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Impact of Irrigation Regimes and Growth Stimulants on Wheat (*Triticum aestivum* L.) Yield and Grain Quality Under Water Stress

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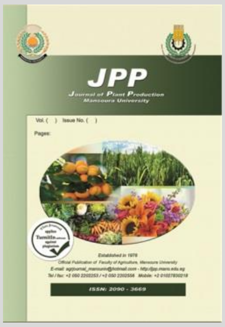

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ABSTRACT

Throughout the two following winter growing seasons of 2023–2024 and 2024–2025, a field experiment was conducted in the field at the Sakha research station, Wheat Research farm, Field Crops Research Institute, Kafr El-Sheikh, Agricultural Research Center, Egypt. The purpose of this study was to examine the effects of growth stimulants (control, Ascobein, Seaweed, and Molasses) and irrigation level (water amount equivalent to 115, 105, and 95% of field capacity (F.C.) in root zone 0-60 cm depth) on the growth, yield, and grain quality of the wheat cultivar (Giza 171).The findings demonstrated a substantial decrease in the majority of growth characteristics, yield and its attributes, and water consumptive use (WCU) when the irrigation water level was lowered from 115% to 95%. Proline, peroxidase activity, catalase activity, dry gluten, protein content, water productivity applied (PWA), and water usage efficiency (WUE) all showed notable increases during season 2024/2025.Grain yield, biological yield, number of spikes per spike, 1000-kernel weight, number of spikes m^{-2}, and WCU all significantly increased when molasses was added to the soil at 115% F.C. In the meantime, proline content, catalase activity, peroxidase activity protein content, dry gluten, PWA and WUE, all increased with molasses 95% irrigation. In the first winter season, the highest dry gluten was associated with treatments of ascobein and Molasses (12.4 and 12.3%), respectively.Taken together, when there was a water scarcity, the application of molasses performed better than seaweed and ascobein in terms of enhancing wheat output, growth characteristics, and grain quality.

Keywords: Ascobein, Protein, Molasses, water deficit, wheat.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is among the most significant cereal crops grown globally and often referred to as the ″king of cereals̏ due to its global significance. It is a member of the Poaceae family and is the second most produced food among cereal crops worldwide, after maize, while rice comes in third. Under irrigation, Egypt's yields surpass 2.9 t fad^{-1} (Ministry of Agriculture and Land Reclamation 2022). Wheat frequently faces unfavorable environmental conditions during the grain filling stage, including a shortage of irrigation water, less rainfall in the winter, and the need to halt irrigation operations in order to save water and get the field ready for the next cropping season early. In Egypt, a major barrier to crop production is water scarcity. The implementation of cutting-edge technologies and creative approaches to improve the effective use of available resources can help solve the pressing need to reduce water usage in irrigation.

Among the critical global challenges, particularly evident in Egypt, is the growing threat of water stress, which is anticipated to intensify considerably in the coming years (Hassan et al., 2016). The depletion of water supplies is putting further strain on the world's wheat sector (Guan *et al*., 2015), in addition, Growth, metabolism, and nutrition absorption are all adversely affected by water stress. Investigating practical methods that can close the gap between population demands and food supply is imperative in order to address this problem. Lack of water also interferes with the synthesis of photosynthetic pigments, which is essential for plant growth because low pigment concentrations can drastically reduce a plant's photosynthetic efficiency and output.

During drought periods, plants tend to accumulate osmotic regulators like amino acids, sugars, mineral ions, hormones and proteins to mitigate the adverse effects. One of the most essential compounds in this adaptive response is proline, which helps maintain osmotic balance. One major consequence of drought is the impaired uptake of nutrients due to reduced water absorption by the plant Rezaei and Pazoki (2015).

Ascobein functions as a natural growth enhancer for plants, primarily due to its content of both ascorbic acids. It has been designated as one of the agricultural products created by the Ministry of Agriculture in Egypt. 38% of these acids are present in this mixture, of which 13% is citric acid and 25% is ascorbic acid. Under various environmental conditions, including drought and salt, treatment with ascobein has been shown to increase plant growth regulators, natural hormones, carbohydrate components, and wheat grain productions (Sadak et al. 2013). Numerous investigations into the properties of ascorbic acid (ASA) and salicylic acid (SA) that affect wheat growing and productivity have shown that these nutrients can enhance several developmental features, yield-related metrics, and grain quality (Aziz et al., 2017; Ullah et al., 2018). Plant health depends on ascorbic acid, also referred to as vitamin C. It functions as a coenzyme for several metabolic processes, such as hormone manufacturing, photosynthesis, and the renewal of other antioxidant molecules, in addition to being an efficient redox

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buffer. It is essential to the signal transduction pathways that allow plant cells to divide (Mohammad et al. 2017). The potential of ascobein, which contains the antioxidants citric acid and ascorbic acid, to stimulate cell division and protect plant cells from free radicals, which result in plant senescence, may account for its growth-promoting benefits (Abu-El-Fotoh et al. 2025).

The beneficial benefits of seaweed on plant growth are mostly due to the existence of various plant growth hormones, such as cytokinin, auxins, gibberellins, and betaines. Important micronutrients including iron, zinc, B, magnesium, cobalt, and molybdenum are also found in seaweed, along with macronutrients like calcium, potassium, and iron. This is primarily because the seaweed contains a number of growth regulators, for example cytokinin, auxins, gibberellins, and betaines, moreover essential macronutrients like calcium, potassium, and iron, as well as micronutrients like zinc, iron, boron, magnesium, cobalt, and molybdenum, all of which are essential for plant development and productivity. Using seaweed extract as an organic foliar fertilizer increased grain yield in agriculture. The extract can therefore be used as a helpful stimulant to encourage better crop development and yield output (Embarek and Mumin 2023).

Due to these properties, seaweed and its derivatives are commonly used as bio-stimulants in modern agriculture. Extensive research has confirmed that seaweed extract positively influences multiple aspects of plant growth, including improved performance, higher yield, faster seed germination, stronger early-stage growth and better tolerance to both biotic and abiotic stress (Begum et al. 2018). According to El-Din (2015), applying seaweed extract at a 20% concentration-especially from Sargassum vulgare resulted in notable improvements in plant height, root growth and biomass compared to untreated plants with Sargassum vulgare (a brown algae) proving more effective than Codium tomentosum, increases in chlorophyll and carotenoid content were also observed, especially when liquid seaweed fertilizers were used.

Molasses, a byproduct obtained from processing sugarcane and sugar beet, is another agricultural input with significant potential (Honma *et al.* 2012). Large volumes of it are manufactured annually and used in a variety of processes, including as the creation of fertilizers, ethanol, and animal feed. In agriculture, molasses enhances nutrient uptake and improve soil microbial motion (Samavat and Samavat 2014). Research has shown that the combination of molasses with organic acids, amino acids and humic substances significantly boosts plant growth (Samavat and Samavat 2014). Due to its low molecular weight, fulvic acid is more effective in penetrating plant roots. Although growth stimulants have been applied to other crops in the past using a variety of techniques, there is insufficient information on their application in Egyptian field settings and the combination of water scarcity and stimulants.

Accordingly, this study aimed to identify the most effective growth stimulants in enhancing grain yield and quality of the Giza 171 wheat cultivar under environments of limited water availability.

MATERIALS AND METHODS

A field experiment was carried out at Sakha research station, Wheat Research Farm, Field Crops Research Institute, Kafr El-Sheikh, Agricultural Research Center, Egypt during the two consecutive winter growing seasons of 2023/2024 and 2024/2025.The study designed to evaluate the effects of irrigation shortage and selected growth stimulants on growth characteristics, grain yield, seed quality, and water relations of wheat (*Triticum aestivum* L.) cultivar Giza171.

A soil auger was used to gather soil samples between 0 and 30 cm to determine nitrogen following the Kjeldahl method described by Bremner (1960). The soil was classified as clayey with an average bulk density of 1.22 g cm^{-3} in the top 30 cm. This soil level involved 1.38 % organic matter, 0.14 % total nitrogen (N), 36 mg kg^{-1} available phosphorus (P) at 15.0 mg/kg and interchangeable potassium (K) at 256.3 mg kg^{-1}, and an electrical conductivity (EC) 4.03 dSm^{-1}. The pH values were (7.9) and the average annual precipitation were recorded for both seasons.

The experimental design split-plot design with four replications. The main plots were allocated to three irrigation levels, while the sub-plots were allocated to different simulative compounds treatments. Irrigation treatments included water amounts equivalent to 115, 105 and 95 % of field capacity at the root zone (60 cm depth). The 115 % and 105 % treatment represented full irrigation plus 15 %, 5 % and full irrigation, respectively, while the 95 % treatment represented a deficit level. The first and second irrigation level were increased 15% and 5% than FC as leaching requirements. The treatments of water levels ware measured using Soil PH Moisture meter. Irrigation was applied five times during the growing season at the sowing, tillering, jointing, heading and milking stages. Sub plots included three growth stimulants treatments and one control (no treatment). The treatments were distributed randomly in CRD.

The stimulant treatments were:

Ascobein (containing 13% citric acid, 25% ascorbic acid and 62% organic matter): was added as foliar spray at a rate of (600 g/fad).

Seaweed extract (*Sargassum* genus), comprising 0.03 % nitrogen, 33.99 mg/L phosphorus, 1.97% potassium, 0.51% sodium, 460.11 mg/L calcium, 581.20 mg/L magnesium, 0.06% Sulphur, 0.30 mg/L copper, 10.59 mg/L iron, 2.50 mg/L manganese and 0.62 mg/L zinc was also used as a foliar spray at a concentration of 200 g/faddan.

The ascobein and seaweed compounds were obtained from the General Authority of the Agricultural Budget Fund, the Ministry of Agriculture, the Agricultural Research Centre.

Additionally, molasses obtained from Delta Sugar Company, El-Hamol, Kafr El-Sheikh Governorate was incorporated into the soil at a rate 20 L/faddan during the sowing irrigation. This molasses included 46.0 % total sugar, 3.0 % crude protein, 36.0 % nitrogen free extract, 0.8 % calcium, 0.08 % phosphorus, 2.4 % potassium, 0.2 % sodium, 1.4 % chlorine, 0.5 % sulfur and 8-20 % water. The ascobein and seaweed solutions were applied as foliar treatments at 35, 48 and 62 days from sowing.

The size of the experimental unite (sub-plot) was 20 m^2 (4 x 5 m). Main plots were surrounded by levees that were 1.5 meters wide in order to stop lateral water movement. The Giza171 wheat cultivar was hand-sewn at a seedling rate of 50 kg/faddan in rows 20 cm apart. There were twenty rows in each sub-sub plot. Calcium super phosphate (15.5% P_2O_5) was supplemented to the well-prepared soil at a rate of 100 kg/fad before planting. At a total rate of 75 kg N/faddan, nitrogen fertilizer in the model of urea (46.5 %) was applicate in three quantities: 20 % at the planting, 40 % at the initial irrigation, and 40 % at the next irrigation. With the exception of the parameters being studied, the standard agricultural methods for cultivating wheat as advised by the Ministry of Agriculture were adhered to. Harvest time was during the third week of May 2024 and 2025. The preceding crop grown in the experimental area was Maize (*Zea mays* L.) for both seasons. Meteorological data, including temperature, humidity and rainfall were gathered from the agro-meteorological station located at Sakha as detailed in Table 1.

Table 1. Every month averages of temperature (AT^{O}C), relative humidity (RH %) and rainfall (mm/month) in winter seasons 2023/2024 and 2024/2025 at Sakha site.

Month	AT°C 2023/2024		AT°C 2024/2025		RH %		Rainfall (mm)		Pan Evaporation	
	Max.*	Min.**	Max.*	Min.**	2023/24	2024/2025	2023/24	2024/2025	2023/24	2024/2025
November	24.04	19.90	25.67	17.45	71.5	70.44	9.01	0.00	178.67	171.04
December	21.50	15.40	20.22	14.31	65.12	75.63	5.60	21.70	145.40	114.21
January	18.85	14.03	19.63	12.69	60.00	67.68	36.4	14.90	256.70	116.92
February	21.53	14.50	19.58	14.95	62.21	70.69	16.60	15.30	275.47	184.17
March	25.51	16.59	22.05	18.21	67.50	72.21	0.00	17.30	425.17	329.00
April	27.80	19.94	22.80	20.64	66.32	69.78	0.00	3.90	531.37	403.23
May	37.00	28.00	33.00	26.26	55.25	57.09	0.00	0.00	631.85	685.77

***Max= maximum temperature, **Min= minimum temperature.**

Studied traits

Agronomic traits:

Ten plants were selected at random from each plot at harvesting time in order to calculate the weight of 1000 kernels (g), the number of spikes m^{-2}, and the number of kernels per spike. Harvesting entire plants in each plot allowed for the conversion of grain production to tons per hectare. The biological yield was calculated by converting each plot's total above-ground dry matter to tons per hectare. The Harvest Index (HI) was calculated using the following formula,

$$HI = GY/BY*100.$$

when GY is grain yield, BY is biological yield

Physiological and biochemical assessment:

1. **Total chlorophyll content:** Chlorophyll a and b (mg/g fresh weight) were determined according to Moran (1982). Leaves were homogenized in N-N-dimethylformamide and measured using the spectrophotometric technique.
2. **Relative water content (RWC %)**: was assessed as described by Gonzalez and Var-Gonzalez (2001) using leaf samples of five plants. It was calculated using the formula:

$$RWC\ \% = [(FW-DW) / (SW-DW)]\ X100$$

Where FW is leaf sample fresh weight, DW is the dry weight (after drying in oven at 70$^{\circ c}$) and SW is the saturated weight after immersing the leaves in distilled water for 24 hours.

3. **Proline content**: Proline levels (mg g^{-1} FW) were analyzed using a Spectrophotometer at a wavelength of 520 nm following the method described by Bates *et al.* (1973).
4. **Enzymatic antioxidants**: activities of the antioxidant enzymes were evaluated using the protocol of Chance and Maehly (1955). This included measuring peroxidase (POD) activity μmol min^{-1} g^{-1} protein) and catalase (CAT) activity (μmol min^{-1} g^{-1} protein).

Water Measurements:

- **Amount of irrigation water applied (AIWA):** The amount of irrigation water applied (WA) was dignified using a portable pump prepared with a water meter for each plot. The irrigation amount was determined according to Phocaides (2001).
- **Water consumptive use (WCU):** Water consumptive use was calculated based on soil moisture diminution following the method of Israelson and Hansen (1962).
- **Water productivity applied (PWA):** Water productivity was calculated as the proportion of grain yield to the quantity of irrigation water applied (PWA).
- **Water use efficiency** (**WUE**) was assessed according to Ali *et al*. (2007).

Quality traits of wheat grains:

- **Crude protein content %**: the content in grain samples was determined using a micro Kjeldahl device. The t content was multiplied by 5.75 to calculate the crude protein, in accordance with AACC. (2000).
- **Dry gluten percentage %**: this was determined by manually washing 25 grams of flour, followed by drying at 105°C for six hours. These results were then weighed according to AACC. (2000) guidelines**.**

Statistical analysis

The data was gathered and examined then analyzed using analysis of variance (ANOVA) based on the methods described by Gomez and Gomez (1984), MSTAT-C (1990) Statistical Software packaged using Duncan (1955) when ANOVA indicated significant different ($P<0.05$).

RESULTS AND DISCUSSIONS

Physiological and biochemical determinations:

The data on physiological traits shown in Tables 2 and 3 indicate that the reduction in the irrigation level from 115 % to 95 % F.C led to a significant decline in most of evaluated parameters. Specifically, there was decrease by around 7.4% and 14.2% in total chlorophyll content also the relative water content declined significantly by around 4.6% and 3.3% during 2023/2024 and 2024/2025 seasons, respectively, as presented in Table 2. Conversely, reduced irrigation level caused a significant increase in proline content (from 0.258 to 0.417 mg g^{-1} F.W) and (from 0.335 to 0.475 mg g^{-1} F.W), catalase activity (from 27.1 to 39.9 μmol min^{-1} g^{-1} protein) and (from 29.6 to 41.5 μmol min^{-1} g^{-1} protein) and peroxidase activity (from 70.2 to 82.4 μmol min^{-1} g^{-1} protein) and (from 69.4 to 87.7 μmol min^{-1} g^{-1} protein) in both following seasons, respectively. Water deficit noticeably decreased the grain yield and related-traits comparison to well-watered conditions Hafez and Gharib (2016). These findings suggest that drought stress likely triggered an increase in proline creation and protein hydrolysis into free amino acids, which function as osmoprotectants. These compounds help regulate osmotic balance at the cellular level and maintain the stability of macromolecular structures. The removal of hydrogen peroxide (H_2O_2) from stressed tissues is supported by antioxidant enzymes as catalase and peroxidases, contributes to the neutralization of oxidative damage against salinity stress (Abdelraouf *et al*. 2013).

Data from Tables 2 and 3 indicated that highest physiological parameters such as total chlorophyll (14.0 and 15.9 mg/g F.W), relative water content (80.9 and 84.8 %) and catalase activity (47.1 and 48.3 mg-1) were observed when molasses were applied as a stimulant during both the 2023/2024 and 2024/2025 winter seasons, respectively. It has been demonstrated that molasses application in agriculture increases soil biological activity and nitrogen uptake efficiency. This is explained by the humic, fulvic, and amino acids found in molasses (Samavat and Samavat, 2014). Mona *et al.* (2019) found that applying molasses to the soil at a rate of 20 L/faddan was one of the most successful treatments. This strategy greatly enhanced the majority of the attributes that were measured. In both growing periods, it was shown that by using foliar spraying of ascobein and adding molasses to the soil decreased the amount of proline in flag leaves when compared to the control treatment. Khedr *et al*., (2022) also reported that soil-applied molasses caused the content of proline of flag leaves to drop compared to the control, While the uppermost peroxidase activity was recorded in treatments involving foliar spraying with ascobein during both seasons. Healthy photosynthesis is indicated by physiological changes like as a high chlorophyll content, which promotes improved growth and increased yields. On the other hand, proline and antioxidant enzyme activities buildup is a stress response that aids plants in surviving harsh environments such as salt or drought. Although it can boost growth and stress tolerance in those situations, excessive stress eventually lowers yield and chlorophyll

Table 2. Effect of irrigation levels and growth stimulants on total chlorophyll (mg/g F.W), relative water content (RWC%) and proline content (mg/g F.W) of wheat cultivar Giza171 during 2023/2024 and 2024/2025 seasons.

Factors	Total chlorophyll (mg/g F.W)		Relative water content (RWC%)		Proline content (mg/g F.W)	
	2023/24	2024/2025	2023/24	2024/2025	2023/24	2024/2025
Irrigation levels						
115%F.C.	13.6 a	16.2 a	81.1 a	84.7 a	0.258 b	0.335 b
105%F.C.	13.3 a	14.4 b	77.9 b	82.8 b	0.323 b	0.383 b
95% F.C.	12.6 b	13.9 b	77.4 b	81.9 b	0.417 a	0.475 a
F-test	**	**	**	**	**	*
Growth stimulants						
Control	12.3 c	13.6 b	76.3 c	81.0 c	0.353 a	0.417 a
Ascobein	13.5 ab	15.2 a	79.4 ab	83.7 ab	0.327 b	0.390 bc
Seaweed	12.9 bc	14.7 ab	78.7 b	83.0 b	0.340 ab	0.403 ab
Molasses	14.0 a	15.9 a	80.9 a	84.8 a	0.310 c	0.377 c
F-test	**	*	*	**	*	*

*and ** indicated significant at P< 0.05 and 0.01, respectively.

Table 3. Effect of irrigation levels and growth stimulants on catalase and peroxidase enzymes activity of wheat cultivar Giza171 during 2023/2024 and 2024/2025 seasons.

Factors	Catalase (µmol min^{-1} mg^{-1} protein)		Peroxidase (µmol min^{-1} mg^{-1} protein)	
	2023/24	2024/2025	2023/24	2024/2025
Irrigation levels				
115 % F.C.	27.1 c	29.6 b	70.2 c	69.4 b
105 % F.C.	36.0 b	37.1 b	75.9 b	81.5 a
95 % F.C.	39.9 a	41.5 a	82.4 a	87.7 a
F-test	**	*	**	*
Growth stimulants				
Control	21.4 c	22.4 c	74.7 a	74.9 b
Ascobein	35.8 b	36.5 b	78.0 a	84.7 a
Seaweed	34.0 b	36.6 b	76.5 a	79.9 ab
Molasses	47.1 a	48.3 a	75.4 a	78.7 ab
F-test	**	**	N.S	*

*, ** and NS indicated significant at P< 0.01, 0.05 and not significant, respectively.

Yield and yield components characteristics:

All measured parameters were significantly influenced by the differenced by irrigation treatments. The highest irrigation level (115%) resulted in notably greater average values for all studied traits including the number of spikes m^{-2}, 1000-kernels weight, number of kernels/spike, grain yield, biological yield and harvest index in 2023/2024 and 2024/2025 seasons, as shown in Tables 4 and 5.

Water shortage adversely affected grain and straw yields during the grain filling stage, most likely as a result of a shorter filling time and rate. Grain size decreased as a result of this stress, as did the number of spikes/m^2, kernels/spike, grain weight/spike, and 1000-kernels weight. Because the effects of drought altered nutrient allocation and induced reproductive organ abortion, reduced photosynthetic activity and impaired reproductive development contributed to the decline in grain yield. Less spikelets number per spike, fewer grains per spike, fewer grains per plant, and a decrease in grain weight were all noticeable effects of drought stress. These observations align with the findings stated by Abdelraouf *et al.* (2013), Sanli *et al.* (2015), Al-Molhem (2016) and Hafez and Gharib (2016).

Table 4. Effect of irrigation levels and growth stimulants on number of spikes m^{-2}, 1000-kernel weight (g) and number of kernels/spike of wheat cultivar Giza171 during 2023/2024 and 2024/2025 seasons.

Factors	Number of spikes m^{-2}		1000-kernel weight (g)		Number of kernels/spike	
	2023/24	2024/2025	2023/24	2024/2025	2023/24	2024/2025
Irrigation levels						
115 % F.C.	444.5 a	438.2a	48.8 a	49.7 a	62.3 a	66.9 a
105 % F.C.	437.3 a	432.4 a	48.8 a	49.4 a	60.8 a	64.9 a
95 % F.C.	413.1 b	422.3 b	47.6 b	48.3 b	58.5 b	60.7 b
F-test	**	**	**	*	*	**
Growth stimulants						
Control	397.3 b	404.3 d	47.0 c	47.5 b	55.3 c	58.1 c
Ascobein	442.3 a	440.2 ab	48.7 ab	49.7 a	61.7 ab	65.5 ab
Seaweed	438.4 a	429.2 b	48.5 b	49.3 a	60.7 b	64.2 b
Molasses	449.3 a	450.0 a	49.4 a	50.0 a	64.4 a	69.1 a
F-test	**	*	**	*	**	**

*and ** indicated significant at P < 0.05 and 0.01, respectively.

Table 5. Effect of irrigation levels and growth stimulants on grain yield (ton/ha), biological yield (ton/ha) and harvest index (%) of wheat cultivar Giza171 during 2023/2024 and 2024/2025 seasons.

Factors	Grain yield, tons/ha		Biological yield, tons/ha		Harvest index (%)	
	2023/24	2024/2025	2023/24	2024/2025	2023/24	2024/2025
Irrigation levels						
115 % F.C.	8.6 a	8.5 a	21.0 a	20.9 a	41.0 a	40.7 a
105 % F.C.	8.4 a	8.4 a	20.9 a	20.7 a	40.1 a	40.5 a
95 % F.C.	7.9 b	8.1 b	20.0 b	20.0 b	39.5 b	40.5 a
F-test	**	**	**	**	*	NS
Growth stimulants						
Control	7.6 c	7.7 c	19.7 c	19.9 c	38.5 a	38.7 a
Ascobein	8.0 a	8.4 ab	20.9 ab	20.7 ab	38.3 a	40.6 a
Seaweed	7.8 b	8.3 b	20.4 b	20.6 b	38.2 a	40.3 a
Molasses	8.6 a	8.7 a	21.0 a	21.1 a	40.9 a	41.2 a
F-test	*	**	**	**	NS	NS

*, ** and NS indicated significant at P< 0.05 ,0.01 and not significant, respectively.

Applying molasses as soil additive, followed by foliar spraying with ascobein led to a substantial rise in the number of spikes m^{-2} compared to the control treatment in both seasons. As shown in Tables 4 and 5 the molasses treatment had a clearly positive and statistically significant impact on all yield and yield components traits. The use of molasses as soil addition notably improved number of spikes m-^{2} (449.3 and 450.0 spikes), 1000-kernel weight (49.4 and 50.0 g), number of kernels spike^{-1} (64.4 and 69.1), grain yield (8.6 and 8.7 ton/ha) and biological yield (21.0 and 21.1 tons/ha) relative to the control, ascobein and seaweed in winter seasons of 23/2024 and 24/2025, respectively, these results are in harmony with Abu-El-Fotoh *et al*. (2025).

These results are in harmony with those by Srivastava *et al*., (2012) who reported that molasses is rich in essential minerals such as nitrogen, phosphorus, potassium, calcium, sulfur, micronutrients and organic matter. Samavat and Samavat (2014) further demonstrated that molasses enhances nutrient elements and boosts soil biological activity, as it contains varying levels of Humic, Fulvic as well as amino acids. These components significantly contribute to plant growth fulvic acids, in particular, is known for its small molecular structure, which allows it to penetrate to the plant roots more effectively. Additionally, Khedr *et al.* (2022) observed that adding molasses to the soil enhanced yield and its components in order to provide the molasses for the important plant nutrients in the soil.

Quality traits:

Regarding grain quality characteristics, the data presented in Table 6 shows that decreasing the irrigation level from 115 % to 95 % of F.C led to significant improvement in most of the measured parameters. For instance, crude protein content increased from 12.0 to 12.6 % and from 12.1 to 13.0 %, while dry gluten elevated from 11.8 to 12.7 % and from 11.6 to 12.2 % during the first and second seasons, respectively. Scarcity of water stress negatively affected seed quality by reducing the production of small and medium size seeds, which exhibited lower germination. It also reduced seed vigor (germination) of large, full, round seeds in severely stressed plants compared to those that were moderately stressed or well-watered. These observations highlight a negative correlation between protein content in grain and grain size (1000-grain weight) as also reported by Gomaa *et al.* (2020).

In the two consecutive growth seasons, there were no appreciable variations in the protein content of the ascobein, seaweed, and molasses treatments. These findings align with those of Osman *et al.* (2019). The highest dry gluten observed in Table 6 were associated with treatments involving molasses and ascobein in both winter seasons of 2023/2024 and 2024/2025, respectively.

Table 6. Effect of irrigation levels and growth stimulants on protein % and dry gluten % of wheat cultivar Giza171 during 2023/2024 and 2024/2025 seasons.

Factors	Protein %		Dry gluten %	
	2023/2024	2024/2025	2023/2024	2024/2025
Irrigation levels				
115 % F.C.	12.0 c	12.1 b	11.8 c	11.6 b
105 % F.C.	12.3 b	12.8 a	12.3 b	12.0 a
95 % F.C.	12.6 a	13.0 a	12.7 a	12.2 a
F-test	**	**	**	**
Growth stimulants				
Control	11.8 b	11.8 b	12.1 c	11.7 b
Ascobein	12.4 a	13.0 a	12.4 a	11.9 ab
Seaweed	12.7 a	12.8 a	12.3 b	12.1 a
Molasses	12.3 a	12.8 a	12.3 a	12.0 a
F-test	**	**	**	**

***and ** indicated significant at P< 0.05 and 0.01, respectively.**

Water measurements:

Seasonal water application (WA) is made up of two main parts: effective rainfall and irrigation water that is applied to the soil. In the first season, 818 m^3 fad^{-1} of effective rainfall were recorded, and in the second season, 381 m^3 fad^{-1}. In both growing seasons, WA was gradually raised by raising the irrigation level from 95 to 115% FC.

Water consumptive use (WCU) considerably greater than before with higher irrigating levels, especially at 115% FC, which showed the highest WCU values, followed by 105 and 95% FC in both seasons as shown in Table 7. The increase in soil moisture likely enhanced plant growth and resulted in greater water consumption, possibly due to increased luxury uptake or leaching from excess irrigation beyond field capacity. These findings are consistent with those reported by Ali *et al.* (2007). Moreover, both productivity of water applied (PWA) and water use efficiency (WUE) decreased as irrigation level rose from 95 % to 115 % FC during the two seasons as presented in Table 7. This trend aligns with the observations of Meleha (2016) and Guendouz *et al.* (2016).

Plants treated with molasses as soil amendment recorded the highest WCU, whereas untreated (control) plants showed the lowest water consumption consumed the lowest water amount. Both PWA and WUE values showed that the best effective grain production per unit of water was achieved when molasses was added to the soil. By cumulative the concentration of accessible nutrients in the soil solution, molasses applied to the soil may encourage the growth of leaf area, which in turn may increase transpiration and total water consumption.

Table 7. Water consumptive use (WCU), productivity of water applied (PWA) and productivity of water use efficiency (WUE) as affected by irrigation level and simulative compounds in 2023/2024 and 2024/2025 seasons.

Factor	WCU (m^3/fad)		PWA (kg/m^3 WA)		WUE (kg/m^3 WCU)	
	2023/24	2024/2025	2023/24	2024/2025	2023/24	2024/2025
Irrigation (I)						
115 % FC	1630	1703	1.63	2.11	1.68	2.04
105 % FC	1582	1637	1.70	2.13	1.75	2.08
95 % FC	1473	1455	1.74	2.15	1.79	2.21
Simulative (S)						
Control	1527	1581	1.55	2.00	1.64	1.99
Ascobein	1576	1598	1.75	2.19	1.77	2.15
Seaweed	1554	1591	1.65	2.09	1.72	2.09
Molasses	1589	1624	1.80	2.23	1.84	2.20

Effect of interaction

The data presented in Tables from 8 to 12 illustrate the interaction effects of different irrigation levels (115 %, 105 % and 95 %) and growth stimulants on several physiological and yield-related parameters, including total chlorophyll, relative water content, proline content, catalase activity, peroxidase activity, number of spikes m^{-2}, 1000-kernel weight, grain yield (tons/ha), biological yield (tons/ha), protein content, dry gluten % and water measurements. The interaction had a major impact on the majority of these characteristics.

Table 8. Effect of the interaction between irrigation levels and growth stimulants on total chlorophyll (mg/g F.W), relative water content (%) and proline content (mg/g F.W) of wheat cultivar Giza171 during 2023/2024 and 2024/2025 seasons.

	Total chlorophyll (mg/g F.W)		Relative water content (%)		Proline content	(mg/g F.W)
	2023/24	2024/2025	2023/24	2024/2025	2023/24	2024/2025
115%F.C.x control	12.7 cd	13.8 d	77.7 cd	82.9 bcde	0.230 e	0.320 e
115%F.C x ascobein	14.3 ab	16.9 ab	82.1 ab	105.6 ab	0.280 de	0.350 e
115%F.C. x seaweed	13.1 bc	16.1 abc	80.6 abc	84.1 abcd	0.250 de	0.340 e
115%F.C.x molasses	14.3 a	17.9 a	84.0 a	86.3 a	0.295 de	0.330 e
105%F.C. x control	12.4 cd	13.8 d	75.9 d	80.4 ef	0.300 cde	0.360 de
105%F.C.x ascobein	13.5 abc	14.7 cd	78.3 cd	82.9 bcde	0.340 abcd	0.403 bcde
105%F.C.x seaweed	12.9 c	14.2 cd	77.9 cd	82.7 cde	0.320 bcde	0.380 cde
105%F.C.x molasses	14.3 ab	15.0 bcd	79.7 bc	105.1 abc	0.330 bcde	0.390 bcde
95%F.C.x control	11.7 d	13.2 d	75.3 d	79.8 f	0.400 abc	0.450 abcd
95%F.C.x ascobein	12.8 cd	13.9 d	77.9 cd	82.6 cdef	0.410 ab	0.455 abc
95%F.C.x seaweed	12.7 cd	13.8 d	77.66 cd	82.1 def	0.420 ab	0.480 ab
95%F.C.x molasses	13.4 abc	14.7 cd	78.9 bcd	83.0 bcde	0.440 a	0.500 a
F-test	**	**	**	**	**	**

***and ** indicated significant at P< 0.05 and 0.01, respectively.**

Table 9. Effect interaction between irrigation levels and growth stimulants on catalase and peroxidase enzymes activity of wheat cultivar Giza171 during 2023/2024 and 2024/2025 seasons.

Factors	Catalase (µmol min^{-1} mg^{-1} protein)		Peroxidase (µmol min^{-1} mg^{-1} protein)	
	2023/24	2024/2025	2023/24	2024/2025
115% F.C.x control	18.2 e	19.0 e	69.0 e	62.4 d
115% F.C. x ascobein	28.6 bcde	31.5 bcde	71.6 de	73.3 bcd
115% F.C. x seaweed	26.5 bcde	27.6 cde	70.8 de	71.5 bcd
115%F.C.x molasses	38.1 abc	38.9 abc	69.5 e	70.4 cd
105%F.C. x control	21.1 de	21.9 de	74.4 cde	77.9 abc
105%F.C.x ascobein	37.2 abc	35.7 bcd	77.7 abcd	90.4 a
105%F.C.x seaweed	34.3 bcd	38.1 abc	76.4 bcde	79.5 abc
105%F.C.x molasses	51.5 a	52.8 a	75.2 bcde	78.4 abc
95%F.C.x control	25.0 cde	26.4 cde	80.8 abc	84.4 ab
95%F.C.x ascobein	41.7 ab	42.4 abc	81.7 abc	90.4 a
95%F.C.x seaweed	41.2 ab	44.1 ab	82.3 ab	88.6 a
95%F.C.x molasses	51.6 a	53.1 a	84.7 a	87.4 a
F-test	**	**	**	**

***and ** indicated significant at P< 0.05 and 0.01, respectively.**

Table 10. Effect of interaction between irrigation levels and growth stimulants on number of spike m^{-2}, 1150-kernels weight (g), grain yield (ton/ha) and biological yield (ton/ha) of wheat cultivar Giza171 during 2023/2024 and 2024/2025 seasons.

Factors	Number of spike (m^{-2})		1000-kernels weight (g)		Grain yield (ton/ha)		Biological yield (ton/ha)	
	2023/2024	2024/2025	2023/2024	2024/2025	2023/2024	2024/2025	2023/2024	2024/2025
115% F. C. x control	413.2 bcd	418.1 bc	47.7 cde	48.3 bcd	7.9 c	8.2 bc	20.2 bc	20.4 bc
115%F. C. x ascobein	454.1 ab	445.3 ab	49.2 abc	50.4 a	9.0 ab	8.7 ab	21.5 a	21.0 ab
115% F.C. x seaweed	449.0 ab	432.1 abc	49.0 abc	49.7 ab	8.3 abc	8.4 ab	20.7 abc	20.8 ab
115% F.C. x molasses	458.3 a	457.8 a	49.4 ab	50.4 a	9.1 a	8.9 a	21.5 a	21.4 a
105%F.C. x control	399.4 cd	408.3 cd	47.2 de	47.9 cd	7.7 cd	7.7 cd	19.8 cd	19.8 cd
105% F.C. x ascobein	446.2 ab	442.1 ab	49.1 abc	49.8 ab	8.5 abc	8.3 abc	20.8 abc	20.7 abc
105% F.C. x seaweed	450.0 ab	430.2 abc	48.9 abc	49.7 ab	8.1 bc	8.3 abc	20.5 abc	20.6 abc
105% F.C. x molasses	452.0 ab	449.0 ab	50.0 a	50.1 a	8.6 abc	8.8 ab	21.0 ab	21.2 ab
95%F.C. x control	378.5 d	315.3 d	47.0 e	47.3 d	7.1 d	7.4 d	19.1 d	19.4 d
95% F.C. x ascobein	425.7 abc	433.1 abc	47.9 b-e	49.0 abc	8.2 abc	8.3 abc	20.4 abc	20.5 abc
95% F.C. x seaweed	415.1 bcd	426.4 abc	47.7 cde	48.4 bcd	8.0 c	8.2 abc	20.0 bcd	20.4 bc
95% F.C. x molasses	436.3 abc	444.5 ab	48.7 a-d	49.5 abc	8.3 abc	8.3 ab	20.6 abc	20.7 abc
F-test	**	**	**	**	**	**	**	**

***and ** indicated significant at P< 0.05 and 0.01, respectively.**

Table 11. Effect of interaction between irrigation levels and growth stimulants on protein % and dry gluten% of wheat cultivar Giza171 during 2023/2024 and 2024/2025 seasons.

Factors	Protein %		Dry gluten %	
	2023/24	2024/2025	2023/24	2024/2025
115%F.C.x control	11.3 d	11.0 c	11.6 h	11.4 f
115%F.C. x ascobein	12.1 bc	12.8 ab	12.0 f	11.7 cdef
115%F.C. x seaweed	12.6 ab	12.4 ab	11.7 g	11.5 ef
115%F.C.x molasses	12.1 bc	12.3 ab	11.9 f	11.6 def
105%F.C. x control	11.9 c	12.1 b	12.2 e	11.7 cdef
105%F.C.x ascobein	12.3 abc	13.1 a	12.3 e	12.0 bcd
105%F.C.x seaweed	12.6 ab	12.9 ab	12.3 e	12.3 ab
105%F.C.x molasses	12.3 bc	13.1 a	12.5 d	11.9 bcde
95%F.C.x control	12.1 bc	12.3 ab	12.6 cd	12.1 abc
95%F.C.x ascobein	12.7 ab	13.2 a	12.6 bc	12.1 ab
95%F.C.x seaweed	12.7 ab	13.1 a	12.7 ab	12.2 ab
95%F.C.x molasses	12.9 a	13.1 a	12.8 a	12.5 a
F-test	**	**	**	**

***and ** indicated significant at P< 0.05 and 0.01, respectively.**

Table 12. water consumptive use (WCU), productivity of water applied (PWA) and productivity of water use efficiency (WUE) as affected by the interaction between irrigation levels and simulative compounds during 2023/2024 and 2024/2025 seasons.

Simulative compound	2023/2024 seasons			2024/2025 seasons		
	Irrigation levels			Irrigation levels		
	115%FC	105%FC	95%FC	115%FC	105%FC	95%FC
	WCU (m^3/fad)					
Control	1598	1559	1423	1692	1625	1425
Ascobein	1650	1588	1491	1696	1635	1461
Seaweed	1618	1572	1473	1689	1630	1455
Molasses	1654	1607	1506	1734	1659	1478
	PWA (kg/m^3 WA)					
Control	1.51	1.56	1.57	1.59	1.65	1.67
Ascobein	1.70	1.75	1.81	1.71	1.76	1.85
Seaweed	1.85	1.66	1.71	1.66	1.73	1.76
Molasses	1.72	1.82	1.87	1.78	1.84	1.90
	WUE (kgm^3 WCU)					
Control	1.99	2.00	2.01	1.94	1.98	2.05
Ascobein	2.18	2.18	2.21	2.07	2.10	2.29
Seaweed	2.07	2.08	2.11	2.03	2.06	2.18
Molasses	2.19	2.24	2.26	2.11	2.16	2.33

The data indicate that the 115% irrigation level combined with molasses soil application caused the maximum results for all total chlorophyll and relative water content, number of spikes m^{-2}, number of kernels/spike, 1000-kernel weight, grain yield, biological yield and WCU. In contrast, the 95 % irrigation level along with molasses treatments considerably augmented the proline content, catalase activity, peroxidase activity, protein content, dry gluten, PWA and WUE.

CONCOLUSION

The current study showed that growth parameters, yield and its components, and grain quality were significantly impacted by both irrigation levels and stimulating substances. With molasses applied as a stimulant, the wheat cultivar Giza171 produced the most favorable growth characteristics, yield, and its constituents and quality at field capacity levels of 115% and 105%. Furthermore, molasses application outperformed the other treatments in improving grain quality, growth attributes, and yield and its components in the Giza171 wheat cultivar when there was a water deficit.

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تأثير أنظمة الري ومحفزات النمو على محصول القمح (*Triticum aestivum* L.) وجودة الحبوب تحت الإجهاد المائي

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الملخص

أجريت تجربة حقلية في مزرعة قسم بحوث القمح، محطة بحوث سخا، معهد المحاصيل الحقلية، كفر الشيخ، مركز البحوث الزراعية، مصر خلال موسمي الزراعة الشتويين ٢٠٢٤/٢٠٢٣ و٢٠٢٥/٢٠٢٤ على التوالي. وكان الهدف من الدراسة هو تقييم استجابة القمح لظروف نقص المياه على النمو والمحصول وبعض مكوناته وصفات الجودة باستخدام بعض منظمات النمو لصنف قمح الخبز جيزة ١٧١. أظهرت النتائج أن خفض متطلبات مياه الري من ١١٥٪ إلى ٩٥٪ من السعة الحقلية أدى إلى انخفاض معنوي في معظم صفات النمو والمحصول ومكونات المحصول وكفاءة استخدام المياه، بينما زاد نشاط البرولين ونشاط انزيم الكتاليز والبيرأوكسيداز ومحتوى البروتين الخام والجلوتين الجاف معنوياً. ومع ذلك، فإن انخفاض متطلبات الري من ١١٥٪ إلى ٩٥٪ أدى إلى انخفاض معنوي في محصول الحبوب والمحصول البيولوجي وفي حين أن إضافة المولاس للتربة أدي إلي تحسين في المحصول ومكوناته وصفات النمو وجودة الحبوب في جميع صفات الدراسة. كما أن استخدام ١١٥٪ من متطلبات الري مع إضافة المولاس للتربة أدي إلى تحسين أغلب الصفات النمو المدروسة مثل عدد السنابل بالمتر المربع، وزن ١٠٠٠ حبة، عدد الحبوب / سنبلة، محصول الحبوب، المحصول البيولوجي ودليل الحصاد، بينما استخدام ٩٥٪ من متطلبات الري مع إضافة المولاس للتربة أعطي أعلي محتوى للبرولين وأنزيم الكتاليز وانزيم البيرأوكسيداز، محتوى البروتين والجلوتين الجاف وكفاءة استخدام المياه وانتاجية المياه المضافة.ازدادت بشكل ملحوظ كل من محصول الحبوب، المحصول البيولوجي، عدد السنابل لكل سنبلة، وزن ١٠٠٠ نواة، عدد السنابل بالمتر المربع، والاستهلاك المائي عندما تمت إضافة المولاس إلى التربة بنسبة ١١٥٪ من السعه الحقلية ري. في هذه الأثناء، زاد محتوى البرولين، نشاط الكاتليز، محتوى بروتين نشاط البيرأوكسيديز، الجلوتين الجاف، إنتاجية المياه المضافة وكفاءة استخدام المياه، جميعها مع الري بالمولاس مع ري ٩٥٪من السعة الحقلية. في موسم الزراعة الأول، ارتبطت أعلى نسبة جفاف للجلوتين بمعاملتي الأسكوبين والمولاس (١٢,٤ و١٢,٣٪) على التوالي. نستخلص أن، عندما كانت هناك ندرة في المياه، كان استخدام المولاس أفضل من الأعشاب البحرية والأسكوبين من حيث تعزيز إنتاجية القمح وخصائص النمو وجودة الحبوب.

الكلمات الدالة : الاسكوبين, البروتين, المولاس, ندرة المياه, القمح.