ef 0.6 treatment.

Tabulated data in Table (5) also show that significant effects on netting percentage were resulted from the studied treatments, the highest value (36.1%) was obtained from irrigation at 1.2 and 1.6 treatments, while the lowest (21.2%) was resulted from irrigation at 0.6 treatment. Regarding pod filling, there are highly significant differences between studied treatments. The highest mean value (0.86) was resulted from irrigation at Ef (1.0, 1.2 and 1.6) treatments. On the other hand, the lowest value (0.76) of the pod filling was obtained from irrigation at Ef 1.4.

Finally, it could also be concluded that, yield is not only function of amount of applied water but it is a function of time of watering. Irrigation scheduling which based on daily evaporation records is more efficient for effective irrigation from point of water view. The effective evaporation pan empirical factor of pea is 1.6 if could be implemented at the short water rotation and use 1.4 at long water rotation which produce high yield and high crop water productivity.

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جدولة ري البسلة باستخدام وعاء البخر تحت نظام الري بالتنقيط بمنطقة شمال دلتا النيل

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أقيمت تجربتان حقليتان خلال موسمى 2009/2008م ، 2010/2009م بحقل الري الحديث - قسم بحوث المقننات المائية والري الحقلي – محطة البحوث الزراعية بسخا – محافظة كفرالشيخ وتناولت الدراسة تأثير استخدام معاملات تجريبية مختلفة من وعاء البخر القياسي طراز أ (0.6 ، 0.8، 1.0 ،1.2 ، 1.4 و 1.6) تحت نظام الري بالتنقيط على محصول البسلة. حيث حددت فترة الري بناء على البخر التجميعي والمعاملات السابقة حيث:

الماء الميسر(مم) X معامل الاستنفاذ الرطوبي المسموح به لمحصول البسلة = البخر التجميعي (مم) X المعامل التجريبي (0.6 أو 0.8 او 1.0 أو 1.2 أو 1.4 أو 1.6).

وعليه: عندما يصل البخر التجميعي إلى القيمة الناتجة من المعادلة تتم عملية الري.

وقد أوضحت النتائج ما يلي:

تقصير الفترة بين الريات نتيجة زيادة المعاملات التجريبية تبدأ من 0.6 إلى 1.6 له تأثير كبير على محصول البذور الخضراء حيث تم الحصول على أعلى متوسط محصول خلال موسمي الزراعة (1066 كجم/فدان) بالري عند معامل تجريبي 1.6 بينما تم الحصول على اقل محصول من البذور الخضراء(507.5 كجم/فدان) بالري عند معامل تجريبي 0.6. كما حققت المعاملة 1.6 اعلي قيمة من إنتاجية وحدة المياه CWP وكانت 0.93 كجم/م^3 بينما حققت المعاملة 0.6 اقل قيمة لإنتاجية وحدة المياه 0.45 كجم/م^3.

أعلى محصول بيولوجي (7.67 طن/فدان) تم الحصول عليه بالري عند معامل 1.4 في حين اقل محصولا (5.16 طن/فدان) كان بالري عند معامل 0.8. وكانت للمعاملات المدروسة تاثيرات عالية المعنوية على محصول القرون الخضراء فأعطت المعاملة التي تروى عند معامل 1.6 أعلى محصول قرون خضراء (2.98 طن/فدان) في حين أعطت المعاملة التي تروى عند معامل 1.0 اقل محصولا من القرون الخضراء(1.94 طن/فدان)، كما لا توجد فروق معنوية بين المعاملات المدروسة على كل من وزن 100 بذرة و النسبة المئوية للرطوبة في البذور.

أظهرت النتائج أن هناك فروق عالية المعنوية بين المعاملات المختلفة في عدد البذور في القرن الواحد حيث أعطت المعاملة التي تروى عند معامل 1.6 اعلي قيمة (9.0) في حين أعطت المعاملة التي تروى عند معامل 0.6 أقل قيمة (7.2)، كما أعطت المعاملتان التي ترويان عند معامل 1.2 و1.6 أعلى قيمة للنسبة المئوية للتصافي (36.1%)، حين أعطت المعاملة التي تروى عند معامل 0.6 اقل قيمة تصافي(21.2%).وكانت درجة امتلاء القرون في أعلى قيمة لها (0.86) في المعاملات التي تروى عند معامل (1.0، 1.2 و 1.6) وكانت اقل درجة امتلاء للقرون (0.76) بالري عند معامل 1.4.

وعليه: ينصح باستخدام المعامل 1.6 (الري كل 3 أيام) لتحديد ميعاد الري في حالة مناوبات الري القصيرة أما إذا كانت فترة المناوبات طويلة فيمكن استخدام المعامل 1.4 (الري كل 4 أيام) وذلك للحصول على أفضل محصول من وحدتي المياه والأرض.

قام بتحكيم البحث

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Table (5): Biological yield and green pods yield and its components as affected by different treatments during seasons of 2008-2009 and 2009-2010.

Treat. (Ef)	Biological yield, ton/fed.			Fresh pods yield, ton/fed.			Weight of 100 seeds, g			Number of seeds/pod			Netting percentage (%)			Pod filling			Percentage of moisture in seeds, %.		
	1st season	2nd season	Mean	1st season	2nd season	Mean	1st season	2nd season	Mean	1st season	2nd season	Mean	1st season	2nd season	Mean	1st season	2nd season	Mean	1st season	2nd season	Mean
0.6	5.46 bc	5.45 b	5.46	2.03 c	2.01 b	2.02	51.0 ab	49.4 ab	50.2	6.7 c	7.6 bc	7.2	18.3 b	24.1 c	21.2	0.72 d	0.87 b	0.80	70.3 b	72.3 a	71.3
0.8	5.04 c	5.25 b	5.16	2.26 bc	2.07 b	2.17	47.0 b	50.5 ab	48.8	7.9 b	6.9 c	7.4	26.6 ab	30.7 b	28.7	0.88 abc	0.72 f	0.80	72.0 ab	70.1 a	71.1
1.0	6.16 bc	5.74 b	5.95	1.89 c	1.99 b	1.94	51.2 ab	47.0 b	49.1	8.1 b	6.9 c	7.5	29.5 ab	25.6 c	27.6	0.95 a	0.77 d	0.86	73.1 a	70.5 a	71.8
1.2	5.88 bc	5.88 b	5.88	2.17 bc	2.24 b	2.21	56.6 a	54.5 a	55.6	7.1 c	8.3 ab	7.7	35.2 a	37.0 a	36.1	0.75 cd	0.97 a	0.86	71.1 ab	71.0 a	71.1
1.4	9.24 a	6.09 b	7.67	2.72 ab	2.94 a	2.83	57.6 a	51.7 ab	54.7	8.5 ab	8.5 a	8.5	33.3 ab	35.3 a	34.3	0.77 bcd	0.74 e	0.76	71.4 ab	70.7 a	70.9
1.6	7.56 ab	7.35 a	7.46	2.91 a	3.06 a	2.98	55.8 a	55.5 a	55.6	8.9 a	9.0 a	9.0	36.3 a	35.8 a	36.1	0.89 ab	0.82 c	0.86	72.0 ab	73.0 a	72.5