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EFFECT OF DEFICIT IRRIGATION AND NITROGEN FERTILIZATION ON COWPEA YIELD, ITS COMPONENTS AND WATER PRODUCTIVITY IN NORTH DELTA OF EGYPT.

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ABSTRACT

Two field experiments were performed at Sakha Agricultural Research Station, (31° 05' N latitude and 30° 56' E longitude), Kafr El-Sheikh Governorate, during the two growing summer seasons of 2009 and 2010, to study the effect of deficit irrigation by watering after 50%, 70% and 90% of available soil moisture deficit (ASMD) and four levels of nitrogen fertilization at 10, 20, 30 and 40 kg N fed.$^{-1}$ on cowpea yield, its components and water productivity in North Delta of Egypt. A split-plot design with four replicates was used. Mean values of seasonal water consumptive use were 42.17, 37.05 and 30.12cm in the 1st season and 41.22, 36.51 and 29.67 cm in the 2nd season for the 50%, 70% and 90% of ASMD, respectively and seasonal amounts of irrigation water applied for cowpea were 63.10 cm, 54.09 cm and 43.10 cm in the 1st season and 61.66, 53.33 and 42.40 cm in the 2nd season for 50%, 70% and 90% of ASMD, respectively. Results revealed that the highest values of plant height, number of leaves plant^{-1}, number of branches plant^{-1} and chlorophyll content were obtained from irrigation at 50% of ASMD in the first season, while the highest values of seed yield plant^{-1}, seed yield fed.$^{-1}$ and number of pods plant^{-1} were obtained from irrigation at 70% of ASMD in the both seasons. The mean results showed that adding 40 kg N fed.$^{-1}$ significantly increased plant height, number of leaves plant^{-1}, number of branches plant^{-1} and chlorophyll content in both seasons, while adding 30 kg N fed.$^{-1}$ gave the highest mean values of seed yield plant^{-1}, seed yield fed.$^{-1}$, number of pods plant^{-1} and 100-seed weight in both seasons. The highest values of water productivity (WP) and productivity of irrigation water (PIW) were 0.763and 0.541kg m^{-3} in the 1st season and 0.568 and 0.403 kg of seeds m^{-3} in the 2nd season as a result of irrigation at 90% of ASMD and fertilization with 30 kg N fed.$^{-1}$ in the both seasons. Irrigation at 90% of ASMD enhanced WP by 29.7 and 33.4% and PIW by 35.9 and 39.7% compared to irrigation at 50% of ASMD in the two seasons, respectively. WP and PIW increased by increasing N application up to 30 kg N fed.$^{-1}$. It can be recommended that the best results under the experimental conditions were irrigating cowpea cultivars at 70% of ASMD and fertilization with 30 kg N fed.$^{-1}$.

Keywords: Cowpea, irrigation, nitrogen fertilization, water productivity.

INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp) is one of the most important vegetable legumes due to its high protein content, heat tolerant, low fertilizer requirements and it can grow easily in the new reclaimed lands. The protein content in cowpea seeds is high and rich in amino acids, lysine and tryptophan compared to cereal grains. Therefore, cowpea can be valued as a nutritional supplement to cereals especially in the semi-arid region where cereals are the staple food and there is the menace of nutritional disorders and food insecurity (El-Bably and El-Waraky, 2006). The new cowpea cultivar Kafr El-Sheikh-1 has a short growth period, an erect and determinate growth habit and resistance to loading (Knany *et al*., 2002; Masoud, 2002 and El-Waraky, 2007).

Nitrogen fertilization, plant population and cultivar are important factors affecting yield and its quality of cowpea. Application of nitrogen fertilizers increased vegetative growth characters as well as yield and its components of cowpea (Hussaini *et al*., 2004 and El-Bably and El-Waraky, 2006). Even though cowpea, a leguminous crop, has the ability to fix atmospheric nitrogen, it requires a starter dose of nitrogen for early growth and establishment. Hussaini *et al.* (2004) reported that small doses of applied N(from 30 to 40 kg N fed.$^{-1}$) may be synergistic and stimulate nodulation and symbiotic fixation in cowpea and even improve seed yield. Geetha and Varughese (2001) and El-Waraky and Kasem (2007) indicated that cowpea plants fertilized with 30 kg N fed.$^{-1}$ produced the greatest pods yield, also, increasing nitrogen fertilization level up to 40 kg N fed.$^{-1}$, gradually increased cowpea plant growth, yield and its components.

Irrigation is a significant factor affecting yield and its quality of cowpea. The irrigation number, amount and uniformity water applications are used mainly to determine the efficiency of irrigation scheduling. Excessive doses of infrequently applied water will lead to high percolation losses. The water saved by reducing drainage losses can be used to obtain higher yields by giving additional application to irrigate other farmlands or to store it as an insurance against the more severe periods of drought. While real-time irrigation schedulers can be used to maximize the yield for a specific growing season, they are less useful for planning and management as simulation models, (Adekalu, 2006 and Uarrota, 2010).

El-Bably and El-Waraky (2006) and Lemma *et al.* (2009) reported that the highest irrigation rate 1.2 of ETc gave the highest values of plant height, number of leaves plant^{-1}, and number of pods plant^{-1}, number of seeds plant^{-1}, 100-seed weight as well as the largest seed yield plant^{-1}, seed yield fed.$^{-1}$ and protein content in percent, compared to irrigation at 1.0 and 0.8 of ETc.

The irrigation number, amount and uniformity of water applications are used mainly to determine the efficiency of irrigation scheduling. Excessive doses of infrequently applied water will lead to high percolation losses. There is stiff competition for water by the agricultural, domestic and industrial users during the dry season, hence there is the need for farmers to conserve and make judicious use of the available water. Adekalu and Okunade (2006) and Kayombo *et al.* (2002) indicated that the crop water use efficiency has been shown to depend on irrigation amount and frequency, also, the type of irrigation system and tillage practices can influence the water use efficiency for a given irrigation frequency. Byan *et al.* (2002) indicated that water consumptive use (WCU) of cowpea amounted to 0.426, 0.532 and 0.639 m^3 m^{-2} when irrigated by 80, 100 and 120% of water calculated by class A pan method, respectively.

Therefore, this investigation aimed to study the effect of deficit irrigation and nitrogen fertilizer levels on the cowpea productivity and water productivity in North Delta of Egypt.

MATERIALS AND METHODS

Tow field experiments were carried out during the two growing summer seasons of 2009 and 2010 at Sakha Agricultural Research Station, (31° 05' N latitude and 30° 56' E longitude), Kafr El-Sheikh Governorate.

The soil of the experimental fields was clayey in texture, some physical analysis of soil samples for experimental site are presented in Table (1). The EC and pH of experimental soil site using the saturated soil paste were 2.10 dSm^{-1} and 8.11, respectively. The electrical conductivity of irrigation water was 0.68 dSm^{-1}. The experimental plots were arranged in a split plot design with four replicates in both seasons. The main plots were randomly assigned to irrigation treatments, i.e. at 50%, 70% and 90% depletion of available soil moisture. Irrigation water was applied when the moisture content reached the desired available soil moisture in each treatment. The sub-plots were allocated randomly for nitrogen fertilizer levels, i.e. 10, 20, 30 and 40 kg N $fed.^{-1}$, (1 feddan = 0.42 hectar). The sub-plot area was 42 m^2 (6 x 7 m). Plots were isolated by ditches of 1.5 m in width to avoid lateral movement of water.

Phosphorus fertilizer was used at seedbed preparation in the form of calcium superphosphate (15.5% P_2O_5) at the rate of 100 kg fed^{-1}. Cowpea seeds cv. Kafr El-Sheikh, were inoculated by Rhizobium bacteria just before sowing. Sowing date was May 13th in the first season and May 17th in the second one at hills 20 cm apart on two side of rows. Plants were thinned to two plants per hill after three weeks from sowing.

Nitrogen fertilizer was given in one dose before the first irrigation (21 days after sowing), using ammonium nitrate (33.5% N) at the rate of 10, 20, 30 and 40 kg N $fed.^{-1}$. Recommended cultural practices for cowpea were applied. Plants were harvested after 90 days from planting, ten guarded plants were randomly taken from the fourth inner ridges to determine yield components. Seed yield was determined from central area of 10.5 m^2 (3 x 3.5 m) of each plot, to eliminate any border effects. Seed yield of cowpea was adjusted at 12% moisture content.

The following traits were measured: Plant height in cm, number of leaves $plant^{-1}$, number of pods $plant^{-1}$, number of seeds $plant^{-1}$, 100-seed weight in gm, seed yield $plant^{-1}$ in gm, seed yield $fed.^{-1}$ in kg and protein content in percent.

Table (1): Some physical analysis of soil samples for experimental site.

Depth (cm)	Particle size distribution			Texture	Field capacity (%)	Permanent wilting point (%)	Bulk density (kg m^{-3})	Available soil water %
	Sand %	Silt %	Clay %					
0- 15	19.88	30.00	50.12	Clayey	46.10	25.35	1100	20.75
15-30	19.56	30.14	50.30	Clayey	41.15	22.92	1160	18.22
30-45	19.38	30.20	50.42	Clayey	37.20	21.10	1230	16.10
45-60	18.70	30.46	50.84	Clayey	35.19	20.15	1300	15.04

Soil moisture content was determined gravimetrically, on oven dry basis, before each irrigation, 48 hours after each watering and at harvesting times. Four soil samples were taken with a soil auger from four consecutive layers, every 15 cm depth to total depth of 60 cm. Samples were immediately transferred, in tightly closed aluminum cans, to the laboratory where they were weighed, dried in oven at 105°C for 24 hours, then reweighed and their moisture content were determined. Field capacity, permanent wilting point and bulk density were executed according to Klute (1986). Available soil moisture was calculated by subtracting permanent wilting point from field capacity (Table 1).

Crop-water Relation Parameters:

Irrigation water applied (IWA):

The amount of water applied at each irrigation was measured by Flowmeter and calculated according to Keller and Karmeli (1974) as follows:

$$IWA = \frac{ETo\,.\,Kc\,.\,Kr.II}{Ea} + LR$$

Where:

IWA = irrigation water applied (mm).
ETo = reference evapotranspiration (mm/day).
Kc = crop coefficient.
Kr = reduction factor (Keller and Karmeli, 1974).
II = irrigation intervals (days).
Ea = irrigation efficiency % = K_1 x K_2 = 0.67.
K_1 = emitter uniformity coefficient = 0.95.
K_2 = irrigation efficiency coefficient = 0.70.
LR = leaching requirements (10% of ETc).

Reference evapotranspiration (ETo) was estimated using penman-Monteith, as calculated by Allen *et al.*, (1998).

Water consumptive use (WCU):

Water consumptive use was calculated using the following equation according to Hansen *et al.* (1979):

$$CU = \sum_{i=1}^{i=4} D_i \times Db_i \times (PW_2 - PW_1)/100$$

Where:

CU = water consumptive use (cm) in the effective root zone (60 cm).
D_i = soil layer depth (15 cm).
Db_i = soil bulk density, (g cm^{-3}) for this depth.
PW_1 = soil moisture percentage before irrigation.
PW_2 = soil moisture percentage, 48 hours after irrigation.
I = number of soil layers.

Water productivity (WP):

It was calculated according to Ali *et al.* (2007).

WP = GY/ET.

Where: WP (kg seeds m^{-3} WCU), GY = grain yield (kg $fed.^{-1}$) and ET = total water consumption of the growing season (m^3 $fed.^{-1}$).

Productivity of irrigation water (PIW)

Productivity of irrigation water (PIW) was calculated as Ali *et al.* (2007)

PIW= GY/I

Where: GY is grain yield (kg $fed.^{-1}$) and I is irrigation water applied (m^3 $fed.^{-1}$).

Statistical Analysis:

All data were statistically analyzed according to the technique of analysis of variance (ANOVA) as published by Gomez and Gomez (1984). Means of the treatment were compared by the least significant difference (LSD) at 5% level of significance which developed by Waller and Duncan (1969).

RESULTS AND DISCUSSION

Vegetative growth characters

a. Effect of irrigation levels

Data presented in Table (2) show that plant height, No. of branches $plant^{-1}$ and chlorophyll content were significantly affected by increasing rate of irrigation, while, No. of leaves $plant^{-1}$ was not significantly affected by increasing rate of irrigation in both growing seasons.

Table (2): Effect of irrigation treatments and nitrogen fertilization levels on cowpea vegetative growth characters in 2009 and 2010 seasons.

Treatments	Plant height (cm)		No. of leaves $plant^{-1}$		No. of branches $plant^{-1}$		Chlorophyll content SPAD unit	
	2009	2010	2009	2010	2009	2010	2009	2010
Irrigation treatments								
I_1 (50% ASMD)	90.2a	86.8a	42.7a	26.0a	3.6a	2.5a	54.54a	53.03a
I_2 (70% ASMD)	79.6b	75.2b	42.5a	25.2a	3.3b	2.4a	53.42ab	51.81ab
I_3 (90% ASMD)	75.2c	69.7c	42.3a	24.4a	3.3b	1.9b	53.23b	51.16b
N levels (kg $fed.^{-1}$)								
10	78.3c	71.5c	38.5c	19.9c	3.2b	1.9b	51.60c	49.53b
20	80.2c	76.7b	40.0b	24.5b	3.3ab	2.2a	53.32bc	52.26a
30	82.6b	80.2a	45.0a	27.5a	3.4ab	2.4a	54.64ab	53.01a
40	85.4a	80.6a	46.7a	28.8a	3.7a	2.6a	55.37a	53.22a

Values having a similar alphabetical letter, within a comparable group of means, are not significantly different, using revised G.S.D. test at 0.05 level.

The highest irrigation rate I_1(50% of available soil moisture deficit (ASMD) gave the tallest plants (90.2 and 86.8 cm), the highest number of leaves (42.7 and 26.0) and number of branches $plant^{-1}$ (3.6 and 2.5) as well as the largest chlorophyll content (54.54 and 53.03 SPAD unit), in the first and second seasons, respectively, while, the lowest irrigation rate I_3 (90% of ASMD) produced the lowest value of each character in the two seasons.

The positive results of the added irrigation effect could be related to increasing the periods of plant uptake of water and fertilizers, where the drought stress decrease water and fertilizer uptake. Similar results on cowpea were recorded by Adekalu *et al.* (2002), Kumaga *et al.* (2003) and El-Bably and El-Waraky(2006).

b.Effect of nitrogen fertilization levels

Data presented in Table (2) show that all vegetative traits were increased by increasing rate of nitrogen fertilization up to 40 kg N fed.$^{-1}$ in both growing seasons.

The highest nitrogen fertilization rate (40 kg N fed.$^{-1}$) gave the tallest plants, the highest number of leaves plant^{-1}, branches plant^{-1}, as well as the higher chlorophyll content. In contrast, the lowest values of all characters were obtained from 10 kg N fed.$^{-1}$. The positive results of the added N effects may be due to the important role of nitrogen and its vital contribution to several biochemical processes in the plant related to growth and to its role in assimilating the photosynthetic reaction.

The present results matched well with those obtained by Knany *et al.* (2002), El-Bably and El-Waraky (2006), and El-Waraky and Kasem (2007).

c. Effect of the interaction between irrigation treatments and N levels:

Data presented in Table (3) indicate that plant growth under high rate of irrigation (50% of ASMD) I_1, and 40 kg N fed.$^{-1}$ had the higher values of plant height, number of leaves plant^{-1}, number of branches plant^{-1} and chlorophyll content in the two seasons. In contrast, the lowest rate of irrigation (90% of ASMD) I_3 and 10 kg N fed.$^{-1}$ produced the lowest values of all growth parameters.

Table (3): Effect of interaction between irrigation treatments and N levels on cowpea vegetative growth characters in 2009 and 2010 seasons.

Treatments		Plant height (cm)		No. of leaves plant^{-1}		No. of branches plant^{-1}		Chlorophyll content SPAD unit	
irrigation	N levels kg fed.$^{-1}$	2009	2010	2009	2010	2009	2010	2009	2010
I_1 50% of ASMD	10	87.9b	82.5cd	36.7d	17.6e	3.4bc	2.2bc	53.75a	51.72ab
	20	89.1b	85.6b	38.9cd	28.6a	3.4bc	2.5ab	54.25a	53.18a
	30	89.5b	88.2ab	47.1a	28.6a	3.6bc	2.6ab	54.80a	53.45a
	40	94.3a	91.0a	48.2a	29.3a	4.1a	2.8a	55.35a	53.78a
I_2 70% of ASMD	10	74.7fg	69.1h	40.8c	20.3e	3.1c	1.8c	52.58a	50.35b
	20	76.9ef	75.2f	42.0bc	22.1d	3.3bc	2.3bc	52.63a	51.97ab
	30	82.5d	76.4ef	42.9bc	28.5a	3.3bc	2.5ab	53.95a	52.60ab
	40	84.1cd	80.0d	44.2bc	29.8a	3.6b	2.9a	54.55a	53.33a
I_3 90% of ASMD	10	72.4g	62.8i	37.9cd	21.8d	3.1c	1.8c	48.47a	46.50c
	20	74.7fg	69.4h	39.2cd	22.9d	3.3bc	1.9c	53.08a	51.63ab
	30	75.7fg	70.7g	45.1a	25.4c	3.3bc	2.0c	55.18a	52.98ab
	40	77.8ef	76.0ef	47.0a	27.4bc	3.5bc	2.1bc	56.20a	53.55a

Irrigation and nitrogen fertilization show synergistic effect and their combined application resulted in higher vegetative growth characters, more than the sum of their independent effects. The availability of nutrients is highest when soil water is adequate and available at low tension because two of three nutrients translocation methods to the root surface (mass flow and diffusion) are depending on moisture presence. The presence of adequate water in soil increases the nitrogen fertilizer use and increasing dose of fertilizer boosts up seed yield (Majumdar,2002). Similar findings, concerning the positive effects of irrigation and nitrogen fertilizer, were recorded by El-Bably and El-Waraky (2006) who reported that fertilizing cowpea plants with nitrogen at the rate of 40 kg N fed.$^{-1}$ accompanied with irrigation at 1.2 of ETc, significantly, increased all studied characters of vegetative growth as compared with the other treatments combinations.

II. Seed yield and its components

a. Effect of irrigation treatments

Data recorded in Table (4) indicate that irrigation at 70% of (ASMD) increased average seed yield plant^{-1}, total seed yield fed.$^{-1}$ and number of pods plant^{-1} than those of the irrigation at 50% of (ASMD) or 90% of (ASMD) in both seasons. Meanwhile, the average number of seeds pod^{-1}, 100-seed weight and protein content were not significantly affected by the different irrigation treatments in the both seasons. Similar results on cowpea were recorded by Lemma *et al.* (2009).

b. Effect of nitrogen fertilization levels

Data in Table (4) indicate that nitrogen fertilization with 30 kg N fed.$^{-1}$, significantly increased seed yield plant^{-1}, seed yield fed.$^{-1}$ and number of pods plant^{-1} in both seasons as compared with the low N levels(10 and 20 kg N fed.$^{-1}$). However, the two higher N levels (30 and 40 kg N fed.$^{-1}$) did not significantly differ in their effects on number of seeds pod^{-1}, 100-seed weight and seed crude protein content in the two seasons, this may be due to that under the experimental farm condition 30 kg N fed.$^{-1}$ was enough starter dose for healthy host plants and Rhizobium complete the plant N need by symbiotic N-fixation.

The obtained increments in the seed yield as a result of N application might be directly attributed to the increase in pod number plant^{-1}, number of seeds pod^{-1} and 100-seed weight. These results seemed to be in accordance with those reported by Bin Ishag (2003) who found that the soil application of N at the rate of 40 or 60 kg fed.$^{-1}$ gave the highest mean values of pea dry seed yield. The latter reported that the increase in seed yield was related to the increments on number of pods plant^{-1} rather than that to increase in weight of seeds pod^{-1}. Similar discussion was reported by Hussaini *et al.*, (2004) who explained the increase in seed yield, as a result of N fertilization, on the basis that the pollen produced by plants with high nitrogen treatment sired significantly more seeds than pollen produced from low nitrogen dose. Similar results on cowpea were recorded by Knany *et al.*, (2002), El-Bably and El-Waraky(2006); El-Waraky (2007) and El-Waraky and Kasem (2007).

c. Effect of the Interaction between irrigation treatments and N levels

Data presented in Table (5) show that the highest values of seed yield plant^{-1}, seed yield fed.$^{-1}$, number of pods plant^{-1}, number of seeds pod^{-1}, 100-seed weight and seed crude protein content were produced from plants irrigated at 70% of (ASMD) I_2 and 30 kg N fed.$^{-1}$ in both seasons, followed by plants grown under irrigation at 50% of (ASMD) I_1, and high N fertilization level (40 kg N fed.$^{-1}$). \

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While, plants grown under low irrigation at 90%, of (ASMD) I_3 and fertilized with the lowest N fertilizer level (10 kg N fed.$^{-1}$) produced the lowest values of seed yield and its components in the two seasons.

Difference between the N levels of 30 and 40 kg N fed.$^{-1}$ with irrigation at 70%, of (ASMD) I_2 was not significant for number of seeds pod^{-1} and seed crude protein content, and 100-seed weight in the first season. Apparently, the promoting effects of irrigation and nitrogen fertilizer application on growth of cowpea plants were reflected on the increased total seed yield and its components. These results are in line with those obtained by Geetha and Varughese (2001), Anitha *et al.* (2004) and El-Bably and El-Waraky (2006) who reported that the application of irrigation at 1.2 of APE combined with 40 kg N fed.$^{-1}$ increased total seed yield and its components.

III- Soil water relations

a. Irrigation water applied (IWA)

Results in Table (6) indicate that watering at 50% ASMD (I_1) resulted in higher amount of irrigation water applied to be 63.10 and 61.66 cm(2650 and 2590 m^3 fed.$^{-1}$) in the 1st and 2nd season, respectively, due to frequent irrigation, followed by watering at 70% of ASMD I_2, 54.09 and 53.33 cm(2272 and 2240 m^3 fed.$^{-1}$) in the 1st and 2nd season, respectively, and 90% of ASMD I_3, 43.10 and 42.40 cm(1810 and 1781 m^3 fed.$^{-1}$) in the 1st and 2nd season, respectively. Amount of irrigation water applied at 50%, 70% and 90% of ASMD was distributed on 7, 6 and 5 irrigations including seeding irrigation.

Table (6): Monthly and seasonal water consumptive use (cm) of cowpea as affected by deficit irrigation and nitrogen levels in 2009 and 2010 seasons.

Deficit irrigation treatments	N. levels kg fed.$^{-1}$	Monthly rates (cm) in 2009 season				Monthly rates (cm) in 2010 season				Seasonal rate (cm)		Irrigation water applied (cm)	
		May	June	July	Aug.	May	June	July	Aug.	2009	2010	2009	2010
I_1 50% ASMD	10	3.25	14.60	19.93	3.22	2.15	14.20	19.30	3.75	41.00	39.40	63.10	61.66
	20	3.25	14.86	20.28	3.48	2.15	14.46	20.51	4.06	41.87	41.18	63.10	61.66
	30	3.25	15.32	20.74	3.58	2.15	14.70	20.78	4.28	42.89	41.91	63.10	61.66
	40	3.25	15.42	20.66	3.60	2.15	14.88	20.93	4.43	42.93	42.39	63.10	61.66
Mean		3.25	15.05	20.40	3.47	2.15	14.56	20.38	4.13	42.17	41.22	63.10	61.66
I_2 70% ASMD	10	3.25	12.56	17.72	2.55	2.15	12.18	18.19	2.94	36.08	35.46	54.09	53.33
	20	3.25	12.81	18.01	2.72	2.15	13.44	18.38	3.13	36.79	36.10	54.09	53.33
	30	3.25	13.10	18.33	2.82	2.15	13.67	18.72	3.43	37.50	36.97	54.09	53.33
	40	3.25	13.21	18.50	2.87	2.15	13.87	18.91	3.58	37.83	37.51	54.09	53.33
Mean		3.25	12.92	18.14	2.74	2.15	12.54	18.55	3.27	37.05	36.51	54.09	53.33
I_3 90% ASMD	10	3.25	10.08	13.88	1.93	2.15	9.84	14.11	2.50	29.14	28.60	43.10	42.40
	20	3.25	10.36	14.02	2.27	2.15	10.15	14.28	2.77	29.90	29.35	43.10	42.40
	30	3.25	10.70	14.25	2.35	2.15	10.32	14.59	3.01	30.55	30.07	43.10	42.40
	40	3.25	10.82	14.41	2.40	2.15	10.57	14.74	3.20	30.88	30.66	43.10	42.40
Mean		3.25	10.49	14.14	2.24	2.15	10.22	14.43	2.87	30.12	29.67	43.10	42.40
Mean of N.F. levels (cm)	10	3.25	12.41	17.18	2.57	2.15	12.07	17.20	3.06	35.41	34.49	53.43	52.46
	20	3.25	12.68	17.44	2.82	2.15	12.35	17.72	3.32	36.19	35.54	53.43	52.46
	30	3.25	13.04	17.77	2.92	2.15	12.56	18.03	3.57	36.98	36.32	53.43	52.46
	40	3.25	13.15	17.86	2.96	2.15	12.77	18.19	3.74	37.21	36.85	53.43	52.46
Overall mean		3.25	12.82	17.56	2.82	2.15	12.44	17.79	3.42	36.45	35.80	53.43	52.46

***ASMD: Available Soil Moisture Deficit.**

b. Water consumptive use (CU)

Mean values of water consumptive use for cowpea in 2009 and 2010 growing seasons are presented in Table (6).

The highest values of water consumptive use (42.17 and 41.22 cm) were obtained under irrigation at 50% of available soil moisture deficit, while the lowest values (30.12 and 29.67 cm) were obtained under irrigation at 90% of available soil moisture deficit in the two seasons, respectively. These results demonstrate that water consumption use increased as soil moisture was maintained high by frequent irrigations. The probable explanation of these results is that higher frequent irrigations provide chance for more consumption of water which ultimately resulted in increasing plant transpiration and evaporation from the soil surface. These results are in agreement with those reported by Byan *et al.* (2002), Anitha *et al.* (2004), El-Bably and El-Waraky (2006) and Uarrota (2010).

c. Water productivity (WP)

Water productivity expressed in kg of seeds m^{-3} of water consumed and productivity of irrigation water(PIW) in Kg seed m^{-3} of irrigation water applied are presented in Table (7). The obtained results show that WP was increased as the irrigation water applied decreased. Cowpea irrigated at 90% of available soil moisture had the highest value of WP to be 0.669 and 0.523 kg of seeds m^{-3} of water consumed, while the lowest one was 0.516 and 0.392 kg seed yield m^{-3} of water consumed, resulted from watering at 50% of available soil moisture deficit .

These findings could be attributed to the highly significant differences among seed cowpea yield as well as differences between water consumed. The present results are in line with those reported by Anyia and Herzog (2004), Adekalu and Okunade (2006) and El-Bably and El-Waraky (2006), who mentioned that the efficiency of water use decreased as the soil moisture was maintained high by frequent irrigation.

Data also show that increasing N- rate resulted in gradual increase in WP values, since values of WP amounted 0.522, 0.580, 0.708 and 0.652 kg seed yield m^{-3} of consumed water in the first season and 0.390, 0.462, 0.528 and 0.493 kg seed yield m^{-3} of consumed water in the second season under 10 , 20 , 30 and 40 kg N $fed.^{-1}$, respectively. The interaction between irrigation treatments and nitrogen fertilization levels(Table 7) show that the highest values of WP (0.763 and 0.568 kg seeds m^{-3} water consumed) in 2009 and 2010 season, respectively, were obtained from irrigation at 90% of ASMD with fertilization at 30 kg N $fed.^{-1}$. These results coincided with those of Geetha and Varughese (2001) and El-Bably and El-Waraky (2006).

d. Productivity of irrigation water (PIW)

Results presented in Table (7) indicate that the highest average values of PIW, 0.469 and 0.366 kg seeds m^{-3} of irrigation water applied were obtained under treatment of watering at 90% of available soil moisture in the 1st and 2nd season, respectively, while the lowest ones, 0.345 and 0.262 kg seeds m^{-3} of irrigation water applied were obtained from treatment of watering at 50% of ASMD in 2009 and 2010 season, respectively. These results could be attributed to the significant differences among cowpea seed yield, evapotranspiration and water applied values (Table 7).

The higher values of PIW of I_3 than that of I_1 are obviously due to the less amount of the applied water (W_a) under treatment I_3, as shown in Table (7).

Average values of the W_a under I_3 is less than that of I_1 by about 27.6 and 33.3% in the 1st and 2nd season, respectively. Thus ,the reduction of the W_a, due to the irrigation regime of I_3, is much lower than of the yield. Therefore, values of PIW were higher under I_3 than I_1 treatment. The interaction between irrigation treatments and nitrogen levels (Table 7) show that the highest values of PIW 0.541 and 0.403 kg seeds m^{-3} water applied in both seasons, were obtained from irrigation at 90% of ASMD with fertilization at 30 kg N $fed.^{-1}$. This finding is in harmony with those obtained by Byan *et al.*, (2002) and El-Bably and El-Waraky(2006).

Table (7): Water productivity (WP) in Kg seeds m^{-3} of water consumptive use and productivity of irrigation water (PIW) in Kg m^{-3} of irrigation water applied in 2009and 2010 seasons.

Treatments of irrigation	N. levels kg N $fed.^{-1}$	WCU m^3 $fed.^{-1}$		Water applied (m^3 $fed.^{-1}$)		WP Kg m^{-3} WCU		PIW Kg m^{-3} IWA	
		2009	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
I_1 50% ASMD	**10**	1722	1655	2650	2590	0.428	0.328	0.278	0.210
	20	1759	1730	2650	2590	0.456	0.354	0.302	0.237
	30	1801	1760	2650	2590	0.609	0.464	0.414	0.315
	40	1803	1780	2650	2590	0.565	0.418	0.385	0.287
Mean		**1771**	**1731**	**2650**	**2590**	**0.516**	**0.392**	**0.345**	**0.262**
I_2 70% ASMD	**10**	1515	1489	2272	2240	0.580	0.380	0.387	0.253
	20	1545	1516	2272	2240	0.654	0.514	0.444	0.348
	30	1575	1553	2272	2240	0.753	0.551	0.522	0.382
	40	1589	1575	2272	2240	0.666	0.519	0.466	0.365
Mean		**1556**	**1533**	**2272**	**2240**	**0.664**	**0.492**	**0.455**	**0.337**
I_3 90% ASMD	**10**	1224	1201	1810	1781	0.558	0.463	0.377	0.312
	20	1256	1233	1810	1781	0.629	0.518	0.427	0.358
	30	1283	1263	1810	1781	0.763	0.568	0.541	0.403
	40	1297	1288	1810	1781	0.725	0.541	0.519	0.391
Mean		**1265**	**1246**	**1810**	**1781**	**0.669**	**0.523**	**0.469**	**0.366**
LSD 5%		18.02	17.21	-----	-----	0.135	0.101	0.0282	0.0489
Mean of Nitrogen treatments	**10**	1487	1449	2244	2204	0.522	0.390	0.347	0.258
	20	1520	1493	2244	2204	0.580	0.462	0.394	0.314
	30	1553	1525	2244	2204	0.708	0.528	0.492	0.367
	40	1563	1548	2244	2204	0.652	0.493	0.457	0.348
Mean		**1531**	**1504**	**2244**	**2204**	**0.616**	**0.469**	**0.423**	**0.322**
LSD 5%		6.454	5.87	-----	-----	0.1192	0.023	0.0337	0.023

Means designated by the same letter at each cell are not significant at the 5 % level according to Duncan's multiple range test.

Concerning the effect of N fertilization on the PIW, as shown in Table (7), results reveal that increasing N fertilization level significantly increased

PIW values of seed yield. This is due to increased seed yield with increasing N level. The highest average values of PIW (0.492 and 0.367 kg seeds m^{-3}) in the both seasons, were obtained under treatment of 30 kg N $fed.^{-1}$, whereas the lowest ones (0.347 and 0.258 kg seeds m^{-3} water applied) in the two seasons, were obtained under treatment of 10 kg N $fed.^{-1}$. These results are in agreement with those of Anitha *et al.*, (2004), El-Bably and El-Waraky (2006) and Uarrota (2010).

Conclusion

The present study recommends irrigating cowpea cultivars at 70% of ASMD with adding 30 kg N $fed.^{-1}$ in North Delta region of Egypt and similar areas.

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تـأثير نقـص مـاء الـري والتسـميد النيتروجينـي علـى محصـول اللوبيـا ومكوناتـه والكفاءة الإنتاجية للمياه في شمال دلتا مصر

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أجريت تجربتـان حقليتـان فـي مزرعـة البحوث الزراعيـة بسـخا، محافظـة كفر الشيخ خـلال موسـمي الزراعة الصيفي ٢٠٠٩ و ٢٠١٠ لدراسة تأثير نقص مياه الري مع مستويات مختلفة من التسميد النيتروجيني على إنتاجية نبات اللوبيا وبعض العلاقات المائية.

استخدم تصـميم القطـع المنشـقة فـي أربـع مكـررات حيث خصصـت القطـع الرئيسـية لمعـاملات الـري الثلاثة، وهي الري عند ٥٠%،٧٠% و٩٠% من استنفاذ الماء الميسر، وخصصت القطـع المنشـقة لمسـتويات التسميد الأربعة وهي ١٠، ٢٠، ٣٠ و٤٠ كجم نيتروجين للفدان. وتم دراسـة الصـفات التاليـة: ارتفـاع النبـات، عدد الأوراق في النبات، عدد الأفرع فـي النبـات، محتـوى الكلوروفيل للنبـات، إنتـاج النبـات مـن البـذور، إنتـاج الفدان من البذور، عدد القرون في النبات، عدد البذور فـي القـرن الواحـد، وزن المائـة حبـة والبـروتين الخـام% بالبذور،

ويمكن تلخيص النتائج المتحصل عليها فيما يلي:

١- أعطى الري بعد فقد ٧٠% من الماء الميسر مع التسميد بمعدل ٣٠ كجم نيتروجين للفدان أعلى إنتاج من بذور اللوبيا للفدان.
٢- بلغت قيم الاسـتهلاك المـائي الموسـمي لمحصـول اللوبيـا ٤٢.١٧ ، ٣٧.٠٥ و ٣٠.١٢ سم فـي الموسـم الأول و ٤١.٢٢، ٣٦.٥١ و ٢٩.٦٧ سـم فـي الموسـم الثـاني لمعـاملات الـري عنـد ٥٠% ، ٧٠% و ٩٠% من استنفاذ الماء الميسر على التوالي، كما بلغت كمية المياه المضـافة ٦٣.١٠ ، ٥٤.٠٩ و٤٣.١٠ سم فـي الموسـم الأول و٦١.٦٦، ٥٣.٣٣ و٤٢.٤٠ سم فـي الموسم الثـاني لـنفس معـاملات الـري علـى التوالي.
٣- أعطى الري بعد استنفاذ ٥٠% من الماء الميسر أعلى القيم لطول النبات وعدد الأوراق في النبات وعدد الأفرع في النبات ومحتوي الأوراق من الكلوروفيل في السنة الأولى، بينما نتجت أعلى القيم لعدد القرون بالنبات ووزن البذور للنبات وإنتاج الفدان من البذور من الري عند استنفاذ ٧٠% مـن المـاء الميسـر فـي كلا الموسمين.
٤- أدى التسـميد النيتروجينـي بمعـدل ٤٠ كجـم نيتـروجين للفـدان إلـى زيـادة معنويـة فـي طـول النبـات وعـدد الأوراق في النبات وعدد الأفرع في النبات ومحتوى الأوراق من الكلوروفيل فـي كـلا الموسـمين، بينمـا نتجت أعلى القيم لوزن البذور للنبات الواحد ووزن البذور للفدان وعدد القرون فـي النبـات ووزن المائـة بذرة، من نباتات تم تسميدها بمعدل ٣٠ كجم نيتروجين للفدان في كلا الموسمين.
٥- كانت أعلى كفاءة إنتاجية للمتر المكعب من مياه الري المستهلكة بواسطة نباتـات اللوبيـا وكـذلك الكفـاءة الإنتاجية لمياه الري المضـافة، عند الري بعد فقد ٩٠% مـن المـاء الميسـر مقارنـة بـالري عنـد فقـد ٥٠% و٧٠% من الماء الميسر في كلا الموسمين.
٦- زادت كفاءة الماء المستهلك والمضـاف بزيادة التسميد النيتروجيني حتى ٣٠ كجم نيتروجين للفدان.

توصي الدراسة بري محصول اللوبيا صنف كفر الشيخ ١ والأصناف المشابهة له عند فقد ٧٠% من الماء الميسر مع التسميد النيتروجيني بمعدل ٣٠ كجم نيتروجين للفدان في منطقة شمال الدلتا بمصر والمنـاطق المشابهة لها.

قام بتحكيم البحث

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Table (4): Effect of irrigation treatments and nitrogen fertilization levels on seeds yield and its components of cowpea in 2009 and 2010 seasons.

Treatments	Seed yield plant^{-1} (g)		Seed yield fed.$^{-1}$ (kg)		No. pods plant^{-1}		No. of seeds pod^{-1}		100-seed weight (g)		Crude protein (%)	
	2009	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
Irrigation treatments												
I_1(50% ASMD)	32.1b	25.6bc	913.49b	679.19ab	18.7b	14.1ab	12.9a	11.0a	13.57a	16.58a	19.7a	20.6a
I_2(70% ASMD)	34.5a	28.2a	1032.97a	754.74a	21.6a	15.8a	12.6a	11.2a	13.59a	16.75a	19.6a	19.5a
I_3(90% ASMD)	29.4c	24.6c	847.90c	651.90b	17.3b	13.5b	12.6a	10.9a	13.26a	15.64b	18.6b	18.2b
N levels (kg fed.$^{-1}$)												
10	26.1c	21.1c	766.17c	555.00c	16.1d	12.7c	12.5a	14.4b	13.02b	15.88b	18.0b	18.0b
20	31.3b	25.2b	867.14bc	676.76b	19.0c	13.9b	12.6a	11.1a	13.41ab	16.47a	19.6a	19.4a
30	36.2a	30.2a	1086.76a	796.76a	21.4a	16.5a	12.8a	11.3a	13.84a	16.74a	19.8a	19.6a
40	34.2ab	28.0ab	1005.74a	752.58ab	20.3b	14.6b	12.8a	11.3a	13.62a	16.22ab	19.8a	20.6a

Values having a similar alphabetical letter, within a comparable group of means, are not significantly different, using revised G.S.D. test at 0.05 level.

Table (5): Effect of the interaction between irrigation treatments and nitrogen fertilization levels on cowpea yield and its components in 2009 and 2010 seasons.

Irrigation deficit	N levels Kg N fed.$^{-1}$	Seed yield plant^{-1} (g)		Seed yield fed.$^{-1}$ (kg)		No. of pods plant^{-1}		No. of seeds pod^{-1}		100-seed weight (g)		Crude protein (%)	
		2009	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
I_1 (50%) ASMD	10	26.1f	20.6ef	737.29e	543.65d	15.8f	12.5e	12.7a	12.7a	13.21a	16.02c	18.8c	19.3a
	20	31.6c	24.6de	801.25de	612.69cd	18.7d	13.4de	12.9a	12.9a	13.52a	16.84b	20.0b	20.3a
	30	36.9a	29.7bc	1096.04ab	816.85ab	21.3b	16.4bc	13.1a	13.1a	13.89a	17.40a	20.1ab	20.3a
	40	33.9bc	27.5c	1019.38bc	743.55b	19.0cd	14.1de	12.9a	12.9a	13.66a	16.08c	20.0b	22.7a
I_2 (70%) ASMD	10	29.2de	22.7e	878.33cd	565.89cd	18.0de	13.4de	12.3a	12.3a	12.86a	16.54bc	17.2e	18.1a
	20	33.6c	26.8cd	1009.79bc	779.42b	21.5b	15.0cd	12.6a	12.6a	13.60a	16.75b	20.1ab	19.7a
	30	38.2a	33.4a	1185.83a	855.85a	24.1a	18.6a	12.8a	12.8a	14.04a	16.95a	20.4ab	19.8a
	40	36.8a	29.8bc	1057.92b	817.81ab	22.9ab	16.3bc	12.8a	12.8a	13.87a	16.77b	20.7a	20.2a
I_3 (90%) ASMD	10	23.1g	19.9f	682.88f	555.47d	14.5d	12.3e	12.4a	12.4a	12.99a	15.07d	18.0d	16.6a
	20	28.7e	24.3de	790.38e	638.18cd	16.8c	13.2e	12.6a	12.6a	13.13a	15.82c	18.8c	18.4a
	30	33.5c	27.6c	978.42c	717.59b	19.0cd	14.7cd	12.6a	12.6a	13.59a	15.86c	18.9c	18.6a
	40	32.2c	26.6cd	939.92c	696.37b	18.8d	13.6de	12.8a	12.8a	13.33a	15.80c	18.8c	19.0a