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Effect of Water Stress and Phosphorus Fertilizer Rates on Growth and Seed Yield of Cowpea Under El-Arish Condition

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ABSTRACT

Two field experiments were carried out during summer seasons of 2014 and 2015 at Exp. Farm, Fac. Environ. Agric. Sci., El-Arish, North Sinai, Egypt, to study the effect of water stress and phosphorus rates on growth, yield and its components as well as water and phosphorus use efficiency on cowpea *cv.* " Kafr-El Sheikh" grown under sandy soil conditions using drip irrigation system. The experiment included 12 treatments, which were the combinations of three water levels; viz., 50, 75 and 100 % of irrigation water requirements (IWR) and four rates of phosphorus (0, 20, 40 and 60 kg P_2O_5 / fed.). The results show that increasing irrigation deficit increased water saving and water use efficiency (WUE), however it reduce seed yield/fed. The highest value of water saving and WUE was obtained from 50% IWR treatment. However, the highest value of phosphorus use efficiency (PUE) was achieved by treatment received 40 kg P_2O_5/fed. as well as, significant differences among irrigation water levels and phosphorus rates and their interactions were detected for all studied traits in both seasons. The high level of IWR (100%) gave the best values for all traits under study without significant differences when compared with 75% of IWR for some traits, except protein % which increased with addition of the lowest level (50% IWR) in both seasons. Application of phosphorus at rates of 40 or 60 kg P_2O_5 /fed. exhibited the highest results for all studied characters in both seasons. The best combinations treatments for growth and yield were supplying cowpea plants with 100 % of IWR and fertilizing the highest two rates of phosphorus (40 or 60 kg P_2O_5/fed. for all traits, followed by the medium level (75% of IWR) with the both high rates of P_2O_5.

Keywords: Cowpea, irrigation water levels, phosphorus use efficiency (PUE), water use efficiency (WUE), plant growth, seed yield and its components.

INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp.) is one of the important vegetable legumes in Egypt. For the view of nutrition, it is a major source of plant proteins content and B vitamins for man (Singh, 2003). Cowpea provides soil and subsequent plant (in rotation) with atmospheric nitrogen. It can grow well in sandy soils due to its deep root and higher tolerant to drought and low fertilizers requirements than other legumes. North Sinai is a newly reclaimed area with poor soil fertility, high PH, low water quantity and quality especially salinity.

Water stress is one of the important factors that decrease seed yield around the world, especially when water deficit occurs during flowering and maturity stages (Singh *et al.,* 1999). Also, decreasing the irrigation water amount added to plant negatively affected most physiological processes such as leaf water potential, photosynthesis activity and absorption and translocation of nutrients which directly reflected on plant growth (Sivakumar and Shaw, 1998). Water stress decreased the leaf area, shoot dry weight and leaves number/plant (Turk and Hall, 2005). Also, it increased the percentage of protein of grains (Wien *et al*., 1979), but it decreased seed yield, number of seeds/pod and weight of 1000 grain when cowpea plants exposed to irrigation cut for two weeks at flowering, poding and seed filling stages (Rezaee and Haghighi, 2009). Choudhury *et al*. (2011) reported that under drought stress for various studied bean genotypes, 1000-seeds weight was decreased, and this decrease may be due to the decrease in seed filling. reduction in seed yield because of increasing irrigation interval may be attributed to the decrease in number of pods/ plant and 100 dry seed weight (Khedri and Mojaddam, 2014).

Phosphorus is a major nutrient for legume crops because it is a part of organic compounds of plant (nucleic acids, coenzymes, phosphoproteins and phospholipids), also it helps in energy transfer in plant cells during respiration and photosynthesis processes (Malavolta *et al*., 1997). Seed yield of cowpea reached the highest value by using 30 kg P/ha in some varieties and by 60 kg P/ ha in others (Okeleye and Okelana, 1997). Haruna and Aliyu (2011) reported that phosphorus is a major and vital nutrient for stimulation legume growth, initiation of nodule formation and enhancing the efficiency of the rhizobium-legume symbiosis which reflected positively on fruit and seed yield. Benvindo *et al.*(2014) found that as the rates of P_2O_5 added to cowpea increased the levels of phosphorous concentration in leaves and seeds, as well as seed yield of cowpea were increased. Nkaa *et al.* (2014) reported that phosphorus fertilizer significantly enhanced plant height, number of leaves, number of pods, length of pod, number of seeds/pod, total seed yield and weight of 50 seeds in all tested varieties.

The interaction effects of water levels and phosphorus fertilization were investigated by Chiulele (2003). In this connection, fertilizing cowpea with high levels of phosphorus survived successively during the periods of drought compared with the other treatments. An increase in phosphorus uptake by plant decreases and adjusts the effects of drought stress and leads to the increase in cowpea root growth (Khedri and Mojaddam, 2014), the interaction between decreasing irrigation interval and increasing phosphorus application rate increased 100-seed weight, number of seeds/ pod and seed yield of cowpea.

Under North Sinai conditions, water shortage and poor soil fertility are important factors that affect negatively plant growth and productivity of cultivated plants. Therefore, this research aimed to study the effect of water stress combined with different phosphorus rates on growth, yield and quality of cowpea crop and to determine the amount of water and the suitable phosphorus rate needed for cowpea to maximize seed yield and saving water irrigation under North Sinai region.

MATERIALS AND METHODS

Two field experiments were carried out during summer seasons of 2014 and 2015 at The Experimental Farm of The Faculty of Environmental Agriculture Sciences, El-Arish, North Sinai, Suez Canal University, Egypt to study the effect of water stress and phosphorus rates on growth and seed yield and its components of cowpea *cv.*" Kafr-El Sheikh" grown under sandy soil conditions using drip irrigation system. Seeds were sown on 24th and 29th April in the first and second seasons, respectively. Planting was done in rows (120 cm width), each row had two dripper lines. The distance between each two double dripper lines was 25 cm. After completely emergence, the plants were thinned leaving two plants/ hill (15 cm between hills). Each experimental unit area was 13.2 m^2 (11m length and 1.2m width) with plant density of 22.3 plant /m^2. The seeds of cowpea were inoculated with N-fixer (*Rhizobium japonica*). Suspension (10^9CFU/ml^{-1}) as recommended using Arabic Gum as an adhesive material, Rhizobia was obtained from General Organization for Agriculture Equalization Fund, Ministry of Agriculture and Land Reclamation. Some physico-chemical properties of the experimental soil cite are shown in Table 1 and chemical analysis of irrigation water is shown in Table 2.

Table 1: Initial soil physical and chemical analysis.

Soil properties	Season 2014			Season 2015		
Depth(cm.)	0-15	15-30	30-45	0-15	15-30	30-45
Mechanical analysis						
Coarse sand %	67.00	68.22	62.70	66.56	67.92	66.41
Fine sand %	21.60	20.41	26.90	22.98	21.02	23.12
Silt %	4.50	4.12	3.95	4.21	4.52	3.60
Clay %	6.90	7.25	6.45	6.25	6.54	6.87
Soil texture	Sandy	Sandy	Sandy	Sandy	Sandy	Sandy
Bulk density ($g.cm^{-3}$)	1.52	1.53	1.57	1.55	1.53	1.57
Chemical analysis (soluble ions in (1:5) extract)						
Ca^{++} ($meq.l^{-1}$)	2.68	3.02	2.68	3.16	3.01	2.96
Mg^{++} ($meq.l^{-1}$)	2.01	2.41	2.12	2.67	2.33	2.55
Na^{+} ($meq.l^{-1}$)	1.41	1.34	1.23	2.59	2.47	1.49
K^{+} ($meq.l^{-1}$)	0.40	0.33	0.27	0.48	0.29	0.30
CO_3^{--} ($meq.l^{-1}$)	-	-	-	-	-	-
HCO_3^{-} ($meq.l^{-1}$)	2.26	2.74	2.48	2.61	2.46	2.96
Cl^{-} ($meq.l^{-1}$)	1.65	1.82	1.35	1.89	2.01	2.54
SO_4^{--} ($meq.l^{-1}$)	2.59	2.54	2.47	4.40	3.63	2.80
Available N (ppm)	16.52	15.98	15.54	16.24	15.42	15.32
Available P (ppm)	46.50	42.12	41.52	45.21	42.01	40.21
Available K (ppm)	97.50	95.64	94.51	96.25	94.34	94.02
EC($dS\ m^{-1}$) in (1:5) extract)	0.65	0.71	0.63	0.89	0.81	0.83
pH in (1:2.5) extract)	8.21	8.36	8.49	8.12	8.24	8.40
$CaCO_3$ %	6.95	8.67	7.15	6.95	8.65	7.16

Table 2: Chemical analysis of irrigation water.

pH	EC dSm^{-1}	EC ppm	Cations Ca^{++}	Cations Mg^{++}	Cations Na^{+}	K^{+}	Anions Cl^{-}	Anions HCO_3^{-}	Anions CO_3^{--}	Anions SO_4^{--}
			Soluble ions ($meq.l^{-1}$)							
First season 2014										
7.2	6.14	3929.6	19.12	23.31	18.77	0.20	43.51	7.25	-	10.64
Second season 2015										
7.01	5.99	3833.6	18.54	22.91	18.23	0.22	41.61	8.15	-	10.14

This experiment included 12 treatments, which were the combinations of three levels of irrigation water requirements (IWR) (50, 75 and 100 % of IWR) and four rates of phosphorus fertilizer (0, 20, 40and 60 kg P_2O_5/fed.). The total amount of phosphorus was added as calcium superphosphate (15.5% P_2O_5) during soil preparation. However, irrigation treatments application were started at the second true leaf stage. Treatments were randomly arranged in spilt- plot system in a complete randomized block design with three replicates. The main plots were assigned to have the irrigation levels, whereas the sub plots were randomly assigned to phosphorus rates. All experimental units received equal amounts of organic fertilizer (compost at 4 tons/fed), ammonium sulphate (20.5%N) and potassium sulphate (48-52% K_2O) at rates of 60 kg for each of N and K_2O/fed. One third of N and K_2O were applied with organic fertilizer (compost) during soil preparation and the other two- thirds were divided into 20 equal portions and added twice weekly through the irrigation water.

The normal agricultural practices were done as needed and similar to those used in commercial cowpea production in El-Arish region.

Data recorded:

Water relationships

1. **Consumptive use of water (CU):** It was calculated using the equation given by Israelson and Hansen (1962) as follows:

$$\mathbf{CU = D \times AD \times \frac{e_z - e_i}{100}}$$

Where:

CU=Consumptive use of water in cm,

D=Irrigated soil depth in cm,

AD=Bulk density, gm cm^{-3}, of the chosen irrigated soil depth,

e_z=Soil moisture percent after irrigation, and

e_i=Soil moisture percent before the next irrigation.

2. **Water use efficiency (WUE):** The consumed water by cowpea plant was calculated according to Yaron *et al.* (1973) as follows:

$$\mathbf{WUE = \frac{Y}{ET_a}}$$

Where:

Y = Crop yield ($kg.fed^{-1}$.), and

ET_a= Evapotranspiration ($m^3.fed^{-1}$.)

The actual evapotranspiration, ET_a, is assumed to be synonymous to the calculated consumptive use of water (CU). Consequently, daily and monthly consumptive use of water were calculated for specified soil depths for all treatments.

3. **The yield reduction and water saving were calculated from the following equations according to Ismail (2010).**

$$\textbf{Reduction in yield} = 100 - \frac{\text{Yield of 75 \% of WR or 50\% of WR}}{\text{Yield of 100 \% of WR}} \times 100$$

$$\textbf{Water saving} = 100 - \frac{\text{Water consumption of 75 \% of WR or 50\% of WR}}{\text{Water consumption of 100 \% of WR}} \times 100$$

Where:

WR = Water requirements

4. **Phosphorus use efficiency (PUE):** it was calculated for the three rates of applied phosphorus as follows:

$$\mathbf{PUE = \frac{Yield\ of\ applied\ P - Yield\ of\ control}{Phosphorus\ (kg\ fed^{-1})}}$$

Vegetative growth: After40 and 60 days from sowing, samples of three plants from each experimental unit were randomly taken and the following parameters were recorded: plant height (cm), number of leaves/plant, root length (cm). All plant parts were dried at 700 till constant weight and total dry weight (g)/plant was recorded.

Dry seed yield and its components: At harvest the following data were recoded: Number of pods/plant, number of seeds/pod, weight of 100 seeds (g) (seed index), pod length (cm) and dry seed yield /fed. (ton).

Chemical analysis: Total nitrogen, phosphorus and potassium were determined in dry seeds according to A.O.A.C. (1990), Piper (1950) and Jackson (1970), respectively. Protein percentage% (N x 6.25) was calculated.

Statistical analysis: The obtained data were subjected to statistical analysis of variance according to Snedecor and Cochran (1980). Duncan's multiple range tests was used for comparison among means (Duncan, 1958).

RESULTS AND DISCUSSION

Effect of irrigation water levels on yield reduction and water saving: Obviously deficit irrigation saves water but reduces the yield (Table 3). From the present study, it is observed that the highest seed yield was obtained from plants grown with no-stress (100% of IWR). Deficit irrigation tended to decrease the seed yield. Irrigating of cowpea plants with 75% of IWR during growing season led to a reduction of 9.90% and 14.21% of total seed yield in the 1st and 2nd seasons, respectively, while adding water at 50% of IWR reduced the yields by 24.35 % and 26.99% in the first and second seasons, respectively. The amount of saved water sharply increased by deficit irrigation treatments, producing about 90.10% and 85.79% of total seed yield led to save 19.65% and 19.88% of IWR in the 1st and 2nd seasons, respectively, while producing about 75.65% and 73.01% of the total yield saved about 59.85% and 58.87% of IWR in the 1st and 2nd seasons, respectively. In conclusion, deficit irrigation could be a suitable irrigation technique for cowpea production where the benefit from saving large amounts of water outweighs the decrease in total yield.

Table 3: Effect of irrigation water levels on reduction in yield % and water saving % of cowpea during 2014 and 2015seasons.

Irrigation level (%) of IWR*	Yield ($kgfed^{-1}$)	Total consumed water (m^3fed^{-1})	Reduction in yield %	Water saving %	Yield ($kgfed^{-1}$)	Total consumed water (m^3fed^{-1})	Reduction in yield %	Water saving %
	First season 2014				Second season 2015			
100%	727	1850.42	0.00	0.00	767	1875.11	0.00	0.00
75%	655	1486.85	9.90	19.65	658	1502.31	14.21	19.88
50%	550	743.21	24.35	59.84	560	771.23	26.99	58.87

***Irrigation water requirements (IWR) for cowpea =2100 m^3/fed**

Water use efficiency (WUE): The water use efficiency for fully and deficit irrigation treatments are presented in Table 4. Increasing the irrigation deficit gained a high increase in the WUE. The highest value of WUE was obtained with 50% of IWR treatment, while the lowest one was recorded with 100% of IWR treatment. The difference in WUE between 100% of IWR and 75% of IWR was slight compared to that between 75% of IWR and 50% of IWR treatments; however, these differences were significant in the two tested seasons. A sharp increase in WUE was obtained by deficit irrigation. This indicates that water movement into seeds may be decreased with the progressive in water deficit without effect on the translocation of dry matter into the seed and this effect resulted in an increase in mass production per unit of water, which in turn increase water use efficiency.

Table 4: Effect of irrigation water levels on water use efficiency (kg dry seed/m^3 water) and phosphorus use efficiency of cowpea during 2014 and 2015 seasons.

Irri. level (%) of IWR	Seed Yield (kg fed^{-1})	Total consumed water (m^{3}fed^{-1})	Water use efficiency (kgm^{-3})	(Yield of applied P- Yield of control) (kg fed^{-1})	Phos. use efficiency (kg kg^{-1})	Seed Yield (kg fed^{-1})	Total consumed water (m^{3}fed^{-1})	Water use efficiency, (kgm^{-3})	(Yield of applied P- Yield of control) (kg fed^{-1})	Phos. use efficiency (kg kg^{-1})
	First season 2014					Second season 2015				
100%	727	1850.42	0.39	120	6.00	767	1875.11	0.41	133	6.65
75%	655	1486.85	0.44	315	7.88	658	1502.31	0.44	305	7.63
50%	550	743.21	0.74	286	4.77	560	771.23	0.73	284	4.73

Effect of phosphorus rates on phosphorus use efficiency (PUE): The highest average phosphorus use efficiency (PUE) was recorded by application of 40 kg P_2O_5/fed. followed by 20 kg P_2O_5/fed., in both studied seasons (Table 4). Therefore, it could be recommend that fertilization with 40 kg P_2O_5/fed was enough to increases in cowpea seed yield. This results agree with the findings of Haruna and Usman (2013) who observed significant and efficient effect due to application of 30 kg P/ha in comparison with 60 kg P/ha.

Vegetative growth

Irrigation levels: Data presented in Table 5 show significant differences among irrigation water levels for all studied vegetative parameters in both seasons. In this respect, addition of 100% of IWR increased plant height, number of leaves/plant and root length at (40 and 60 days after sowing) in the two seasons. It is clear also that at 40 days after sowing, no significant differences were recorded between 100 and 75% of IWR for root length in both seasons, and plant height in the 2nd season as well as number of leaves in the 1st one. These results indicate that better root growth was observed under high irrigation levels which enhanced water and nutrients uptake from the soil and consequently, led to stimulate plant growth. From the previous results it could be suggested that water deficit is more effective on vegetative growth parameters of cowpea crop.

Both irrigation water levels 100 and 75% of IWR recorded the highest dry weight/plant in both seasons at 40 and 60 days after sowing with no significant differences between them. This means that water stress (50% of IWR) decreased plant height, number of leaves and root length which led to decrease in total dry weight of cowpea. These results are in a good line with those of Hussein *et al.* (2014) who observed that cowpea crop subjected to shortage of water decreased plant growth parameters (leaf number, total fresh weight and stem length). Sangakkara *et al.* (2001) refer the reason of negative effect of water stress on cowpea plant growth to its influence on photosynthesis process, and also to its effect on seed yield as well as its quality (Gardner *et al*., 1985 and Hale and Orcutt, 1987). In this connection, same trend was achieved by Sivakumar and Shaw (1998) on soybean and Turk and Hall (2005) on cowpea.

Table 5: Effect of irrigation water levels and phosphorus rates on vegetative characters of cowpea plants at 40 and 60 days after sowing during 2014 and 2015 seasons.

Treatments	Plant height (cm)		No. leaves/plant		Root length (cm)		Total dry weight (g)	
	40	60	40	60	40	60	40	60
Irrigation levels				First season 2014				
50%	31.69c	43.97c	14.45b	23.52c	6.98b	14.08c	7.84b	26.02b
75%	34.21b	54.07b	21.86a	35.24b	9.22a	17.49b	8.74ab	29.08ab
100%	39.35a	63.71a	23.02a	39.06a	10.13a	20.02a	10.16a	31.11a
Phosphorus rates								
0 kg	26.53c	44.14c	15.44c	24.78c	7.04c	13.80c	6.81d	20.41c
20 kg	31.10b	51.21b	18.47b	30.67b	8.39b	15.99b	7.90c	26.34b
40 kg	41.03a	61.99a	22.59a	37.70a	9.96a	20.04a	10.98a	34.28a
60 kg	41.67a	58.31a	22.61a	37.29a	9.72a	18.96a	9.97b	33.92a
Irrigation levels				Second season 2015				
50%	34.47b	49.33c	16.48c	23.95c	6.68b	15.22c	8.22b	28.13b
75%	40.18a	55.45b	23.65b	36.14b	8.05ab	17.68b	9.23ab	31.34ab
100%	44.14a	62.61a	26.53a	42.08a	10.36a	19.83a	10.56a	33.21a
Phosphorus rates								
0 kg	33.14c	46.64d	17.42c	24.28c	7.07c	13.34c	7.28d	23.92c
20 kg	38.32b	52.17c	20.39b	31.47b	7.92bc	16.93b	8.51c	27.50b
40 kg	43.93a	62.61a	25.32a	40.02a	9.07ab	20.31a	11.32a	37.56a
60 kg	43.00a	61.76b	25.74a	40.46a	9.39a	19.71ab	10.23b	34.60a

Values having the same alphabetical litter (s) did not significantly different 0.05 level of significance according to Duncan's multiple range test.

Phosphorus rate: Phosphorus fertilizer applied to cowpea plant had a significant effects on all recorded vegetative growth parameters in both growing seasons (Table 5). No significant differences were recorded between 40 and 60 kg P2O5/fed on all studied traits at 40 and 60 days, except total dry weight/plant at 40 days in both seasons. The highest values of plant height, number of leaves/plant and root length at 40 and 60 days were recorded with application of 40 and 60 kg P2O5/fed with no significant difference between them in both seasons. These results may be due to explained that the high amount of phosphorus required for stimulating root and shoot growth in legume plants that affect the efficiency of the Rhizobium-legume symbiosis via energy transfer reactions including activity of nitrogenase enzyme ATP compound store and transfer energy produced through photosynthesis process which reflected directly on plant growth and yield (Leidi and Rodriguez, 2000). For total dry weight, the best phosphorus rate stimulate dry weight production in cowpea plants was 40 kg P2O5/fed in the two seasons at 40 and 60 days. This means that applying high rates of phosphorus improved root growth at 60 days (Table 5) this was reflected directly on stimulation the root to absorb water and nutrients. Similar result was observed by Nkaa et al.(2014) on cowpea plants

Interaction between irrigation level and phosphorus rate: Vegetative characters of cowpea plant in both seasons were significantly affected by the interaction treatments (Table 6). For plant height, leaves number and root length the interaction between the highest level of irrigation water (100% of IWR) with 40 and 60 kg P2O5/fed recorded the highest values of the previous mentioned traits (at 40 and 60 days) with no significant difference between them in both growing seasons, except plant height at 60 days in both seasons. Increasing phosphorus application enhance P uptake within plant and reduce and adjusts the harmful effect of drought stress and this in turn lead to promote the root growth (Khedri and Mojaddam, 2014).

Table 6: Effect of interaction between irrigation water levels and phosphorus rates on vegetative characters of cowpea plants at 40 and 60 days after sowing during 2014 and 2015 seasons.

Treatments		Plant height (cm)		No. leaves/plant		Root length (cm)		Total dry weight (g)	
Irrigation levels %	Phosphorus rates kg	40	60	40	60	40	60	40	60
					First season 2014				
50	0	23.80e	37.60g	10.87e	17.67g	5.90f	10.23g	5.97g	17.87g
	20	28.17d	39.83g	13.23e	22.07f	6.60ef	13.67f	6.47g	23.53ef
	40	37.20b	49.63ef	16.47d	28.10e	8.10cd	16.20d	9.87c	30.17bcd
	60	37.60b	48.80ef	17.23d	26.27e	7.33de	16.23d	9.07cd	32.53abc
75	0	27.20d	45.33f	17.20d	27.40e	7.03def	14.27ef	6.77fg	20.33fg
	20	32.00c	50.17e	20.27bc	31.47d	8.73c	15.63de	8.20de	27.20de
	40	38.37b	62.90c	25.13a	41.33bc	10.30ab	20.97b	10.93b	35.17ab
	60	39.27b	57.87d	24.83a	40.77bc	10.80ab	19.10c	9.07cd	33.63ab
100	0	28.60d	49.50ef	18.27cd	29.27de	8.20cd	16.90d	7.70ef	23.03ef
	20	33.13c	63.63c	21.90b	38.47c	9.83b	18.67c	9.03cd	28.30cde
	40	47.53a	73.43a	26.17a	43.67ab	11.47a	22.97a	12.13a	37.50a
	60	48.13a	68.27b	25.77a	44.83a	11.03a	21.53ab	11.77ab	35.60a
					Second season 2015				
50	0	27.80g	41.70k	11.73e	18.33f	4.97f	9.70g	6.63j	21.07f
	20	33.50f	46.13j	14.43e	22.67ef	5.77f	15.27ef	7.57hij	24.97e
	40	37.87def	53.37f	19.43d	27.47de	7.30e	18.60bcd	9.70de	34.23b
	60	38.73de	56.10e	20.30d	27.33de	8.67d	17.30cde	8.97efg	32.27bc
75	0	34.03ef	48.67i	19.60d	25.60e	7.30e	13.80f	7.17ij	24.67e
	20	40.33cd	52.27g	21.97cd	33.40cd	8.03de	16.50def	8.47fgh	27.93de
	40	44.07bc	60.60c	26.47b	42.10b	8.23de	20.27abc	11.03bc	38.73a
	60	42.30cd	60.27c	26.57b	43.47b	8.63d	20.13abc	10.27cd	34.03b
100	0	37.60def	49.57h	20.93d	28.90de	8.93cd	16.53def	8.03ghi	26.03e
	20	41.13cd	58.10d	24.77bc	38.33bc	9.97bc	19.03a-d	9.50def	29.60cd
	40	49.87a	73.87a	30.07a	50.50a	11.67a	22.07a	13.23a	39.70a
	60	47.97ab	68.90b	30.37a	50.57a	10.87ab	21.70ab	11.47b	37.50a

Values having the same alphabetical litter (s) did not significantly different 0.05 level of significance according to Duncan's multiple range test.

Concerning total dry weight/plant, it is clearly from data in Table 6 that the highest total dry weight was obtained with the combination between 100% of IWR and the high rates of phosphorus (40 and 60 kg P_2O_5/fed) at 40 and 60 days, as well as 75% of IWR with the same high rates of phosphorus at 60 days in the 1st season. However, in the 2nd one the best interaction treatments were 100% of IWR with 40 kg P_2O_5/fed at 40 days, 100% of IWR with 40 and 60 kg P/fed and medium irrigation level (75% of IWR) with 40 kg P_2O_5/fed at 60 days. These results may indicate that there are positive effects of phosphorus fertilizer at the highest applied level of irrigation water than low level in all tested vegetative traits. The same trend of results was achieved by Hussein *et al.* (2014) who found positive effects of phosphorus fertilizer under normal irrigation treatments than under stress treatments for plant height, number of leaves and dry weight of plant.

Yield and its components

Irrigation levels: It is obvious from the data presented in Table 7 that yield and its attributes were significantly affected by irrigation levels in both seasons. The best irrigation water level for enhancing number of pods/plant and seed yield /fed was 100% of IWR, while both of 100% and 75% of IWR were the best levels for number of seeds/pod, weight of 100 seed and pod length in the 1st and 2nd seasons. Application of 100% of IWR did not significantly differ when compared with 75% of IWR for all studied yield traits in the 2nd season, indicating that increases in seed yield with high level of irrigation water were the result of high yield attributes. Exposure cowpea plants to water stress during flowering and pod filling resulted in reducing number of pods/plant. Such effect may be due to flower abscission and reduced in translocation of the carbohydrates to the seed (Turk *et al*., 1980). Mohamed and Abd El-Hady (2009) found that increasing irrigation intervals significantly decreased fresh pod yield of cowpea. The same trend of results was found in the study of Choudhury *et al*. (2011) and Khedri and Mojaddam (2014).

Phosphorus rate: Yield and its components of cowpea plants were increased gradually by the increase in phosphorus rates. Application of 40 and 60 kg P_2O_5/fed recorded the highest number of pods/plant, number of seeds/pod, 100 seed weight, pod length and seed yield/fed with no significant differences between the two rates, followed by 20 kg P/fed for all the previous characters in both seasons. Therefore, phosphorus had a vital role in several physiological process; viz., cell division and, root growth, root nodule formation, , photosynthesis, starch utilization, initiation of flower and development of seeds (Gangasuresh *et al.,* 2010). Also, phosphorus nutrition increased cowpea yield (Okeleye and Okelana, 1997). Cowpea plants amended with 30 kg P/ha recorded the highest values of number of pods/plant, number of seeds/pod, 100 seed weight and seed yield/ha compared to application of 60 kg P/ha (Haruna and Usman, 2013). Moreover, the maximum seed yield (1.32 ton/ha) was obtained from plants fertilized with 168 kg P_2O_5/ha (Benvindo *et al*., 2014). Also, addition of phosphorus to cowpea plants increased number of pods/plant, pod length, number of seeds/pod, seed yield as well as 50 seed weight (Nkaa *et al.*, 2014). So, responses of yield components to phosphorus application could be attributed to the role of phosphorus in seed filling and formation (Haruna, 2011). In general, cowpea requires phosphorus for plant growth and seed development, so we can conclude that cowpea is phosphorus needed plant.

Interaction between irrigation level and phosphorus rate

Interaction between of irrigation with 100% of IWR and 40 kg P_2O_5/fed in the 1st season and with 40 and 60 kg P_2O_5/fed in the 2nd season recorded the highest number of pods/plant. No significant differences were found between the treatments of high and medium level of IWR combined with 40 and 60 kg P_2O_5/fed for number of seeds/pod, weight of 100 seeds and pod length in both seasons, except 75% of IWR with 60 kg P_2O_5/fed for number of seeds/pod in the 1st season (Table 7).

Table 7: Effect of irrigation water levels and phosphorus rates on yield and its components and chemical analysis of cowpea seeds during 2014 and 2015 seasons.

Treatments	Yield and its components					Chemical analysis		
	No. pods/plant	No. seeds/pod	Weight 100 seeds(g)	Pod length (cm)	Seed yield /fed. (ton)	Protein %	P	K
Irrigation levels				*First season 2014*				
50%	9.70c	8.93b	10.92b	13.40b	0.550c	24.57a	0.417c	1.198b
75%	10.77b	10.75a	12.81ab	14.92a	0.655b	22.81b	0.466b	1.254a
100%	11.88a	10.98a	14.00a	15.47a	0.727a	22.71b	0.560a	1.268a
Phosphorus rates								
0 kg	8.38c	8.50c	9.81c	11.51c	0.464c	19.90c	0.373c	1.118c
20 kg	10.20b	9.96b	12.13b	13.94b	0.584b	22.68b	0.425b	1.214b
40 kg	12.50a	11.38a	14.31a	16.71a	0.779a	25.46a	0.561a	1.303a
60 kg	12.07a	11.03a	14.04ab	16.22a	0.750a	25.42a	0.564a	1.324a
Irrigation levels				Second *season* 2015				
50%	9.50b	9.77b	11.68b	14.08b	0.560b	24.90a	0.469b	1.229c
75%	11.24ab	11.18a	13.03ab	15.19a	0.658ab	23.40b	0.546a	1.265b
100%	12.87a	11.42a	14.51a	15.87a	0.767a	23.32b	0.567a	1.306a
Phosphorus rates								
0 kg	8.81c	9.02c	10.39c	11.93c	0.481c	20.14c	0.395c	1.152c
20 kg	10.55b	10.54b	12.64b	14.77b	0.614b	22.86b	0.509b	1.260b
40 kg	12.82a	11.94a	14.87a	17.04a	0.786a	26.40a	0.601a	1.323a
60 kg	12.62a	11.64a	14.50ab	16.44a	0.765a	26.11a	0.604a	1.332a

Values having the same alphabetical litter (s) did not significantly different 0.05 level of significance according to Duncan's multiple range test.

Regarding seed yield/fed, data in Table 7 revealed that the high level of irrigation water (100% of IWR) combined with high rates of phosphorus (40 and 60 kg P_2O_5/fed) gave the highest dry seed productivity, followed by 75% of IWR with the same two high phosphorus rates in both seasons. These results are in harmony with the finding of Uarrota (2010) on cowpea who reported that the effect of phosphorus fertilizer was more pronounced on seed yield and pod number/plant under irrigated plants compared to control irrigation treatment. Although, increasing irrigation interval decreased phosphorus uptake from the soil. It decreased the negative impact of water stress on seed yield of cowpea plants (Khedri and Mojaddam 2014).

Table 8: Effect of interaction between irrigation water levels and phosphorus rates on yield and its components and chemical analysis of cowpea seeds during 2014 and 2015 seasons.

Treatments		Yield and its components					Chemical analysis		
		No. pods/plant	No. seeds/pod	Weight 100 seeds(g)	Pod length (cm)	Seed yield/ fed. (ton)	Protein %	P	K
Irri. levels %	Phos. rates kg	First season 2014							
50	0	6.97g	7.50e	8.87g	10.83f	0.431f	18.96e	0.273i	1.110d
	20	9.37f	8.17de	10.83efg	12.70de	0.509e	25.21b	0.417gh	1.167d
	40	11.20cd	10.00c	12.03def	15.43bc	0.635cd	28.77a	0.499d	1.240c
	60	11.27cd	10.03c	11.93def	14.63c	0.625cd	25.33b	0.478e	1.277bc
75	0	8.96f	9.00d	10.00fg	11.80ef	0.475ef	19.38e	0.402h	1.117d
	20	10.27e	10.83bc	12.30cde	13.93cd	0.584d	20.84d	0.430fg	1.240c
	40	12.10c	12.10a	14.63ab	17.20a	0.806b	25.63b	0.515cd	1.327ab
	60	11.77cd	11.07b	14.30abc	16.73ab	0.756b	25.42b	0.518c	1.333ab
100	0	9.20f	9.00d	10.57efg	11.90ef	0.485ef	21.35cd	0.445f	1.127d
	20	10.97de	10.87bc	13.27bcd	15.20c	0.658c	21.98c	0.429fg	1.237c
	40	14.20a	12.03a	16.27a	17.50a	0.898a	21.98c	0.669b	1.343a
	60	13.17b	12.00a	15.90a	17.30a	0.868a	25.52b	0.697a	1.363a
		Second season 2015							
50	0	6.93f	7.87f	9.27f	11.47e	0.444f	19.59f	0.334i	1.120h
	20	9.15e	9.33e	11.23ef	13.80d	0.535e	26.88ab	0.481f	1.250f
	40	10.57cde	10.97d	13.17cde	15.97bc	0.635d	27.09a	0.536d	1.247f
	60	11.33cd	10.90d	13.03cde	15.10cd	0.627d	26.06bc	0.524de	1.300d
75	0	9.47e	9.63e	10.40f	12.10e	0.477ef	20.84de	0.402h	1.124h
	20	10.67cde	11.20bcd	12.60de	14.57cd	0.614d	20.44def	0.537d	1.260ef
	40	12.90b	12.17abc	14.93abc	17.30ab	0.794b	26.46abc	0.611c	1.348b
	60	11.93bc	11.73a-d	14.20bcd	16.80ab	0.748bc	25.86c	0.635b	1.327c
100	0	10.03de	9.57e	11.17ef	12.23e	0.521ef	20.00ef	0.448g	1.211g
	20	11.83bc	11.10cd	14.10cd	15.93bc	0.694cd	21.25d	0.510e	1.271e
	40	15.00a	12.70a	16.50a	17.87a	0.930a	25.65c	0.657a	1.375a
	60	14.60a	12.30ab	16.27ab	17.43ab	0.921a	26.40abc	0.653a	1.369a

Values having the same alphabetical litter (s) did not significantly different 0.05 level of significance according to Duncan's multiple range test.

Chemical analysis

Irrigation levels: Results in Table 6 show that, irrigation levels had a significant effect on all traits of chemical analysis. Protein percentage of stressed plants (50% of IWR) was higher (24.57% and 24.90%) than that of plants irrigated with 75 and 100% of IWR (22.81%, 23.40% and 22.71%, 23.32%) in the 1st and 2nd seasons, respectively indicating that water stress increased protein percentage in cowpea seeds. The same trend of water stress effects on increasing the seed protein content was found by Wien *et al*. (1979). Supplying 100% of IWR to cowpea plants increased seed P% and K% in both seasons, as well as 75% of IWR increased P % in seed in the 1st season.

Phosphorus rate: In all studied chemical analysis traits, cowpea plants fertilized with 40 and 60 kg P_2O_5/fed had higher content of P and K compared to those supplied with low rate in both seasons (Table 6). These results were in harmony with the finding of Benvindo *et al*. (2014) who concluded that using high rates of phosphorus increased the phosphorus percentage in cowpea seeds.

Interaction between irrigation levels and phosphorus rates: Protein percentage was at its highest value (28.77% and 27.09%) when cowpea plants received 50% of IWR and 40 kg P_2O_5/fed in both seasons (Table 7). Regarding P and K seed content, data revealed that the highest level of irrigation (100% of IWR) combined with 60 kg P_2O_5/fed in the 1st season and with both 40 and 60 kg P_2O_5/fed in the 2nd season were the best interaction treatments for increasing P and K seed content (Table 7), without significant differences when compared with the treatments of 75% of IWR combined 40 and 60 kg P_2O_5/fed for K content in the 1st season.

Finally, we can conclude that both of water stress and phosphorus application were important factors limiting the productivity of cowpea plants under North Sinai conditions because they had several effects on physiological process of plant growth, yield and its attributes and protein and minerals content.

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تأثير الإجهاد المائي والتسميد الفوسفاتي على النمو والمحصول لنباتات اللوبيا تحت ظروف العريش

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أجريت تجربتان حقليتان بالمزرعة التجريبية لكلية العلوم الزراعية البيئية بالعريش، شمال سيناء، خلال الموسم الصيفي ٢٠١٤ و٢٠١٥ بهدف دراسة تأثير ثلاثة مستويات من مياه الري هي ١٠٠% و٧٥% و٥٠% من الاحتياجات المائية مع إضافة الفوسفور بمعدلات صفر و٢٠و ٤٠ و ٦٠ كيلوجرام للفدان على النمو والإنتاجية لنباتات اللوبيا النامية في ارض رمليه مع استخدام نظام الري بالتنقيط بمنطقه العريش. اشتملت التجربة على١٢ معاملة وهى كل التوليفات الممكنة بين ٣ مستويات ري و٤ معدلات فوسفور. تمثلت أهم النتائج المتحصل عليها في تناقص كفاءة استخدام نباتات اللوبيا للمياه مع زيادة كميات المياه المضافة تدريجيا حتى ١٠٠% من الاحتياجات الكلية من المياه وكانت أعلى كفاءة عند مستوى ٥٠%, بينما أدت أضافه ٤٠كجم فو/ فدان للحصول على أعلي كفاءة لاستخدام الفوسفور مقارنه ب ٢٠ و ٦٠ كجم فو/فدان خلال الموسمين. أدت أضافه مستوى ١٠٠% من الاحتياجات المائية للحصول على أعلي القيم لجميع الصفات تحت الدراسة, والتي لم تختلف معنويا عن ٧٥% لبعض الصفات خلال موسمي الزراعة ما عدا صفه محتوى البروتين بالبذور, حيث أعطى مستوى الري المنخفض٥٠% أفضل قيمه. أعطت معدلات الفوسفور المرتفعة (٤٠ او ٦٠ كجم فو/فدان) أفضل القيم لجميع الصفات المدروسة في الموسمين. أما معاملات التفاعل بين المستوى العالي من مياه الري (١٠٠%) وإضافة الفوسفور بمعدل مرتفع (٤٠ او ٦٠ كجم فو/لفدان) في الموسمين فكانت أفضل المعاملات لجميع صفات النمو والإنتاجية والتحليل الكيماوي, والتي لم تختلف معنويا عن أضافه مستوى ٧٥% من الاحتياجات المائية مع معدلي الفوسفور ٤٠ او ٦٠ كجم فو/لفدان.