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OPTIMIZE IRRIGATION WATER USE OF GREEN PEAS UNDER DEFICIT IRRIGATION IN SEMI-ARID REGIONS

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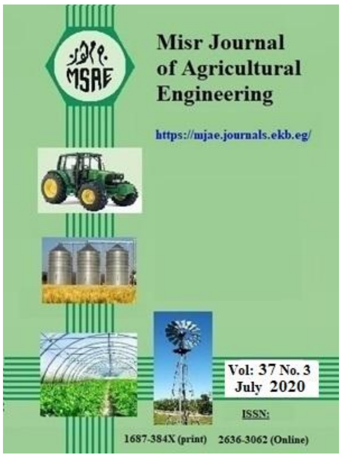

Keywords:
Peas, Deficit irrigation, water use efficiency, stressed-growing stages.

ABSTRACT

A study was carried out in the 2017 and 2018 cropping seasons, to determine the effect of deficit irrigation and stressed growing stages on the green pea yield and water use efficiency under semi-arid climatic conditions of Elbayda, Libya. Irrigation treatments included *(IR100: 1 time potential crop evapotranspiration* (ET_c), *IR90: 0.9* ET_c, *IR80: 0.8 IR70 and 0.7* ET_c, ET_4*)*, and stressed-growing stages included vegetative (*V*), flowering (*F*), pods (*P*) and all stages (*A*). It is clear from the results that the water regime affected the growth and yield of the pea plants. Both the level of deficit and its timing during the plant life had an effect on the plant growth indicators and the final plant yield. In general the yield decreased as the deficit level increased but the water use efficiency increased with mild water deficit (*IR90*) then decreased as the deficit level increased. The drought stress during the flowering stage resulted in an increase in the final yield of the pea plants. The water regime to achieve the highest water use efficiency (*WUE)* while minimizing the water use is 80 % ET_c during the flowering stage (IR80). The highest value of yield production would be at 90% ET_c during the flowering stage (*IR90F*).

INTRODUCTION

Agriculture practices is the largest freshwater consumer worldwide, these processes are responsible for the largest share of freshwater use worldwide (Gan et al., 2013). The problem of freshwater supply is becoming eminent all over the world, (Chai et al., 2014), the overuse of irrigation water is becoming a serious problem in some areas of the world specially in arid and semiarid areas (Forouzani and Karami, 2011). The problem seems to be getting worse with a 30% increase in world population projected by 2050 (Godfray et al. 2010), and the now present climatic changes (de Wit and Stankiewicz, 2006). Schiermeier (2014) said that up to 20% of the world population may have severe fresh water shortage in the near future. Some countries, like Egypt the amount of water per capita has been decreasing for several years because of the rapid increase of population. Fawaz and Soliman (2016) reported that availability of water resources per capita in Egypt decreased by 8.9% from 2007 to 2011 and that the water deficits in Egypt is expected to reach 8.84 billion m^3 in 2030. Fereres and Soriano (2007) pointed out that other humane activities are competing with

Agricultural production for fresh water, and with the rapid increase in water demand the agricultural share of fresh water is decreasing. Johnson et al., (2001) defined sustainable water management as all practices that can improve crop yield, and minimize water losses thus improving irrigation water use efficiency. Different method can be used to conserve water in agricultural practices such as changing the irrigation system to a more efficient system, or using water conservation techniques such as deficit irrigation. Deficit irrigation is maximizing the yield per water unit while using the minimum amount of water possible (Fereres and Soriano 2007). Chai, et al. (2016) and Kögler and Söffker (2017) found that exposing plants to some drought stress using Regulated Deficit Irrigation (RDI) can lead to a yield reduction of up to 10 % with water saving exceeding 20% of the crop water requirements resulting in an increase in the crop water use efficiency. Deficit irrigation planning can either use Sustained deficit (deficit all around the growing season) (Fernandes-Silva et al., 2018), or regulated deficit (the growing season is divided to different stages based on the plant physiological process and deficit irrigation is applied in some certain stages) (Capra et al., 2008; and Chai et al., 2016). Regulated deficit irrigation needs good planning and an accurate scheduling of the water amount applied or it will lead to sever yield decrease. Nagaz et al. (2012) studied the effect of deficit irrigation on the production of onions they reported that sever water deficit significantly decreases the yield and the quality of the produced onion. But good planning of the deficit strategy can increase the water use efficiency by reducing the amount of used water without significant reduction in yield. Taha et al. (2019) achieved a 20% reduction in applied water for onion grown under sprinkler irrigation system. This water reduction caused only 8% yield reduction. Shalaby et al. (2014) found a yield loss of 7–9% in tomato grown under drip irrigation when reducing the applied water by 25%. Pea (*Pisum sativum* L.) is one of the major legume vegetable crops produced and consumed all over the world. It's important for human nutrition because it has a high content of vitamins, protein, minerals and carbohydrates (Ashraf et al., 2011). Fallon et al., 2006, and Jin et al., 2014 reported that pea yields are reduced by water deficits and air temperature extremes. In general, peas are more sensitive to water deficit during of flowering and pods/grains filling than is the vegetation stage (Lecoeur and Guilioni, 2010; and Rasaei et al., 2012). Sorensen et al. (2003) reported that although the yield of green peas was affected by the drought stress but the texture quality could be maintained if green peas were harvested at the optimum maturity.

The aim of this work is to maximize the water use efficiency and the expected yield of green pea under deficit irrigation in the semi-arid regions.

MATERIALS AND METHODS

1. Study area

The study was conducted at the experimental farm of Horticultural Department, Faculty of Agriculture, Omar El-Mukhtar University. The site was located at 449m altitude, 32.8^{o} N latitude and 21.8^{o}E longitude. The experiment was conducted in the spring season of 2017 and 2018. Some chemical and physical characteristics of the experimental field soil are shown in tables (1) and (2). Also table (3) shows some physical analysis of irrigation water used in the experiment. The average monthly metrological data (from March to June) for the location of the experimental field are shown in table (4).

Table (1): Some chemical properties of the experimental field soil

Depth, Cm	EC_e dS/m	Cations (meq/L)				Anions (meq/L)		
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-} + CO_3^{--}	SO_4^{--}
0 – 25	0.86	2.4	1.5	4.5	0.3	3.5	2.2	3
25 – 50	0.76	2.0	1.4	3.8	0.4	3.4	2.1	2.1

Table (2): Some physical properties of the experimental field soil

Depth, cm	Particle size distribution (%)			Texture Class	F.C %	W.P %	Soil Bulk Density, g/cm^3
	Sand	Silt	Clay				
0 - 25	28.2	34.1	37.7	Clay loam	35.2	21.1	1.29
25 - 50	22.3	38.0	39.7	Clay loam	37.5	22.2	1.27

Table (3): Analyses of the irrigation water samples.

EC	Cations (meq/L)				Anions (meq/L)		
ds/m	Na^{+}	Ca^{++}	Mg^{++}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{--}
0.72	3.2	2.1	1.5	0.4	2.6	3.5	1.1

Table (4): Average monthly metrological data of the experimental field zone and the calculated reference evapotranspiration.

Month	Tmin (°C)	Tmax (°C)	Humidity, %	Wind, km/day	Sunshine, hrs	Radiation, MJ/m²/day	ET_o, mm/day	Eff. Rain mm
March	6	16	73	389	5.7	14.9	2.63	58.2
April	8.2	20.5	65	380	7	18.9	3.95	29.5
May	11.6	24.3	60	259	8.9	23	4.86	6.9
June	15	28.2	56	251	10	24.9	5.86	2

2. Plantation and management

Vitto Peas (*Pisum L*) were grown for two consecutive years at the same season each year. For each of the two years of the experiment the pea seeds were sown (in a nursery) in the middle of March, and the plants were transplanted in the permanent field at the stage where plants are about 10 cm in height. The plantation distances were 15 cm in the same row with row spacing of 50 cm. A 16 mm (OD) drip irrigation lines with 4 l/h (operating at 1 bar), pressure compensating inline emitters at an emitter spacing of 30 cm were used for water delivery. Figure (1) shows the experimental layout. The experimental design was factorial two factors (Complete Randomized Design, CRD) with 3 levels of irrigation as one factor and 4 different drought stress stages as the second factor, and a control treatment with 100% of the plant water requirement *IR100A*. The 3 levels of irrigation were (90% of the plant water requirement *IR90*, 80% of the plant water requirement *IR80*, and 70% of the plant water requirement *IR70*), and the four stressed-growing stages were (vegetative *V*, flowering *F*, pods *P* and all *A)*. Each combination was replicated three times. Thus, the total number of experimental units was 39 units, and the length of each experimental unit was 10 m with a separating distance of 1.0 m left blank between the units. The field experiment was divided into 13 treatments as shown in table (5). Plant water requirements were estimated using the ***CROPWAT*** software and the recommendations of the ***FAO Penman-Monteith*** paper (FAO 56, Allen et al., 1998) for the crop coefficient and the lengths of the growing stages. The total crop evapotranspiration ET_c was then calculated as mm. The initial soil moisture content before water application ranged from 22.8 to 24.9 % by weight.

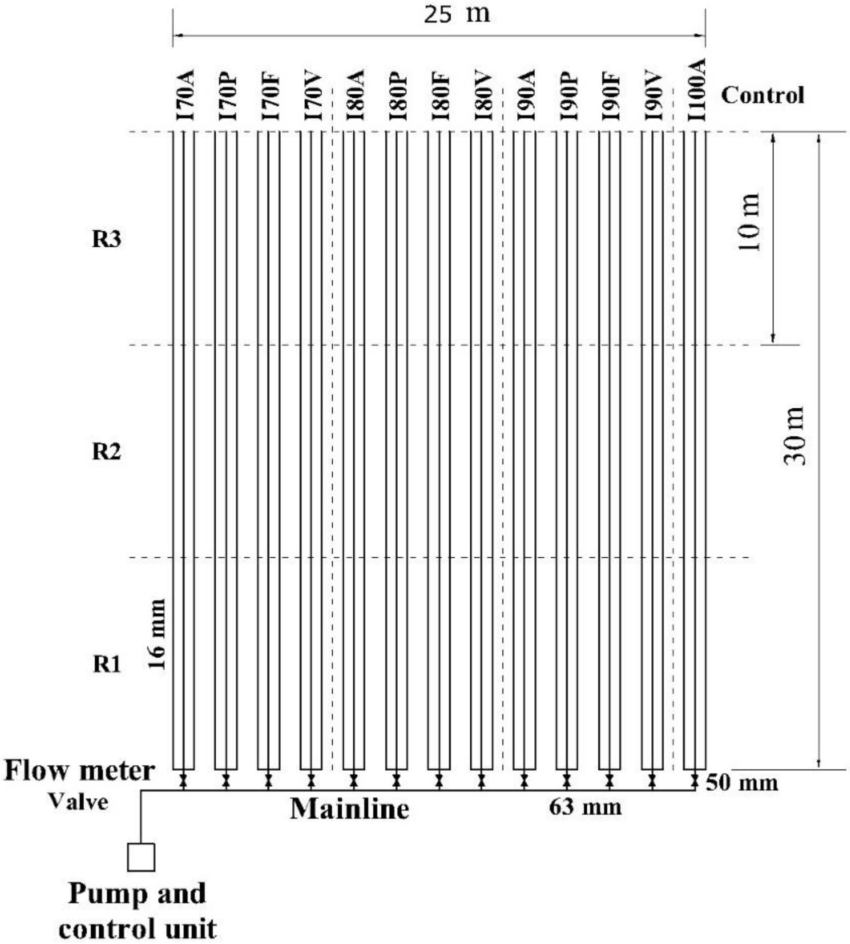

Figure (1): Experimental layout

3. Measurements and calculations

3.1. The total yield (*Y*)

The total green peas yield (fresh weight) of each experimental unit were harvested at end of June and weighed.

3.1. Water use efficiency (WUE)

The water use efficiency (*WUE*) was calculated from equation (1) according to Lovelli et al. (2007).

$$WUE = \frac{Y}{IRR} \qquad (1)$$

Where:

WUE = The water use efficiency, kg.m^{-3};

Y = The total green peas yield, kg.ha^{-1};

IRR = The total amount of irrigation (table 5) supplied (According to ***FAO Penman-Monteith***), m^3 ha^{-1}.

3.2. Crop parameters of pea

The measured parameters included crop seed yield, above ground biomass, plant height, number of pods per plant, 1000 seed weight, and resulting harvest index (*HI*). The harvest index was calculated from equation (2).

$$HI = \frac{Y}{B} \qquad (2)$$

Where, Y is the total yield (kg.ha^{-1}), and B is the above ground biomass (kg.ha^{-}1).

Table (5): Experimental treatments

Treatment description	Treatment symbo
1. 90% of the plant water requirement at vegetative stage	IR90V
2. 90% of the plant water requirement at flowering stage	IR90F
3. 90% of the plant water requirement at pods stage	IR90P
4. 90% of the plant water requirement at all stages	IR90A
5. 80% of the plant water requirement at vegetative stage	IR80V
6. 80% of the plant water requirement at flowering stage	IR80F
7. 80% of the plant water requirement at pods stage	IR80P
8. 80% of the plant water requirement at all stages	IR80A
9. 70% of the plant water requirement at vegetative stage	IR70V
10. 70% of the plant water requirement at flowering stage	IR70F
11. 70% of the plant water requirement at pods stage	IR70P
12. 70% of the plant water requirement at all stages	IR70A
13. 100% of the plant water requirement at all stages (control)	IR100A

3.3. Statistical analysis

The results were statically analyzed using the ***ANOVA*** analysis and the means were compared using the Duncan ***LSD*** method.

RESULTS AND DISCUSSION

1. Applied water

Before planting, 85 mm irrigation water was applied to all treatments to bring the soil water content in 0–60 cm soil depth up to the level of field capacity. The total amounts of irrigation water applied (from transplantation to harvest) in this study were 214.5 and 236 mm for control treatment *IR100A* (100 % ETc) in seasons, 2017 and 2018, respectively as shown in table (5). The results showed that the treatments with deficit irrigation during the flowering stage (*F*) only, received the second largest amount of water between all treatments after the control in both years of the experiment. This is because the flowering stage is the shortest period in all of the plant growing stages. The treatments with deficit in the pods stage (*P*) was next then the treatments with deficit in the vegetation stage (*V*), whereas the least amounts of water occurred in the treatments with irrigation deficit all around the growing season for all levels of irrigation deficit used.

1. Green peas yield

Seed yields (kg ha^{-1}) of pea were affected by the irrigation deficit level and the different stressed growth stages table (7). The obtained results indicated that pea seed yield decreased as the level of deficit irrigation increased. Moreover, for the stress stage the treatments with deficit irrigation in the flowering stage (***F***) had the highest seed yields followed by the treatments with deficit irrigation in the pods stage (*P*) then the treatments with deficit irrigation in the vegetation stage (*V*). Whereas the least seed yields occurred in treatments with deficit irrigation all the season (*A*) for all levels of irrigation deficit. The maximum average seed-yield for the treatment was within 90 % ET_c at the flowering stage (*IR90F*) with an average seed yield of (5412 kg ha^{-1}). The comparison of the means showed that in case of the *IR90F* there was no significant difference between *IR90F* treatment and the control *IR100A*. The least average value of seed-yield (3395 kg ha^{-1}) was recorded with 70 % ET_c treatment for all the season (*IR70A*). Decreased yield could be largely attributed to the decrease in soil moisture, which led to increasing plant growth and, hence, increasing nutrients uptake.

Table (6): Applied water depth in (mm) for different stressed-growing stages under different irrigation deficits.

Irrigation level	Year	Growing stage			
		V	***F***	***P***	***A***
IR90	**2017**	204.0	210.0	208.0	193.1
	2018	224.5	231.6	229.2	212.4
	Average	214.3	220.8	218.6	202.7
IR80	**2017**	193.0	206.1	201.0	171.6
	2018	212.7	226.8	222.1	188.8
	Average	202.9	216.5	211.6	180.2
IR70	**2017**	182.5	207.8	195.0	150.2
	2018	200.9	222.1	215.1	165.2
	Average	191.7	212.0	205.1	157.7
Control *IR100A*	**2017**	214.5			
	2018	236			
	Average	225.3			

V = Vegetative stage, F = Flowering stage, P= Pods stage and A = All stages

Table (7): Total green peas yield (kg ha^{-1}) under deficit irrigation levels and stressed-growing stages.

Irrigation level	Year	Growing stage			
		V	***F***	***P***	***A***
IR90	**2017**	4876^{abAB}	5140^{aA}	4992^{abAB}	4633^{abB}
	2018	5411^{aA}	5684^{aA}	5524^{aAB}	4993^{abB}
	Average	5144	5412	5258	4813
IR80	**2017**	4139^{bcBC}	5031^{aA}	4623^{abB}	3865^{bcC}
	2018	4591^{bB}	5443^{aA}	5175^{aA}	4195^{bC}
	Average	4365	5237	4899	4030
IR70	**2017**	3776^{cBC}	4846^{abA}	4368^{bAB}	3361^{cC}
	2018	3843^{bcB}	4918^{abA}	4840^{abA}	3429^{cC}
	Average	3810	4882	4604	3395
Control *IR100A*	**2017**	5083^{aA}			
	2018	5655^{aA}			
	Average	5369			

Means with the same letters within the same treatment and column are not significantly different at $P<0.05$.

2. Physical crop parameters of green peas

The measured pea crop physical parameters (plant height, number of branches per plant, number of pod per plant, 1000-seed weight, biomass and harvest index) for all treatments at different levels of deficit irrigation is given in table (8). As shown in Table 8, it is clear that all physical crop parameters decrease with increasing level of deficit irrigation.

For stressed-growing stages, the maximum values of plant height (62.2 and 66.9 cm for both seasons, respectively), number of branches (7 and 7 for both seasons, respectively), number of pods (21 for second season), 1000-seed weight (274.3 and 286.7 g for both seasons, respectively), biomass (13653 and 13946 kg ha^{-1} for both seasons, respectively) and harvest index (0.38 and 0.41 for both seasons, respectively) were recorded with *IR90F*. The minimum values of number of branches (5 and 6 for both seasons, respectively), number of pods (10 and 11 for both seasons, respectively), biomass (9841 and 10641 kg ha^{-1} for both seasons, respectively) and harvest index (0.33 and 0.32 for both seasons, respectively) were recorded with *IR70A*. While minimum values of 1000-seed weight (246.8 and 251.3 g for both seasons, respectively) were recorded with *IR70P*. The analysis showed that water levels and stressed-growing stages significantly ($p<0.05$) influenced crop parameters, plant height, number of pods, 1000 seed-weight biomass and harvest index, while number of branches was not significantly affected.

Table (8): Crop parameters of pea crop under deficit irrigation levels and stressed-growing stages.

Treats.	Plant height, Cm		Number of branch		Number of pod		1000 seed-weight, g		Biomass, kg ha^{-1}		Harvest index	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
IR100A	61.3^{a}	67.9^{a}	7^{a}	7^{a}	18^{b}	20^{a}	276.2^{a}	283.1^{a}	13519^{a}	14023^{a}	0.40^{a}	0.40^{a}
IR90A	57.9^{ab}	62.1^{ab}	6^{b}	7^{a}	18^{b}	19^{a}	267.4^{b}	277.9^{ab}	13045^{ab}	13576^{ab}	0.36^{ab}	0.37^{ab}
IR80A	53.6^{bc}	57.6^{b}	6^{b}	7^{a}	15^{cd}	16^{c}	258.3^{bc}	264.5^{b}	11647^{bc}	12304^{bc}	0.33^{c}	0.34^{b}
IR70A	51.4^{c}	52.4^{c}	5^{c}	6^{b}	10^{e}	11de	250.3^{c}	253.8^{c}	9841^{c}	10641^{c}	0.33^{c}	0.32^{c}
Vegetative stage												
IR90V	59.4^{a}	61.7^{ab}	7^{a}	7^{a}	18^{b}	18^{b}	273.7^{a}	280.7^{a}	13264^{ab}	13173^{b}	0.37^{ab}	0.41^{a}
IR80V	53.1^{bc}	56.3^{b}	7^{a}	7^{a}	17^{c}	18^{b}	264.3^{b}	271.6^{ab}	12715^{b}	13107^{b}	0.35^{b}	0.35^{b}
IR70V	52.8^{c}	51.1^{c}	6^{b}	6^{b}	12de	15^{cd}	259.2^{bc}	263.4^{b}	10443^{c}	10814^{c}	0.35^{b}	0.36^{ab}
Flowering stage												
IR90F	62.2^{a}	66.9^{a}	7^{a}	7^{a}	19^{a}	21^{a}	274.3^{a}	286.7^{a}	13653^{a}	13946^{a}	0.38^{ab}	0.41^{a}
IR80F	61.5^{a}	64.2^{a}	7^{a}	7^{a}	18^{b}	20^{a}	270.6^{ab}	279.2^{a}	13426^{a}	13516^{ab}	0.37^{ab}	0.40^{a}
IR70F	59.1^{a}	61.7^{a}	6	7^{a}	17^{c}	19^{b}	258.1^{bc}	271.9^{ab}	13198^{ab}	13587^{ab}	0.37^{ab}	0.36^{ab}
Pods stage												
IR90P	53.6^{bc}	52.9^{bc}	7^{a}	7^{a}	20^{a}	20^{a}	270.7^{ab}	285.6^{a}	13317^{ab}	13376^{b}	0.37^{ab}	0.41^{a}
IR80P	50^{cd}	51.4^{c}	7^{a}	7^{a}	19^{a}	20^{a}	261.7^{bc}	271.5^{ab}	13241^{ab}	13397^{b}	0.35^{b}	0.39^{a}
IR70P	48.6^{d}	50.3^{d}	6^{b}	7^{a}	19^{a}	20^{a}	246.8^{c}	251.3^{c}	12526^{b}	12810^{bc}	0.35^{b}	0.38^{ab}

NS and *: Non-significant, significant at $P > 0.05$. Means with the same treatment and column sharing the same letters are not significantly different at $P<0.05$.

3. Water use efficiency (*WUE*) of green peas

Deficit irrigation significantly influenced *WUE* at all stages. As shown in Table (9), the values of *WUE* increased with the increase of the deficit level then decreased as the level of deficit increased.

The comparison between the stressed stages shows that the treatments with the deficit during the flowering stages had the highest values of *WUE* for all levels of irrigation deficit, followed by the treatments with the deficit at the pods stage *(P*) then the treatments with the deficit at the vegetation stage (*V).* The maximum *WUE* in 2017 and 2018 was 2.45 kg m^{-3} for the treatment with 90% ETc at the flowering stages (*IR90F*). At 80 % ETc at the flowering stages (*IR80F*) the average *WUE* for the two seasons was 2.42 kg m^{-3}.

Table (9): Water use efficiency (kg.m^{-3}) of pea crop under deficit irrigation levels and stressed-growing stages.

Irrigation level	Year	Growing stage			
		V	F	P	A
IR90	2017	2.39^{a}	2.45^{a}	2.40^{a}	2.40^{a}
	2018	2.41^{a}	2.45^{a}	2.41^{a}	2.35^{a}
	Average	2.40	2.45	2.41	2.38
IR80	2017	2.28^{ab}	2.44^{a}	2.30^{ab}	2.25^{ab}
	2018	2.16^{ab}	2.40^{a}	2.33^{ab}	2.22^{ab}
	Average	2.22	2.42	2.32	2.24
IR70	2017	2.01^{c}	2.33^{ab}	2.24^{ab}	2.17^{bc}
	2018	1.91^{c}	2.21^{ab}	2.25^{ab}	2.08^{bc}
	Average	1.96	2.27	2.25	2.12
Control IR100A	2017	2.37^{a}			
	2018	2.40^{a}			
	Average	2.385			

Means with the same letters within the same treatment and column are not significantly different at $P<0.05$.

Different levels of water regimes applied at different growth stages of green peas showed sound effects on the growth and yield of the pea plants. Water deficit are usually accompanied with a decrease in photosynthetic carbon assimilation, which causes a reduction in both vegetative growth and total yield (Yordanov et al., 2000). Water deficit together with high temperature constitute the main abiotic stresses that affect pea crops (Guilioni et al. 2003). The effect of the drought stress on plants was highly proportional to the level of the drought and its duration. The results indicated that *IR90* promoted the positive effects of drought stress such as earlier and heavier plant flowering. Both the level of water deficit and its timing during the plant life had an effect on the plant growth indicators and the final plant yield. In general, higher irrigation deficit resulted in decrease in the yield and most of its growing parameters. The results of *WUE* showed that the highest levels of the *WUE* was for the treatments at *IR90*. At this level of deficit, the reduction in yield is insignificant; moreover, the total yield of this treatment and the control is statistically the same. With a water consumption reduction of 10% of the total amount of water supplied, the WUE of this treatment was the highest. For treatments with higher deficit, the water shortage started to affect the plant growth resulting in a significant reduction in yield, and the extent of yield reduction increased with the increase of the deficit level. This may be due to the way plant use water. Plants with no water shortage tend to use water to control its temperature and for photosynthesis processes. When mild drought stress is exerted on plant, it tends to conserve water with several conservation techniques such as closing stomata and decreasing the photosynthesis rate without significantly affecting the vital processes of the plant. If the level of drought stress increases, the ability of plant to cope with the stress and the effectiveness of such conservation techniques decreases affecting the final yield of the plant. Similar results were reported by Riaz et al. (2013). They found that both CO_2 assimilation rate and stomatal conductance decreased with the increase of the water deficit level in marigold plants. The effect of the stressed stage depends on the physiological process in the plant during the drought stage. The results indicated that the water shortage during the vegetation stage (*V*) limits the production ability of the plants and its' growth parameters. This was clear in the shorter plants, resulting from inducing deficit irrigation during the vegetation stage as shown in table 7. At the flowering stage (*F)* drought promotes the flowering process, results in earlier, and heavier plant flowering. These results agreed with Din et al. (2011) who studied the effect of water deficit on canola plants at flowering stages and found that drought promoted earlier flowering and pod development in plants. The effect of the drought stress on plants is highly proportional to the level of the drought and its duration. The results indicated that *IR90* promoted the good effects of drought stress like earlier and heavier plant flowering without the disadvantages of drought such as chlorophyll degradation and less photosynthesis rates.

CONCLUSION

Water deficit is an important factor that can affect the yield of peas in semi-arid areas. The water use efficiency of peas would increase if a mild water stress were exerted on the plants. Drought stress during the flowering stage had the best effect on plant production and *WUE*. The results indicated that the water strategy to achieve the highest *WUE* (2.44 kg m^{-3} in both season) while minimizing the water use is 80 % ET_c during the flowering stage. The highest value of yield production (5684 kg ha^{-1} in 2018 season) would be 90% ET_c during the flowering stage.

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الاستخدام الامثل لمياه ري البازلاء الخضراء تحت النقص المائي في المناطق شبه الجافة

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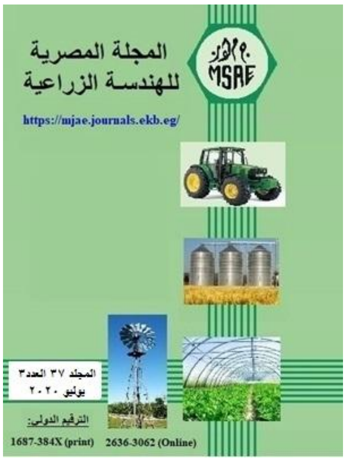

الكلمات المفتاحية:
البازلاء، النقص المائي، كفاءة الاستخدام المائي، إجهاد مراحل النمو.

الملخص العربي

البازلاء هو أحد أهم محاصيل الخضر في جميع أنحاء العالم نظرا لاحتوائها على العديد من الفوائد الغذائية حيث أنها غنية بالمركبات الغذائية الهامة المفيدة لصحة الإنسان. يعتبر عجز المياه عاملاً هاما يمكن أن يؤثر على الناتج الكمي والنوعي لمحصول البازلاء. أجريت هذه الدراسة بمزرعة قسم البستنه، كلية الزراعة، جامعة عمر المختار، مدينة البيضاء (ليبيا) في المواسم ٢٠١٧ و٢٠١٨ (٣٢,٨° شمالاً و ٢١,٨° شرقاً و ٤٤٩ م فوق سطح البحر) بهدف دراسة تأثير ثلاثة مستويات للنقص المائي ٩٠٪ من الاحتياج المائي للنبات *IR90* و٨٠٪ من الاحتياج المائي للنبات *IR80* و٧٠٪ من الاحتياج المائي للنبات *IR70* خلال ثلاثة مراحل لنمو نبات البسلة (مرحلة النمو الخضري *V*، مرحلة التزهير والعقد *F*، مرحلة اكتمال القرون *P* وجميع المراحل *A*) وتم استخدام ١٠٠٪ من الاحتياج المائي للنبات *IR100A* كمعاملة للمقارنة، على نمو وانتاجية محصول البازلاء وكفاءة الاستخدام المائي للمحصول (*WUE*).

وقد بينت الدراسة ما يلي:

١. قدر عمق مياه الري المضافة الكلية لمحصول البازلاء (من بداية الزراعة الي نهاية الحصاد، ١٠٦ يوم) بمقدار ٢١٤,٥ و٢٣٦ مم لمعاملة الكنترول (*IR100A*) للمواسم ٢٠١٧ و٢٠١٨ على الترتيب.
٢. تقل جميع الخواص المدروسة للبازلاء (ارتفاع النبات، عدد الفروع لكل نبات، عدد القرون لكل نبات، وزن ١٠٠٠ بذرة، الكتلة الحيوية، مؤشر الحصاد) مع زيادة النقص المائي.
٣. تحققت أعلى قيمة لإنتاجية محصول البازلاء الخضراء للمعاملة *IR90F* .
٤. تحققت أعلى *WUE* لمحصول البازلاء الخضراء للمعاملة *IR80F* .