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Response of barley to different moisture depletion rates and n-fertilization forms within the root zone

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ABSTRACT:

Two field trials were carried out in Fayoum Governorate (Tamiea, Station of Agricultural Research), Egypt, during the seasons (2019/20) and (2020/21). This study aims at determining the response of yield components grain and straw yields and some water relations of barley variety (Giza 132) to different rates of available soil moisture depletion and nitrogen fertilization forms. Three irrigating regimes at 40%, 60%, and 80% of total available soil moisture depletion (ASMD) and three N fertilization forms, i.e., ammonium sulfate (20.5%N), ammonium nitrate (33.5%N), and Urea (46%N) were tested in the split-plot design with four replications. The results showed that, the highest straw and grain yield, and its components were resulted from a mixture of irrigated barley under 40% ASMD with ammonium sulfate as a form of N fertilization. Furthermore, it yielded the highest seasonal water use and water productivity results. In addition, the farm economic retune of treatments take the same trend.

KEYWORDS: Barley yield – water management- N fertilization forms– consumptive use- water productivity.

1. INTRODUCTION:

Barley (Hordeum Vulgare L.) is Egypt's 4th most important cereal crop. It is a tolerant crop to an adverse environment compared to other cereals. In Egypt, it is grown in 0.06 Mha with productivity of 6.2 Mt at an average of 3.6 Mgha^{-1}(FAOstat 2021). In this respect, Egypt ranks an average of the top 70 countries for barley productivity.

The scarcity and limitations of water resources are among Egypt's most important challenges in producing crops. Improving new methods and techniques, which are highly effective in reducing and rationalizing irrigation water consumption, is a prerequisite to reaching this purpose (Hozayn et al. 2016; Abdelraouf et al. 2020 a, b).It is possible to reduce the huge gap between the production of crops and the growing and increasing consumption of the population, which can be achieved through the development and modernization of various agricultural practices in arid areas (Abdelraouf, et al. 2016; Eid and Negm 2018).

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The water productivity indicator is considered one of the most crucial indicators of field crops (WP) and it is very important because of the scarcity and limitation of water in Egypt as one of the dry areas in the world. The scarcity of irrigation water is one of the primary causes of low crop productivity worldwide. Therefore, irrigation water usage should be appropriate, and we should accept a small yield reduction under deficit irrigation conditions. (Okasha et al. 2013; EL-Metwally et al. 2015). Irrigation is a main significant input in crop production, and the irrigation water deficit strongly affects both the productivity and profitability of the crops. Additional inputs availability such as sunlight, nutrients, and management practices., all influence how plants and crops respond to water. (Zoebl 2006; Passioura 2006; Molden et al. 2010; Zwart et al. 2010; Abdou et al. 2018; Cao et al. 2022;).

The wheat's highest productivity components and grain yield resulted from irrigation at 35% ASMD; a significant reduction in yield components, straw, and grain yields was detected from increasing ASMD to 55 or 75 %. Seasonal ET_C values were: 43.13, 40.12 and 39.05 cm for irrigation at 35, 55 and 75 % ASMD, respectively. The peak of water consumption occurred during March and April, and the K_C values were: 0.53, 0.74, 0.87, 0.91, 0.99, 0.60, and 0.410 for November, December., January, February, March, April, and May months, respectively (Yousef and Ashry 2006; Abdou and Emam 2016). Irrigation at 1.2 CPE (cumulative pan evaporation) Barley grain and straw yields were highest when irrigation was done in short intervals or with a wet irrigation regime. (Abd El-Rahman et al. 2012; Abdelraouf and Ragab 2018).

Nitrogen fertilizer is essential for all crop production. In the past ten decades, its use has increased by above 100 folds (Franzluebbers 2007; Herrero et al. 2010; Mohammed and Maqsuda 2015). Nitrogen fertilizer increased growth metrics, grain production, chlorophyll, and grain protein content (Giambalvo et al. 2010; Tariq Jan et al. 2011; Boukef et al. 2013).

2. MATERIALS AND METHODS:

Current investigation was carried out during winter season of 2019/20 and 2020/21 at Tamiea, Station of agricultural research, Fayoum Gov., Egypt. (Long. 30.51 E, Lat.29.18 N, Alt. 30 m above the mean sea level (MSL). Some chemical and physical of soil properties of the selected site were determined according to Klute 1986, and Page et al. 1982 include soil type: clay loam with 28.4% sand, 23.9% silt, and 47.6% clay. Soil organic matter content of 1.9% with $CaCo_3$ content of 6.7%. The soil's pH is 8.13, and ECe is 3.17 DSm^{-1}. The soluble cation content is as follows (in meq L^{-1}; K^+ (0.50), Mg^{++} (4.28), Ca^{++} (8.48), Na^+ (18.53), Cl^- (20.87), So_4^- (8.10), Hco_3^-(2.74). The CEC of soil is 33.07 meq (100g soil)$^{-1}$. Some soil moisture contents were determined gravimetrically on an oven-dry basis (wt wt^{-1}, %) up to 60 cm depth (Field capacity (FC) 39.60%, permanent wilting point (PWP) 19.26%, available of soil moisture 20.33%, the bulk density (Bd) is 1.38 g cm^{-3}), thus available soil moisture in a depth of 60 soil is 168.3 mm. The meteorological climate data for Fayoum Region (arid regions) during the two successive growing seasons (temperature, rain, relative humidity, and wind speed) are illustrated in Fig 1. (The meteorological station is located inside Tameia agricultural station).

This investigation's goal was to study the effects of available soil moisture depleted (ASMD), i.e., I_1: 40% (6 irrigation plus planting one), I_2: 60% (5 irrigations plus planting one), and I_3: 80 %(4 irrigations plus planting one) (Table 1) and three Nitrogen forms fertilizes i.e., F_1: Ammonium sulfate (20.5% N), F_2: Ammonium nitrate (33.5% N) and F_3: Urea (46% N) as traditional forms of nitrogen fertilizer in Egypt (to select the suitable form under farmers current economic conditions) as well as their interaction on barley yield components, grain, straw yields, and some crop- water relations. The applied treatments with 4 replicates were arranged in the split-plot design. The main plots were devoted to irrigation regimes, while the subplots were assigned to N-fertilizer forms. The sub-plot was 10.5 m^2 in area (3 ×3.5 m) 15 rows 20 cm apart and 3.5 m long. Calcium superphosphate (15.5% P_2O_2) at a 238 K ha^{-1} rate was incorporated into the soil surface during seedbed preparation. Barley variety (Giza 132) was sown at the rate of 120 k ha^{-1} on Nov. 20^{th} and 18^{th}in the 1^{st} and 2^{nd} seasons, respectively. N-fertilizer was added at rate of 107 k N ha^{-1}in three equal doses at sowing and 1^{st} and 2^{nd}irrigations. All other the ministry of agriculture recommendations have been applied during the two growing seasons. However, harvesting occurred on the 24^{th} and 21^{st} of April in the two seasons, respectively.

2.1. Yield components: At harvesting time, samples of ten guarded plants were randomly taken from the central row in each sub-plot to determine the following traits: number of spikes m^{-2}, and the weight of 1000 grain (g) were measured.

2.2. Grain and straw yields: Grain and straw yields data (kg ha^{-1}) was determined from central area (1 m^2) in each sub- plot. Most of the obtained data were subjected to statistical analysis according to Snedecor and Cochran 1980 at a level of significance of 5%.

***2.3.* The relations of crop-water**

2.3.1. Seasonal water consumption in cm (ET_C): The calculation of consumptive use of water was done based on the depletion of soil moisture according to the following Equation. Hansen et al. (1979) as follows:

$$CU = SMD = ETc = \frac{(h2 - h1)}{100} \times Bd \times Di$$

Where, CU: Consumptive use of irrigation water in the root zone (60 cm)
h_2: soil moisture at 48 h after irrigation, %,
h_1: soil moisture before next irrigation, %,
Bd: The soil bulk density (g cm^{-3}) for a given soil layer and
Di: depth of soil layer at 60 cm.

2.3.2. Daily ET_C rate (mm/day): The daily ET_C rate was calculated from the ET_C between every two successive irrigations divided by the number of days.

2.3.3. Ref. evapotranspiration: The ref. (reference) Evapotranspiration (ET_0) reflects the effect of weather conditions on evapotranspiration and transpiration. ET_0 was estimated as a daily mean (mm/day^{-1}) using daily weather data for Fayoum Governorate (Fig. 1) according to the Equation of Penman-Monteith procedure (Allen et al. 1998).

2.3.4. The crop coefficient (K_C):

The crop coefficient (K_C) is the ratio of the observed ET of a crop (ETc) and ET_0 under the same conditions. K_C was calculated by the Israelelsen and Hansen 1962 formula. $K_C = ET_C / ET_0$

Where: ET_C: Crop evapotranspiration, mm day^{-1} and ET_0: Ref. evapotranspiration, mm day^{-1}.

2.3.5. Water productivity (WP):

2.3.6. The water productivity was estimated according to the equation of Jensen 1983 as follows: $WP = \frac{Y}{CU}$

Where: WP: Consumed of irrigation water per each kg grain produced, kg m^{-3}, Y: Grain yield of barley (kg ha^{-1}) and CU: the seasonal consumptive use of irrigation water, m^3 ha^{-1}.

Fig 1. Daily weather during 2019/20 and 2020/21 barley growing seasons.

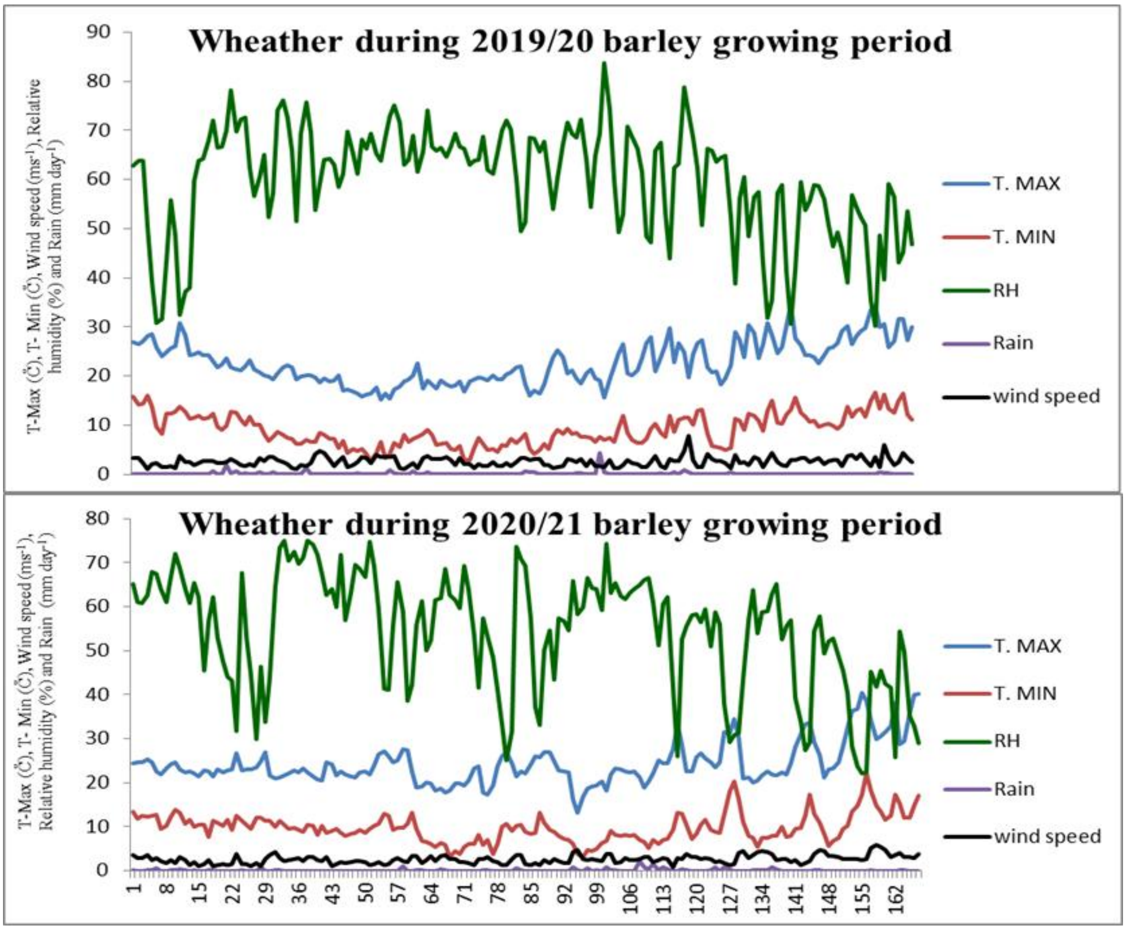

Table 1. Dates and irrigation number of barley, as affected by irrigation regime of barley in 2019/20 and 2020/2021 seasons.

Season	2019/ 20 Available soil moisture depletion (ASMD)			2020/21 Available soil moisture depletion (ASMD)		
	(I_3)40%	(I_2)60%	(I_1)80%	(I_3)40%	(I_2)60%	(I_1)80%
	Date	**Date**	**Date**	**Date**	**Date**	**Date**
Planting	20/11	20/11	20/11	18/11	18/11	18/11
1st irrigation	11/12	11/12	9/12	9/12	9/12	11/12
2nd irrigation	1/1	8/1	13/1	30/12	6/1	15/1
3rd irrigation	22/1	5/2	17/2	20/1	3/2	19/2
4th irrigation	12/2	5/3	24/3	10/2	3/3	26/3
5th irrigation	5/3	2/4	-	3/3	31/3	-
6th irrigation	26/3	-	-	24/3	-	-
Harvesting	24/4	24/4	21/4	21/4	21/4	24/4
Irrigation count	**7**	**6**	**5**	**7**	**6**	**5**

3. RESULTS AND DISCUSSION:

3.1. The yield components

The irrigation regime treatments significantly affected the yield components of barley. in the 1st and 2nd seasons (Table 2). The highest values of yield components i.e., spike numbers m^{-2} and the weight of 1000-grain were recorded with the highest irrigation rate (irrigation at 40% of ASMD) and amounted to (503.11 and 478.80) and (44.58 and 44.42 g) in the both 1st and 2nd seasons, respectively. Irrigating at 60 or 80% ASMD resulted in lower values of the above-mentioned yield components reached (32.8 and 40.9%) for spike number and (4.04 and 11.40%) for 1000-grain weight in the 1st and (31.5 and 39.8%), (4.4 and 11.9%) in the 2nd seasons, respectively. All these results may be attributed to the reduction of water and nutrients absorption due to the impact of soil moisture stress, and this, in turn, reduced photosynthesis, cell division, and dry matter accumulation in storage organs (Yordanov et al. 2003; Abd El- Rahman et al. 2012; Abdou and Emam, 2016).

The collected data show that the applied N fertilization forms have significantly affected the yield components of barley in the two successive seasons. Applying nitrogen fertilizer as ammonium sulfate form gave the highest values of yield components i.e., spike No. m^{-2} and the weight of 1000-grain (g), which were higher than those with urea form by (10.4 and 3.9%) in the 1st season and by (13.2 and 4.0 %) in the 2nd season, respectively. These increments may be due to the organic form of urea in which crops only absorb 20-50% of N and the rest is lost from the soil via volatilization, leaching, and denitrification. Besides, urea uptake is too slow (Maria-Ramirez et al. 2011; Mohammed and Maqsuda 2015).

Barley yield components were significantly affected by the interaction of available soil water depletion (ASMD) regimes and N fertilization forms in the 1st and 2nd seasons. The extreme values of spike No. m^{-2} and 1000- grain weight were recorded under irrigating at 40% ASMD and applying ammonium sulfate as N fertilization form in the two successive seasons. In contrast, the lowest values of the above-mentioned yield components resulted from irrigating barley at 80% ASMD by applying urea as N fertilization form (Table 2).

3.2. The straw and grain yields

Application of irrigation water regimes or N fertilization forms significantly influenced the barley straw and grain yields in 1st and 2nd seasons (Table 2). Highly barley straw and grain yields were recorded at 40% ASMD regime which amounted to 5049 and 5461 kg ha^{-1}in the 1st season and 4983 and 5402 kg ha^{-1} in the 2nd one, respectively. Irrigating at 60% or 80% ASMD resulted in reduced figures for barley grain and straw yields, where the reduction reached (7.7 and 16.3%) and (9.2 and 16.7%) in the 1stseason and by (8.1 and 16.7%) and (9.3 and 16.6%) in the 2nd season, respectively, (Table 2).

Likely to yield components, grain and straw yields exhibited similar tends under Applying N fertilization forms. Results in Table 2 show that applying ammonium sulfate gave the highest grain yield i.e., 4839 and 4762 kg ha^{-1}, and straw yield i.e.,5299 and 5241 kg ha^{-1}in the 1st and 2nd seasons, respectively. Appling urea as N fertilization form resulted in lower grain and straw yields, where the reduction comprised 8.04 and 11.5%, respectively, in the first season and reached 8.2 and 11.7%in the second one, respectively, as compared to ammonium sulfate as N fertilization form.

Barley straw and grain yields were high significantly affected under the interaction between irrigation regimes and N-fertilization forms (Table 2). Irrigating at 40% ASMD and applying ammonium sulfate gave the highest grain of yields (5228 and 5170 kg ha^{-1}) and the straw yields were (5787 and 5703 kg ha^{-1}) in the 1st and 2nd seasons, respectively, (Table 2).

Table 2. Effect of irrigation regime treatments and N fertilization forms and their interaction on yield components, grain and straw yields of barley in 2019/20 and 2020/21 seasons.

Treatment		Spike number^{-3}		1000-grain weight (gm)		Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})	
Irrig. (ASMD)	**Nitrogen Source**	**2019/ 20**	**2020/21**	**2019/ 20**	**2020/21**	**2019/ 20**	**2020/ 21**	**2019/ 20**	**2020/ 21**
(I_1) 40%	F_1: Am.S	516.50	500.81	45.35	45.22	5228	5170	5787	5703
	F_2: Am.N..	502.10	480.22	44.22	44.08	5054	4989	5436	5398
	F_3: Urea	490.73	455.36	44.17	43.97	4864	4790	5161	5106
Mean of I_1		**503.11**	**478.80**	**44.58**	**44.42**	**5049**	**4983**	**5461**	**5402**
(I_2) 60%	F_1: Am.S	392.62	384.72	43.94	43.63	4859	4770	5209	5172
	F_2: Am.N..	316.43	306.75	42.51	42.11	4636	4579	4988	4925
	F_3: Urea	304.80	292.56	41.89	41.60	4478	4394	4684	4601
Mean of I_2		**337.95**	**328.01**	**42.78**	**42.45**	**4658**	**4581**	**4960**	**4899**
(I_3) 80%	F_1: Am.S	304.90	298.91	40.63	40.28	4430	4347	4900	4847
	F_2: Am.N..	295.29	286.30	39.07	38.74	4244	4173	4535	4490
	F_3: Urea	291.71	280.19	38.81	38.43	4008	3935	4221	4178
Mean of !$_3$		**297.30**	**288.47**	**39.50**	**39.15**	**4227**	**4151**	**4552**	**4505**
Mean of Am. .		404.67	394.81	43.31	43.04	4839	4762	5299	5241
Mean of Am. N.		371.27	357.76	41.93	41.64	4645	4580	4986	4938
Mean of Urea		362.41	342.70	41.62	41.33	4450	4373	4689	4628
L.S.D at 5%									
I		96	90	1.07	1.04	360	325	305	270
F		8	7.2	1.11	1.07	167	154	260	248
I x F		N.S	N.S	0.96	0.90	160	148	205	200

3.3. The relationships of crop water

3.3.1. Seasonal consumptive use (ET_C):

The seasonal consumptive of water use or evapotranspiration (ET_C) of barley crop as a function of the irrigation regime and applied N fertilization forms were 28.12 and 27.86 cm in the 1st and 2ndseasons, respectively, (Table 3). The difference may be due to the variation in weather factors of the two seasons (Table 3). Irrigating barley at 40% ASMD (6 irrigation events plus planting one were applied) produced the highest values of ET_C i.e., 29.87 and 29.62 cm in the 1st and 2ndseasons, respectively. Furthermore, irrigation at 60 or 80% ASMD (5 and 4 irrigation events plus planting one were applied, respectively) decreased ET_C by 5.6 and 11.95% and by 5.5 and 12.36%, in the 1st and 2nd seasons, respectively, comparable to 40% ASMD. It is obvious that increasing the availability of soil moisture in the root growth zone of barley plants caused an increase in ET_C. These results may be due to the high transpiration rates from soil under high available soil moisture. Conversely, under water stress, the transpiration from plants may decrease as a result of poor vegetative growth; also the evaporation decreases from the dry soil surface (Ouda et al. 2007; Abdou et al. 2011; Abd El-Rahman et al. 2012; Abdou and Emam 2016).

Applying ammonium sulfate as a form of N fertilization gave the highest values of ET_C i.e., 28.96 and 28.53 cm in the 1st and 2nd seasons, respectively. Applying urea resulted in a reduction in ET_C amounted to 5.39 and 4.70%, respectively, comparable with ammonium sulfate in the 1st and 2nd seasons (Table 3) (Malhi et al. 2009; Abd El-Rahman et al. 2012).

Irrigation of barley at 40% ASMD and applying ammonium sulfate gave the highest values of ET_C i.e., 30.61 and 30.33 cm in the 1st and 2nd seasons, respectively (Table 3). On the contrary, the lowest ET_C i.e., 25.41 and 25.24 cm is due to irrigate at 80% ASMD with applied urea as N-fertilization form in the 1st and 2nd seasons, respectively.

Table 3. Effect of irrigation regime and N fertilizer forms and their interaction on water consumptive use (cm) of barley in 2019/20 and 2020/2021 seasons.

Irrigation	2019-20 season			Mean	2020-21 season			Mean
	F_1	F_2	F_3		F_1	F_2	F_3	
I_1	30.61	29.83	29.18	29.87	30.33	29.62	28.90	29.62
I_2	28.94	28.05	27.60	28.20	28.66	27.86	27.44	27.99
I_3	27.04	26.44	25.41	26.30	26.61	26.04	25.24	25.96
Mean	28.96	28.11	27.40	28.12	28.53	27.84	27.19	27.86

3.3.2. Daily ET_C (mm day^{-1}):

The daily ET_C rates as a function of the adopted treatments in both seasons were started with low values during Nov. and then decreased more during Dec., then increased again during January and February to reach their maximum during March. Thereafter, it decreased during April (plant harvesting) (Table 4). These results are attributed to that at the initial growth stages (germination and seedling), most of the water loss was due to evaporation from the bare soil. In addition, the reduction in ET_C rate during December is due to the lower evaporation demands (air temperature, air humidity, and solar radiation). Thereafter, the plant cover and plant transpiration increased and reached maximum values throughout the heading and grain filling phases in March. At the maturity stage, the plants tended to dry and the ET_C rate decreased again during April (harvesting).

Irrigation at 40% ASMD regime exhibited higher daily ET_C values during the entire growing season than 60 or 80% ASMD regimes in the 1st and 2ndseasons. Such results could be attributable to the luxury of available soil moisture at 40% of the ASMD regime which is subjected to transpiration through the crop canopy and evaporation from the soil surface as well (Table 4) (Abdou et al. 2011; Abdou and Emam 2016: El-Akram and Emam, 2014).

The daily values of ET_C were slightly higher under ammonium sulfate than ammonium nitrate or urea, and such results were true in the 1st and 2nd seasons (Table 4). As for daily ET_C peak during March and April, with applying ammonium nitrate the values were lower by (1.80% and 2.7%) and by (1.52% and 1.83%) than those with applying ammonium sulfate form, respectively, in 1st and 2nd seasons. Such results are attributable to vigorous plant growth and higher grain yield due to applying ammonium sulfate.

3.3.3. Reference evapotranspiration (ET_0):

The reference evaporation rate (ET) in mm on the first day was estimated during the entire barley growing seasons i.e. 2019/20 and 2020/21 using the FAO Penman-Monteth method and meteorological data for Fayoum Governorate shown in (Fig. 1). The data obtained indicated that ET_0 rates were somewhat high during November and then decreased during December and January. After that, ET_0's daily averages increased from February through April in seasons 1 and 2. These results are attributed to the variation in climatic factors from month to month. (Allen et al. 1998) reported that, reference ET values depend mainly on the evaporative energy of a given area, that is, air temperature, solar radiation, air relative humidity, and wind speed.

Table 4. Effect of irrigation regime and N fertilizer forms and their interaction on daily water consumptive use (mm / day of barley in 2019/20 and 2020/2021 seasons.

Treatments		2019/20						2020/21					
Irrig. (ASMD)	**Nitrogen Forms**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**
	F_1:Am.S	1.03	0.93	1.21	1.77	3.50	2.33	1.02	0.90	1.17	1.74	3.48	2.29
(I_1)	F_2:Am.N	1.03	0.89	1.13	1.72	3.46	2.28	1.02	0.88	1.14	1.71	3.44	2.24
40%	F_3: Urea	1.03	0.86	1.07	1.66	3.43	2.24	1.02	0.85	1.07	1.64	3.39	2.22
Mean of I_1		**1.03**	**0.89**	**1.14**	**1.72**	**3.46**	**2.28**	**1.02**	**0.88**	**1.13**	**1.70**	**3.44**	**2.25**
	F_1:Am.S	1.03	0.84	1.11	1.64	3.35	2.24	1.02	0.83	1.10	1.61	3.33	2.22
(I_2)	F_2:Am.N	1.03	0.80	1.08	1.55	3.25	2.20	1.02	0.81	1.06	1.58	3.28	2.18
60%	F_3: Urea	1.03	0.77	1.05	1.52	3.20	2.19	1.02	0.78	1.02	1.53	3.23	2.14
Mean of I_2		**1.03**	**0.80**	**1.08**	**1.57**	**3.27**	**2.21**	**1.02**	**0.81**	**1.06**	**1.57**	**3.28**	**2.18**
	F_1:Am.S	1.03	0.79	1.03	1.46	3.17	2.08	1.02	0.78	1.00	1.48	3.10	2.02
(I_3)	F_2:Am.N	1.03	0.78	1.01	1.42	3.13	1.99	1.02	0.75	0.97	1.45	3.04	2.00
80%	F_3: Urea	1.03	0.77	1.00	1.35	2.93	1.93	1.02	0.73	0.95	1.40	2.95	1.93
Mean of I_3		**1.03**	**0.78**	**1.01**	**1.41**	**3.08**	**2.00**	**1.02**	**0.75**	**0.97**	**1.44**	**3.03**	**1.98**
Mean of N forms													
F_1: Am.S		1.03	0.85	1.12	1.62	3.34	2.22	1.02	0.84	1.09	1.61	3.30	2.18
F_2:Am.N		1.03	0.82	1.07	1.56	3.28	2.16	1.02	0.81	1.06	1.58	3.25	2.14
F_3: Urea		1.03	0.80	1.04	1.51	3.19	2.12	1.02	0.79	1.01	1.52	3.19	2.10
Over all mean		**1.03**	**0.83**	**1.08**	**1.57**	**3.27**	**2.16**	**1.02**	**0.81**	**1.05**	**1.57**	**3.25**	**2.14**

3.3.4. Crop coefficient (K_C):

The most well-known and most widely used method for estimating ET is the method based on the K_C approach (Allen et al. 1998), in which the ET_C is calculated using standard agro-meteorological variables and a crop-specific coefficient (K_C crop coefficient) that must take into account the atmospheric relationship Crop physiology and agricultural practices. Crop modulus reflects the ratio of crop cover and soil conditions to ET_0 values. K_C values were estimated from daily ET_C rates and daily ET_0 rates during the two growing seasons. K_C values as a function of the interaction between irrigation regimes and applied N forms (as a general average) were low during November and December, then increased during January (0.37 and 0.44) and February (0.45 and 0.48) with increasing vegetative growth to boot stage. K_C values reached their maximum values (0.68 and 0.70) during the month of March (Title - Grain Filling Phase). K_C values decreased again during April (0.36 and 0.36) as plants began to mature and harvest in both seasons respectively. These results can be attributed to the large spreading resistance of bare soil during the initial growth stage (germination and seedling stages) which gradually decreases with increasing crop cover up to the head stage and grain filling stages. At maturity (April), transpiration decreased due to leaf and stem drying causing lower K_C values during April (Table 5).

Increasing the ASMD from 40 to 60 or 80% reduced K_C values throughout the entire growing season in the 1st and 2nd seasons (Table 5). Applying ammonium nitrate or urea exhibited trends similar to that under increased ASMD from 40 to 60 or 80%. The K_C average values of the two seasons as a function of different treatments were (0.31, 0.35, 0.41, 0.47, 0.69, and 0.36) for the months from November to April, respectively (Abdou et al. 2011; El- Akram and Emam 2014; Abdou and Emam 2016).

Table 5. Effect of irrigation regime and N fertilizer forms and their interaction on crop coefficient (K_C) of barley in 2019/20 and 2020/2021 seasons.

Treatments		2019/20						2020/21					
Irrig. (ASMD)	Nitrogen source	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Reference ET(ET_0)		3.4	2.5	2.9	3.5	4.8	6.1	3.2	2.2	2.3	3.2	4.8	6.5
(I_1) 40%	F_1:Am.S	0.3	0.37	0.42	0.51	0.73	0.38	0.32	0.41	0.48	0.54	0.75	0.39
	F_2:Am.N	0.3	0.36	0.39	0.49	0.72	0.37	0.32	0.40	0.46	0.53	0.74	0.38
	F_3: Urea	0.3	0.34	0.37	0.47	0.71	0.37	0.32	0.39	0.45	0.52	0.73	0.38
Mean of I_1		**0.30**	**0.36**	**0.39**	**0.49**	**0.72**	**0.37**	**0.32**	**0.40**	**0.49**	**0.53**	**0.72**	**0.34**
(I_2) 60%	F_1:Am.S	0.3	0.34	0.38	0.47	0.70	0.37	0.32	0.38	0.44	0.51	0.72	0.37
	F_2:Am.N	0.3	0.32	0.37	0.44	0.68	0.36	0.32	0.36	0.41	0.48	0.70	0.36
	F_3: Urea	0.3	0.31	0.36	0.43	0.67	0.36	0.32	0.35	0.44	0.48	0.67	0.35
Mean of I_2		**0.30**	**0.32**	**0.37**	**0.45**	**0.68**	**0.36**	**0.32**	**0.37**	**0.46**	**0.49**	**0.68**	**0.34**
(I_3) 80%	F_1:Am.S	0.3	0.32	0.36	0.42	0.66	0.34	0.32	0.35	0.43	0.45	0.69	0.35
	F_2:Am.N	0.3	0.31	0.35	0.41	0.65	0.33	0.32	0.34	0.42	0.43	0.66	0.34
	F_3: Urea	0.3	0.31	0.34	0.39	0.61	0.32	0.32	0.33	0.39	0.42	0.63	0.32
Mean of I_3		**0.30**	**0.31**	**0.35**	**0.41**	**0.64**	**0.33**	**0.32**	**0.34**	**0.42**	**0.45**	**0.63**	**0.31**
Mean of N forms													
F_1: Am.S		0.30	0.34	0.39	0.47	0.70	0.36	0.32	0.38	0.47	0.50	0.69	0.33
F_2:Am.N		0.30	0.33	0.37	0.45	0.68	0.35	0.32	0.37	0.46	0.49	0.68	0.33
F_3: Urea		0.30	0.32	0.36	0.43	0.66	0.35	0.32	0.36	0.44	0.48	0.66	0.32
Over all mean		**0.30**	**0.33**	**0.37**	**0.45**	**0.68**	**0.36**	**0.32**	**0.37**	**0.46**	**0.49**	**0.68**	**0.33**

3.3.5. The water productivity of barley:

3.3.6. The water productivity of barley is an efficiency term that is quantified as a ratio of yield (crop grain, forage, etc.) and evaporation. The WP values as a function of the irrigation regime and nitrogen fertilization forms were 1.65 and 1.64 kg m^{-3} of grain consumed in the first and second seasons, respectively (Table 6). Barley at 40% ASMD gave the highest WP values with grain consumption being 1.69 and 1.68 kg m^{-3} of water in the first and second seasons, respectively. Conversely, irrigation at 60 or 80% of ASMD systems decreased WP values in the two successive seasons by 2.37 and 3.55% in the first season and by 2.98 and 4.76% in the second season, respectively, compared to 40% in the first season. ASMD system. . It can be seen that WP decreased with the increase of ASMD (El-Akram and Imam 2014; Abdou and Imam 2016). In contrast, Abdel-Khaleq et al. 2015 found that barley water productivity decreased with increased irrigation events; This difference can be attributed to different experiences, agricultural practices, prevailing climatic conditions…etc.

For the tested nitrogen fertilization forms, the data indicate that the use of ammonium sulfate as the nitrogen fertilization form resulted in higher WP values of 1.68 and 1.66 kg of grain per cubic meter in the first and second seasons, respectively. The use of ammonium nitrate as a form of nitrogen fertilization showed WP values less than 1.79 and 1.22% lower than those of ammonium sulfate in the two consecutive seasons.

Data in (Table 6) show that, the interaction data showed that the highest WP values of 1.71 and 1.70 kg of grain consumed at m^{-3} were recorded with 40% ASMD barley irrigation and also reacted with ammonium sulfate as nitrogen fertilization form in the first and second seasons, respectively Table 6).

Table 6. Effect of irrigation regime and N fertilizer forms and their interaction on water productivity (kg grains / m^3 water consumed) of barley in 2019/20 and 2020/2021 seasons.

Irrigation	2019-20 season			Mean	2020-21 season			Mean
	F_1	F_2	F_3		F_1	F_2	F_3	
I_1	1.71	1.69	1.67	1.69	1.70	1.68	1.66	1.68
I_2	1.68	1.65	1.62	1.65	1.66	1.64	1.60	1.63
I_3	1.64	1.61	1.58	1.61	1.63	1.60	1.56	1.60
Mean	1.68	1.65	1.62	1.65	1.66	1.64	1.61	1.64

3.4. Economic return

It is evident from data in (Table 7) that the highest net income (26432 L. E. ha $^{-1}$) was obtained by irrigating barley at 40% ASMD, but irrigating barley at 60 or 80% ASMD led to a decrease in the net income by 13.9 and /or 28.2%, respectively. Furthermore, the fertilization barley with ammonium sulfate gave the highest average of the net farm come (23891 L.E ha^{-1}) compared with the other form of nitrogen forms.

Data in (Table 7) show that the interaction between irrigation barley at 40% ASMD and fertilizing it with ammonium sulfate gave the highest average of all interaction treatments (27533 L.E ha^{-1}). Whereas the lowest one was detected from irrigating barley at 80% ASMD and fertilizing with urea as a form of nitrogen fertilizer.

Table 7: Economic return (L.E.* ha^{-1}) of barley production under irrigation regime and N fertilizer forms treatments, combined over two seasons.

Irrigation ASMD	Parameters	Fertilizer form Am. S.	Am. N.	Urea	Average of net income (L.E.*ha^{-1})
I_1	Total income	53383	51350	49244	
40%	fixed and Variable costs	25850	24760	24070	**26432**
	Net income	**27533**	**26590**	**25174**	
I_2	Total income	49234	47099	45135	
60%	fixed and Variable costs	25350	24260	23570	**22763**
	Net income	**23884**	**22839**	**21565**	
I_3	Total income	45106	42998	40482	
80%	fixed and Variable costs	24850	23760	23070	**18969**
	Net income	**20256**	**19238**	**17412**	
Average of net income (L.E.*ha^{-1})		**23891**	**22889**	**21384**	

L.E.* (Egyptian pound)

CONCLUSION:

It can be concluded that it is advisable to irrigate barley at 40% ASMD and fertilize it with ammonium sulfate to get the highest net income. Under deficit irrigation water conditions, it can be irrigated barley under 60% ASMD (5 irrigation events plus planting irrigation one) to save irrigation water as we can save the amount of water reaching 167 m^{3}ha^{-1} (6%). Meanwhile, the decrease in grain yield occurred only 391 kg ha^{-1} (7.7%), offset by a reduction in net income is about only 3669 L.E. ha^{-1} (Egyptian pound)

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الملخص العربي

إستجابة الشعير لمعدلات مختلفة من استنزاف الرطوبة الأرضية وصور التسميد النستروجيني داخل نطاق منطقة الجذور

تم إجراء تجربتين حقليتين في محافظة الفيوم (طامية ، محطة البحوث الزراعية) ، مصر ، خلال الموسمين (20/2019) و (21/2020). هدفت هذه الدراسة إلى تحديد استجابة مكونات المحصول ومحصول الحبوب والقش وبعض العلاقات المائية لصنف الشعير (جيزة 132) لمعدلات مختلفة من استنزاف رطوبة التربة المتاحة وصور التسميد النيتروجيني. تم اختبار ثلاثة أنظمة ري بنسبة 40٪ و 60٪ و 80٪ من إجمالي استنزاف رطوبة التربة المتاح (ASMD) وثلاثة صور تسميد النيتروجيني ، أي كبريتات الأمونيوم (20.5٪ ن) ونترات الأمونيوم (33.5٪ ن) واليوريا (46٪ ن) في تصميم القطع المنشقه مع أربعة مكرارات. أظهرت النتائج أعلى محصول من القش والحبوب ، وكذلك مكونات المحصول من تفاعل الري تحت 40٪ ASMD مع كبريتات الأمونيوم كصورة من صور التسميد النيتروجيني وعلاوة على ذلك، فقد أسفرت عن أعلى استخدام موسمي للمياه وإنتاجية المياه وكذلك العائد المزرعي.