J. Agric. & Env. Sci. (Damanhour University) 2024, 23 (3): 45-76
Print: ISSN 1687-1464 Online: 2735-5098

HEAT STRESS EFFECTS ON THE PERFORMANCE OF SOME EGYPTIAN WHEAT CULTIVARS

Sabah.M. Morsy, Eman.N.Hamed, Mohammed.A. Foda and Yossry.E.Salama

Crop Science Department, Faculty of Agriculture, Damanhour University, Damanhour 22516, Egypt.

Corresponding: yuosry.salama@ agr.dmu.edu.eg

ABSTRACT

Six commercial bread wheat cultivars were planted in Abo Elmatameir region, Behera governorate, Egypt, during the two successive seasons 2021/2022 and 2022/2023 under three sowing dates; 20 November (recommended), 20 December, and 20 January (late as heat stress). A split-plot arrangement was used in a randomized complete block design (RCBD) with three replicates. The three sowing dates were randomly assigned to the main plots, while the six wheat cultivars were assigned randomly to the subplots. The primary goal of this investigation was to determine the most appropriate cultivar for heat stress and recommended conditions. Our results concluded that heat stress had a significant adverse impact on most of the studied traits. Sids14 exhibited the highest spikes and flag leaf area among the evaluated cultivars in both seasons. Sakha95 was the tallest cultivar in both seasons, whereas Misr2 outperformed other tested cultivars regarding the number of spikelets/spikes, harvest index, and grain yield. Misr1 showed the highest straw yield, while Giza171 and Sids14 presented elevated canopy temperatures. Furthermore, Giza171 had the highest 1000-grain weight, grain yield, and straw yield under the recommended sowing date. Additionally, Sakha95 had the highest value of proline content under heat-stress conditions. Moreover, Misr2 and Giza171 were the ideal cultivars for the late-sowing conditions. The results showed that evaluating wheat cultivars under late heat-stressed conditions in Egypt is required to face the effects of global warming and reduce large wheat imports.

Keywords: Wheat, Heat stress, Sowing date, Yield

https://doi.org/ 10.21608/jaesj.2024.334893.1208

INTRODUCTION

Wheat is one of the most widely produced grains in the world, leading the grain market along with corn and rice in production and sales **(Shahbandeh 2024)**. Wheat, the second most important staple food of the human population, is adapted to various environmental conditions worldwide. About 36% of the world's population depends on wheat to meet its calorie requirements. Wheat grains provide 21% calories and 20% protein requirements to about 4.5 billion people worldwide, most belonging to developing countries (Braun ***et al*.,2010).** 40% of the calories in a diet are derived from wheat, a staple meal in most countries and a rich source of carbohydrates **(Kumar *et al*., 2013; Sihag *et al*., 2023).**

Egypt is the most populous country in North Africa (**Worldometer, 2023**). Moreover, Egypt, the second largest wheat importer worldwide, was forecast to import about 11 million metric tons of wheat and wheat-derived products in 2023/2024 **(Shahbandeh 2024)**. All Egyptians regularly consume bread made from wheat, the country's first strategic cereal crop. In Egypt, 3.9 million feddan were grown during the 2022 growing season, yielding approximately 14.2 million tons of dry grains (**FAOSTAT 2022)**.

Due to significant population growth, Egypt faces a significant gap between the amount of wheat produced and consumed. Consequently, increasing wheat production under Egyptian conditions is the major concern of agronomists **(Gheith *et al*., 2018**). Numerous abiotic stresses, including drought, heat stress, and the quantity of rain, affect wheat yield. Climate change and the complex effects of global warming might push wheat crops further into heat-stressed conditions (**Ahlawat *et al.*, 2022).**

The wheat area and production in the world have adequately increased. This increase happened due to the advancement of new climate-resilient wheat varieties by many researchers worldwide. Additionally, the use of inorganic fertilizers like DAP, Urea, and Potash has also increased many folds, and farmers demanded heat-tolerant varieties and advanced technology along with other facilities for climate-resilient wheat farming **(Dahal *et al*.,2015)**

Heat stress has a potential reverse effect on wheat production worldwide **(Sharma *et al.*,).** It reduces wheat growth by undesirable influences on most physiological and biochemical processes. Moreover, heat stress causes damage to cellular structure, shortens the time required for grains to fill and mature, increases the percent of flower abscission, and reduces the amount of seeds throughout the reproductive stage. Contrarily, as a cool-season crop, wheat has an optimal daytime growing temperature of 15 °C during the reproductive stage **(Zhongfu *et al.*, 2018).**

Also, under heat stress conditions, reactive oxygen species accumulate and cause oxidative damage to the crop. Plants under heat stress rapidly produce heat shock proteins to minimize the negative effects. Heat stress significantly reduces seed germination, seedling growth, cell turgidity, and crop water-use efficiency. At a cellular level, heat stress disturbs cellular functions by generating excessive reactive oxygen species, leading to oxidative stress. Many major responses of wheat to heat stress include enhancement of leaf senescence, reduction of photosynthesis, deactivation of photosynthetic enzymes, and generation of oxidative damage to the chloroplasts. Heat stress also reduces the number and size of grains by affecting grain setting, assimilating substances translocation, and duration and growth rate of grains. A well-integrated genetic and agronomic management selection may enhance wheat tolerance to heat. However, the success of applying various techniques of heat stress management requires a greater understanding of heat tolerance features **(Akter and Islam 2017).**

Several indicator traits, such as chlorophyll fluorescence, stay-green leaves, and plant canopy temperature, significantly affect heat stress tolerance. Under high-temperature stress in wheat, the grain filling period is reported to shorten by 45–60% **(Vignjevic *et al.*, 2014).**

Meanwhile, to improve new crop varieties that can cope with future climate changes, knowledge of heat stress effects and tolerance at morphological, physiological, and biochemical processes is highly important **(Poudel and Poudel 2020)**. Many different physiological mechanisms have been identified as selection targets for heat tolerance. However, the complex nature of the trait and the high interaction between genotype × temperature limits the selection process **(Ullah *et.al.*, 2021).** Additionally, searching for suitable management strategies can increase the productivity and sustainability of growing wheat crops.

Due to the high demand for heat-tolerant wheat cultivars for human consumption (Pimentel et al., 2015), heat-acclimated varieties are needed to adapt to expanding cultivation areas in warmer regions.

Producing temperature-acclimated novel varieties could increase wheat output worldwide by 7% and protein yield by 2% **(Asseng *et al.*, 2019).**

The recommended sowing date for wheat in Egypt is around mid-November. However, due to the limited availability of land and water and the importance of wheat as a strategic crop, several growers in Egypt tend to sow wheat after sugar beet (*Beta vulgaris* L.), carrot (*Daucus carota* L.), or pea (Pisum sativum L.), which results in sowing wheat around Mid-January. These later sowing dates expose wheat plants to terminal heat stress during the reproductive stage (El Basyoni,2018). To develop or improve wheat genotypes for heat stress tolerance, the first step is to evaluate the cultivated germplasm's genetic diversity for heat stress tolerance and select genotypes with a higher heat tolerance level **(Riaz *et a*l., 2021**).

In our current study, six wheat cultivars from the widely commercially grown cultivars in Egypt were evaluated under recommended (around mid-November) and late sowing dates (heat stressed). These cultivars were used to study the effect of heat stress (late sowing date) on several morphological, physiological, and yield traits**.** Substantial genetic variability was observed among wheat genotypes for their ability to cope with heat stress **(Shah and Paulsen 2003).**

The key hypothesis is that if global climate changes cause a dramatic increase in temperature, there will be an adverse impact on wheat productivity in Egypt. To achieve the proposed aim, evaluate under Egyptian field conditions in successive episodes of heat during the reproductive stage (Shenoda et al. **2021)**. Therefore, the current study aims to evaluate the effect of heat stress resulting from delayed sowing date on the growth and yield of some Egyptian bread wheat cultivars and identify the more suitable cultivar for recommended conditions and heat-stressed conditions.

MATERIALS AND METHODS

1. Experimental Material:

The present study was carried out in open fields in Abo Elmatameir distract **(30°54′29″N 30°10′27″E / 30.9081°N 30.1743°E) during** 2021/2022 and 2022/2023 to examine the impact of the three sowing dates 20th November (Recommended), 20th

December and 20th January (late as heat stress) on growth, yield and yield components of six commercial bread wheat cultivars (Sakha 95, Misr1, Misr2, Sids14, Giza168 and Giza171). For this purpose, a field experiment was performed in a split-plot arrangement in a randomized complete block design, and three replicates were used. The three sowing dates were randomly assigned to the main plots, while the six wheat cultivars were assigned randomly to the subplots. The experimental soil's physical and chemical properties are presented in Table 1. Name, pedigree, and selected history of the six wheat cultivars produced by the Wheat Research Department, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt, are presented in Table 2. Also, some agro-climatic factors of the experiment area during the two growing seasons of 2021/2022 and 2022/2023 that were recorded by the Central Laboratory for Agricultural Climate, Agriculture Research Center, Egypt, are shown in Table 3.

Table 1: Physiochemical properties of the experimental soil during both seasons.

Parameters	Amount
Mechanical analysis	
Clay %	23.84
Silt %	8.40
Sand %	67.76
Soil texture	Sand clay Loam
PH	8.15
EC dSm^{-1}	1.45
Total CaCO3%	3.4
Organic matter (%)	0.61
Soluble Cations and Anions (meq/ L)	
Calcium	2.18
Magnesium	2.41
Sodium	5.23
Potassium	0.91
Bicarbonate	1.85
Chloride	4.81
Sulphate	4.38
Available macronutrients, (mg/ kg soil)	
Nitrogen	111.92
Phosphorus	7.12
Potassium	220.16

Table (2): Name, pedigree, and selected history of the six tested wheat genotypes.

Name	Pedigree	Selected history
Giza 171	SAKHA 93/GEMMEIZA 9	S.6-lGZ-4GZ-lGZ-2GZ-S
Sids 14	BOW"S"/VEE"S"//BOW"S"/TSI/3/BANI SEWEF 1	SD293-1SD-2SD-4SD-SD
Sakha 95	PASTOR//SITE/MO/3/CHEN/AEGILOPS SQUARROSA(TAUS)//BCN/4/WBLL1	CMSA01Y00158S-040 POY-040M-030ZTM 040SY-26M-0Y-0SY-0S.
Misr1	OASIS/SKAUZ//4*BCN/3/2*PASTOR	CMSS00Y01881T-050M-030Y-030M-30WGY33M-0Y-0S
Misr 2	SKAUZ/BAV92	CMSS96M03611S-1M-010SY-010M-010SY8M-0Y-0S
Giza 168	MIL/BUC// Seri	

Table 3: Some agro-climatic factors of the experiment area during 2021/2022 and 2022/2023 growing seasons.

Month	HC Air temperature [°C]			Solar radiation	HC Relative humidity [%]			Wind speed [m/s]	
	Min	Max	Avg	Dgt [W/m2]	min	max	avg	avg	max
2021/2022									
Nov.	11.06	24.29	17.67	75.27	45.89	98.37	72.13	0.52	2.68
Dec.	10.40	21.60	16.00	70.67	60.63	99.82	80.23	0.58	2.02
Jan.	8.36	17.62	12.99	97.33	61.21	100.00	80.61	1.63	4.10
Feb.	13.61	23.58	18.60	94.06	68.39	98.79	83.59	1.52	3.91
Mar.	14.99	25.82	20.40	96.28	60.55	99.37	79.96	1.37	3.78
Apr.	17.40	28.43	22.91	99.87	82.19	88.46	85.33	1.02	1.76
May.	19.66	32.90	26.28	101.30	84.87	87.89	86.38	0.99	1.45
2022/2023									
Nov.	11.53	23.88	17.71	77.13	42.66	96.46	69.56	0.62	2.86
Dec.	10.26	22.07	16.17	74.28	68.34	95.32	81.83	0.55	1.95
Jan.	9.74	16.85	13.30	93.11	59.43	94.63	77.03	1.73	4.18
Feb.	12.79	22.36	17.58	96.42	70.22	94.15	82.19	1.58	4.02
Mar.	14.09	24.48	19.29	100.05	65.14	96.94	81.04	1.44	3.84
Apr.	16.74	27.69	22.22	100.01	80.65	89.57	85.11	1.08	1.64
May.	21.56	32.55	27.05	102.62	83.09	88.42	85.76	0.96	1.09

2. **Agriculture procedure:**

Wheat grains were planted during the two study seasons on November 20th, December 20th, and January 20th. The experimental unit area was three meters long and six rows wide, within 25 cm between rows and 10 cm between hills. Standard agronomic practices, including recommended fertilization, pest control, and irrigation schedules, were followed.

3. **The studied traits:**

3.1. Earliness traits:

The number of days to heading was recorded visually as the number of days to anther exertion from 50% of the main spikes (days), and grain filling duration was measured from flowering to physiological maturity (when the peduncle changed color). The number of days to full maturity was estimated as the number of days from sowing to harvest.

.3.2. Growth traits:

Plant height was measured on a random sample of ten plants in each plot as the distance from the soil surface to the tip of the spike awns excluded at harvest time (cm). During the flowering stage, the total leaf chlorophyll content (SPAD index) was estimated using a spad-502 chlorophyll meter (spad-502 plus, Konica Minolta, Kearney, NE, USA). Leaf area (LA) was estimated on three samples according to the following equation (Bavec, et al., 2007):

Leaf area (LA) = L × W ×0.75

Where: L and W are the flag leaf's length and width, respectively.

3.3. Yield and its components traits:

At the harvest, 10 plants were taken from each plot to determine spike length (cm), number of spikelets/spike, and 1000-grain weight (g). Grain yield was measured by harvesting the six rows of each plot (tons/ha). The harvest index is calculated as the percentage of grain yield (economic yield) to the biological yield by the following formula:

Harvest index (%) = Grain yield /Biological yield × 100

3.4. Physiological Traits:

3.4.1. Canopy temperature at grain filling stage (CTG):

Canopy temperatures (Tc) were measured using a handheld infrared thermometer (KM 843, Comark Ltd., Hertfordshire, UK) with a field view of 100 mm to 1000 mm. Canopy temperatures (Tc) data were taken from the same side of each plot at 1m distance from the edge and approximately 50 cm above the canopy at an angle of 30^o to the horizontal. Readings were made between 1300 and 1500 h on sunny days.

3.4.2. Proline content:

It was determined according to the method described by **Bates, *et al*., (1973**)

Samples:

0.5 g of the fresh sun leaves from field-grown plants.

Reagents:

Acid-ninhydrin was prepared by warming 1.25 g ninhydrin in 30 ml glacial acetic acid and 20 ml 6 M phosphoric acid with agitation until dissolved. The reagent was kept cool (stored at 40C) and remained stable for 24 hours.

Procedure:

1- 0.5 g of the plant material was homogenized in 10 ml of 3 % aqueous sulfosalicylic acid and the homogenate was filtered through Waxman 2 filter paper.

2- Two ml of filtrate was reacted with 2 ml acid ninhydrin and 2 ml of glacial acetic acid in a test tube for 1 hour at 100 C^o, and the reaction terminated in the ice path.

3-The reaction mixture was extracted with 4 ml toluene, and mixed vigorously with a test tube stirrer for 10-15 sec.

4- The chromophore containing toluene was aspirated from the aqueous phase, warmed to room temperature, and absorbance was read at 520 nm using toluene as a blank.

5- The proline concentration was determined from a standard curve and calculated on a fresh weight basis as follows:

{(µg proline / ml X ml toluene) / 115.5 µg / mole} / {(g sample) / 5} =

µ proline / g fresh weight material.

Statistical Analysis:

All data collected were subjected to analysis of variance according to (**Gomez and Gomez, 1984)**. All statistical analyses were performed using variance analysis using the (**Costat 2005)** computer software package. In the two years, homogeneity of variance was tested, following Hartley's test (Hartley, 1950). Data was analyzed by season, with block treated as a random effect. Mean comparisons were made using Fisher's protected *Lsd* test ($P \leq 0.05$)

RESULTS

1. Effect of sowing date, wheat cultivar, and their interaction on earliness traits:

1.1. Analysis of variance

Mean squares due to sowing dates, wheat cultivars, and their interactions for all earliness traits are presented in Table 4. The results indicated significant and highly significant effects on all earliness traits in both seasons.

Table (4): Mean squares due to sowing date, wheat cultivar, and their interaction for earliness traits across 2021\2022 and 2022\2023 seasons.

SOV	DF	Heading date		Full maturity date		Grain filling	
		1st	2nd	1st	2nd	1st	2nd
Rep.	2	0.35	38.31	12.79	11.69*	0.43	0.71**
Sowing date	2	2445.3	2343.0	6646.7	4338.0	3048.6	38.95*
Main Plot Error	4	0.43	11.05	17.06	0.19	0.08	0.03
Cultivar	5	33.59*	30.39*	31.47*	69.99*	76.42*	55.99*
Sowing date x	1	29.06*	39.14*	46.79*	53.49*	64.25*	18.97*
Error	3	0.24	1.58	10.21	0.29	0.23	0.11

* and ** significant at 0.05 and 0.01 levels of probability, respectively.

1.2. Mean performances of earliness traits:

a. Sowing date effect:

The effect of the sowing date on the number of days to heading, full maturity date, and grain filling duration are presented in Table 5. The number of days to heading differs among all sowing dates. sowing wheat on 20 Jan was earlier than 20 Nov and 20 Dec, where it recorded the lowest number of days to heading (83.22 and 74.74 days), while the highest number of days to heading (103.57 and

J. Agric. & Env. Sci. (Damanhour University) 2024, 23 (3): 45-76
Print: ISSN 1687-1464 Online: 2735-5098

97.55 days) obtained under the recommended sowing date in the first and second seasons, respectively. The full maturity of wheat plants gradually decreased with delays in the sowing date in both seasons. the lowest number of days to full maturity (123.83 and 121.06 days) recorded on 20 Jan. On the other hand, the highest number of days to full maturity averages, 162.22 and 151.50 days, were recorded on 20 Nov in the first and second seasons, respectively. A decrease in grain filling duration was observed with the delay in the sowing date. Sowing wheat on 20 Jan had the lowest grain filling duration (30.58 days), while sowing wheat on 20 Nov recorded the highest number of days to heading (54.04 days) in the first season.

Table (5): Means of heading date, full maturity date, and grain filling duration as affected by sowing date, wheat cultivar, and their interaction during 2021\2022 and 2022\2023 seasons.

Factors		Heading date (day)		Full maturity date (day)		Grain filling duration (day)	
		1st season	2nd Season	1st season	2nd season	1st season	2nd Season
20-Nov		103.57a	97.55a	162.22 a	151.50 a	54.04a	39.28b
20-Dec		103.25a	86.54b	144.61 b	131.00 b	32.56b	38.68c
20-Jan		83.22b	74.74c	123.83 c	121.06 c	30.58c	41.48a
LSD 5%		0.61	3.08	3.82	0.40	0.26	0.17
Cultivar							
Giza171		95.70 cd	83.90 c	144.89 a	132.67 d	40.44 b	40.19 c
Sids14		100.50 a	86.45 b	144.33 a	133.33 c	35.74 d	39.20 d
sakha95		95.81 c	86.29 b	140.33 b	132.78 d	35.32 d	39.16 d
Misr1		95.32 d	87.25 b	142.33 ab	132.33 d	41.97 a	35.86 e
Misr2		95.98 c	89.08 a	145.22 a	139.00 a	41.72 a	41.12 b
Giza168		96.80 b	84.72 c	144.22 a	137.00 b	39.20 c	43.39 a
LSD 5%		0.47	1.21	3.08	0.51	0.46	0.32
Interaction							
20-Nov	Giza171	104.60	90.75	167.00	146.00	50.08	42.50
	Sids14	113.53	94.17	167.67	148.00	44.40	38.27
	sakha95	100.40	95.51	162.00	147.00	51.73	37.17
	Misr1	99.33	98.93	154.67	146.00	59.73	35.50
	Misr2	99.97	106.37	162.33	161.00	63.93	37.30
	Giza168	103.60	99.60	159.67	161.00	54.40	45.00
20-Dec	Giza171	100.87	85.87	144.33	131.00	34.60	35.67
	Sids14	103.97	88.28	143.67	131.00	33.82	38.17
	sakha95	103.83	87.74	140.67	131.00	29.22	39.07
	Misr1	102.93	86.97	146.67	131.00	34.57	36.00
	Misr2	104.10	86.87	147.67	131.00	31.80	40.07
	Giza168	103.83	83.57	144.67	131.00	31.37	43.17
20-Jan	Giza171	81.63	75.08	123.33	121.00	36.63	42.42
	Sids14	84.00	76.90	121.67	121.00	29.00	41.17
	sakha95	83.20	75.62	118.33	120.33	25.00	41.25
	Misr1	83.70	75.85	125.67	120.00	31.60	36.07
	Misr2	83.87	73.99	125.67	125.00	29.42	46.00
	Giza168	82.97	71.00	128.33	119.00	31.83	42.00
LSD 5%		0.81	2.10	5.33	0.89	0.79	0.55

b. Cultivars effect:

A wide diversity was observed among all tested wheat cultivars in their heading in both seasons (Table 5). Giza171 was the earliest among all the tested cultivars in their heading date, and it recorded the lowest number of days to heading (83.90 days) in the second season. On the other hand, the highest number of days to the heading was recorded in Sids14 (100.50 days) in the first season and Misr2 (89.08 days) in the second season. The highest numbers of days to full maturity were shown in Misr2 (145.22 and 139 days) in the first and second seasons, respectively. On the contrary, the lowest number of days to full maturity was recorded in Misr1 (132.33) in the second season. Sakha 95 had the lowest grain-filling duration (35.32 days) among all tested cultivars in the first season, while the highest grain-filling duration (43.39 days) was recorded with Giza168 in the second season. Also, Sids14 and Sakha95 recorded the shortest grain filling duration compared to other cultivars in both seasons.

c. Interaction effect:

Data illustrated in Table 5 indicated that all tested wheat cultivars differ in heading dates under all sowing dates in both seasons. Giza 171 had the lowest number of days to heading (81.63 days) in the first season under a 20 Jan sowing date, while Giza 168 had the lowest heading date in the second season under a late sowing date with an average of 71.00 days. In contrast, Sids14 and Misr2 recorded the highest numbers of days to the heading (113.53 and 106.37 days) under the recommended sowing date in the first and second seasons, respectively. In all cases, all tested cultivars were earlier in their heading dates in the late sowing date (20 Jan) than with 20 Nov and 20 Dec. in both seasons. Sowing Sakha95 on 20 Jan had the lowest number of days to full maturity (118.33) in the first season, while Giza168 expressed the lowest number of days to full maturity (119.00 days) under 20 Jan in the second season. Generally, all tested cultivars mature later in the optimum sowing date (20 Nov.) than the late sowing dates in both seasons. Wheat cultivars sown on 20 Jan had a short grain filling duration compared to early sowing dates. Sakha 95 was sown on 20 Jan and had the lowest grain filling duration (25.00 days) in the first season, while Misr1 was sown on the recommended sowing date and had the lowest grain filling duration (35.50 days) in the second season. In contrast, sowing Misr1 on 20 Nov and Misr2 on 20 Jan recorded the highest grain filling durations (59.73 and 46.00 days).

2. Effect of sowing date, wheat cultivar, and their interaction on growth traits:

2.1. Analysis of variance

Analysis of variance for total chlorophyll content, flag leaf area, and plant height are presented in Table 6. The Hartley test for homogeneity of variance showed homogenous variances in the two seasons for the flag leaf area. A significant and highly significant mean squares due to sowing dates, wheat cultivars, and their interactions for all growth traits were observed. However, season x cultivar and season x sowing date x cultivar had highly significant effects on the flag leaf area.

Table (6): Mean squares due to sowing date, wheat cultivars, and their interaction for growth traits.

SOV	DF		Total chlorophyll (mg/100g fw)		Plant height		Flag leaf area		
	S	C	Season 1	Season 2	Season1	Season 2	Season 1	Season 2	Combined
Rep.	2		81.04^{ns}	49.91^{ns}	9.33^{ns}	73.34^{ns}	0.50^{ns}	1.07^{ns}	
Season		1							0.07**
Rep. / Season		4							0.79
Sowing date	2	2	627.93*	511.48*	2455.08**	3158.29**	769.91**	755.67**	1524.64**
Sowing date x season		2							0.95^{ns}
Error (a)	4	8	90.41	39.00	2.17	24.74	0.09	0.81	0.45
Cultivar	5	5	263.29**	471.71**	134.86**	124.88**	116.48**	157.10**	271.09**
Cultivar x Season		5							2.49**
Sowing date x Cultivar	10	10	261.70**	181.16**	53.22**	99.48**	8.09**	17.96**	24.05**
Sowing date x Cultivar x season		10							2.01**
Error (b)	30	60	38.92	17.67	11.18	32.1	0.23	0.21	0.22

* and ** significant at 0.05 and 0.01 levels of probability respectively. ns: not significant S: single season C: combined data

2.2. Mean performances of growth traits:

a. Sowing date effect:

The effect of sowing date on total chlorophyll content, flag leaf area, and plant height are shown in Table 7. The results illustrated that the leaf content of total chlorophyll was significantly affected by sowing dates in both seasons. Chlorophyll content significantly increased by delaying the sowing date. Sowing wheat on 20 Jan recorded the highest leaves content of total chlorophyll (55.95 and 54.94 mg/100g fw) without any significant difference with those sowing on 20 Dec (54.36 and 52.45 mg/100g fw) in the first and second seasons, respectively. On the contrary, the lowest leaf contents of total chlorophyll were found under the recommended sowing date with averages of (45.02 and 44.72 mg/100 g fw) in the first and second seasons, respectively. A significant decrease in plant height and flag leaf area with the delaying of sowing date in both seasons was observed. the highest plants with averages of 114.16 and 103.83 cm recorded under the recommended sowing date. On the other hand, the sowing on 20 Jan recorded the shortest wheat plants with averages of 90.80 and 82.53 cm in the first and second seasons, respectively. Sowing wheat on 20 Nov measured the largest average of flag leaf area (49.39 cm^2) while sowing wheat on 20 Jan measured the lowest average (36.47 cm^2).

b. Cultivars effect:

The presented data in Table 7 cleared a wide diversity among all tested wheat cultivars in leaves content of total chlorophyll, flag leaf area, and plant height. The highest content of total chlorophyll was found in Sakha 95 leaves (60.38 and 63.34 mg/100 g fw). On the other hand, Misr2 had the lowest leaves content of total chlorophyll in the first season (46.42 mg/100 g fw), while the lowest chlorophyll content in the second season was recorded in Giza171 leaves (44.19 mg/100 g fw). plant height of all tested wheat cultivars significantly differ in respect to the diversity among cultivars in both seasons. The tallest plants were shown in Sakha95 (109.09 cm). The tallest plants in the second season were recorded in Giza168 (100.56 cm) without any significant difference with all other tested cultivars except Misr2. On the contrary, Giza171 was the shortest in the first season (99.46 cm) while Misr2 was the shortest in the second season (90.27 cm^2). The highest flag leaf area was shown in Sids14 (48.61 cm^2). On the other hand, the lowest flag leaf area was recorded in Sakha95 (38.96 cm^2).

Table (7): Means of chlorophyll content (mg/100 g fw), plant height (cm), and flag leaf area (cm) as affected by sowing date, wheat cultivar, and their interaction.

Factors		chlorophyll content		Plant height (cm)		Flag leaf area (cm^2)
		1st Season	2nd season	1st season	2nd season	Combined
20-Nov		45.02 b	44.72 b	114.16 a	107.69a	49.39 a
20-Dec		54.36 a	52.45 a	102.74 b	102.27 b	41.58 b
20-Jan		55.95 a	54.94 a	90.80 c	82.53c	36.47 c
LSD 5%		8.80	3.78	1.36	4.6	0.39
Cultivars						
Giza171		49.21 bcd	44.19 c	99.46 c	98.22 a	39.42 e
Sids14		52.64 bc	55.21 b	105.54 b	99.66 a	48.61a
Sakha95		60.38 a	63.34 a	109.09 a	97.77 a	38.96 f
Misr1		46.81 cd	47.28 c	100.74 c	98.16 a	45.83 b
Misr2		46.42 d	46.13 c	100.41 c	90.27 b	41.59 c
Giza168		55.19 ab	48.06 c	100.14 c	100.88 a	40.48 d
LSD 5%		6.01	4.05	3.22	5.45	0.32
Interaction						
20-Nov	Giza171	47.27	45.78	113.30	106.66	44.77
	Sids14	49.37	49.75	111.63	108	58.30
	Sakha95	42.23	41.07	121.53	109.33	44.09
	Misr1	42.73	43.50	112.33	116.5	53.85
	Misr2	43.67	43.87	113.83	97.33	48.23
	Giza168	44.83	44.33	112.30	108.33	47.12
20-Dec	Giza171	61.77	42.67	96.73	100	38.20
	Sids14	52.53	58.00	113.73	105.5	48.62
	Sakha95	57.23	67.67	110.87	109	39.20
	Misr1	47.37	48.00	100.63	102	44.95
	Misr2	47.50	46.87	99.30	93.16	39.98
	Giza168	59.77	51.50	95.17	104	38.55
20-Jan	Giza171	38.60	44.13	88.33	88	35.30
	Sids14	56.02	57.87	91.27	85.5	38.90
	Sakha95	81.67	81.30	94.87	75	33.60
	Misr1	50.33	50.33	89.27	76	38.70
	Misr2	48.10	47.67	88.10	80.33	36.55
	Giza168	60.97	48.33	92.97	90.33	35.77
LSD 5%		10.40	7.01	5.57	9.44	0.64

c. Interaction effect:

Data in Table 7 showed that all tested wheat cultivars differ in their leaf content of total chlorophyll concerning the different sowing dates in both seasons. Sakha 95 was sown on 20 Jan and had the highest leaf contents of total chlorophyll (81.67 and 81.30 mg/100g fw) in the first and second seasons, respectively. In contrast, the lowest leaf contents of total chlorophyll (38.60 and 41.07 mg/100 g fw) were found when sowing Giza171 on 20 Jan and Sakha95 on 20 Nov, respectively. In all cases, all tested cultivars recorded higher leaf contents of total chlorophyll under the late sowing date (20 Jan) than (20 Nov and 20 Dec) in both seasons. All tested wheat cultivars were taller under the recommended sowing date (20 Nov) than the late sowing dates in both seasons. Sowing Sakha95 on 20 Nov had the highest means of plant height (121.53 cm and 109.33) in the first and second seasons, respectively. The flag leaf area significantly differs in all tested wheat cultivars under the different sowing dates in both seasons. Sids14 under the recommended sowing date had the highest flag leaf area (58.30 cm^2). On the other hand, Sakha95 under the late sowing date (20 Jan) recorded the lowest flag leaf area with an average of 33.60 cm^2. In general, flag leaf areas were lower in the late sowing date of 20 Jan across all tested cultivars than with 20 Nov and 20 Dec.

3. Effect of sowing date, wheat cultivar, and their interaction on yield and yield components traits:

3.1. Analysis of variance:

The results in Table 8 showed that the mean squares due to sowing date, cultivar, sowing date x cultivar for the studied yield, and its components traits were significant and highly significant in both seasons. Hartley's test for homogeneity of variance in the two seasons for spike length, number of spikelets per spike, and straw yield showed homogenous variances. Regarding the combined analysis (Table 8), it is valuable to note that season x sowing date, season x cultivar, and Season x sowing date x cultivar had highly significant effects on spike length, number of spikelets per spike, and straw yield.

3.2. Mean performances of yield and yield components.

a. Sowing date effect:

Data in Table 9 confirmed a gradual decrease in spike length and the No. of spikelet /spike and straw yield with delaying sowing date. The longest spike, 13.49 cm, was recorded under the recommended sowing date, while the shortest spike, 11.28 cm, was recorded on 20 Jan. The highest number of spikelets/spikes was recorded under the recommended sowing date (21.42). On the other hand, sowing wheat on 20 Jan. recorded the lowest number of spikelets/spikes, with an average of 18.21. The highest Straw yield/m^2 was recorded in wheat plants sowing on 20 Nov. (2467.75 g). On the other hand, sowing wheat on 20 Jan. recorded the lowest Straw yield/m^2 with averages of

(1796.11 g) this value did not differ significantly from (1825.72 g) obtained with the 20 Dec. Harvest index affected considerably by the sowing date in both seasons. An increase in the harvest index was observed with a delay in the sowing date. The highest harvest indexes (29.82 and 30.13) were measured under 20 Dec in the first and second seasons, respectively. In contrast, sowing wheat on 20 Nov recorded the lowest harvest indexes (24.65 and 25.52) in the first and second seasons, respectively. A gradual decrease in 1000-grain weight and grain yield/ha with delayed sowing date in both seasons was observed (Table 10). Sowing wheat on 20 Nov. recorded the highest means of 1000-grain weight (44.24 and 44.43 g) and grain yield/ha (8.21 and 8.15 tons) in the first and second seasons, respectively. On the other hand, sowing wheat on 20 Jan. had the lowest 1000-grain weight (40.20 and 40.62 g) and grain yield/ha (7.23 and 7.54 tons) in the first and second seasons, respectively.

b. Cultivars effect:

All tested wheat cultivars significantly differ in spike length (Table 9). Sids14 and Misr2 had the longest spikes among all tested cultivars (14.06 and 13.97 cm, respectively). On the other hand, the shortest spikes were recorded in Sakha95 and Misr1 (10.86 and 11.33cm), respectively. The highest number of spikelets/spike was recorded in Misr2 (21.03), but the superiority of the Misr2 cultivar in this trait did not differ significantly from that of Giza 168 (21.44). On the other hand, the lowest number of spikelets/spike was recorded in Misr1(18.95) with no significant difference with Sids14 and Sakha95. The highest Straw yield/m^2 was recorded in Misr2 (2372.89 g), while the lowest Straw yield/m^2 was recorded in Giza168 (1716.22 g). Concerning the effect of cultivars on the harvest index, the results in Table 9 showed that the harvest index significantly differs in all tested wheat cultivars in both seasons. Misr1 had the highest harvest indexes (30.09 and 30.37), but Misr2 had the lowest harvest indexes (26.31 and 25.93) in the first and second seasons, respectively, and without any significant difference with Giza 171 in the two seasons. 1000-grain weight significantly differs in all tested cultivars in both seasons (Table 10). Giza171 had the highest means (50.87 and 51.28 g) in the first and second seasons, respectively. On the contrary, the lowest 1000-grain weights were recorded in Giza168 (36.60 and 36.08) in the first and second seasons, respectively. The grain yield/ha of the studied wheat cultivars differed significantly in both seasons (Table 10). Misr2 had the highest grain yield/ha (8.37 tons) in both seasons, while the lowest grain yields/ha were recorded in Giza168 (6.95 and 7.24 tons) in the first and second seasons, respectively.

J. Agric. & Env. Sci. (Damanhour University) 2024, 23 (3): 45-76
Print: ISSN 1687-1464 Online: 2735-5098

Table (8): Mean squares due to sowing date, wheat cultivar, and their interaction for Spike length, No. of spikelets per spike, Straw yield, Harvest index,1000-grain weight, and Grain yield.

SOV	DF		Spike length			No. spikelet per spike.			Straw yield			Harvest index		1000-grain weight		Grain yield	
	S	C	Season 1	Season 2	C	Season 1	Season 2	C	Season 1	Season 2	C	1st season	2nd season	1st Season	2nd Season	1st Season	2nd season
Rep.	2		3.56^{ns}	5.62*		1.87^{ns}	2.57^{ns}		21369.39^{ns}	767.39^{ns}		3.24^{ns}	0.5^{ns}	0.03^{ns}	0.17^{ns}	68.93^{ns}	1.39^{ns}
Season		1			26.01^{ns}			19.17^{ns}			24210.088^{ns}						
Rep. /Season		4			4.59**			2.22**			11068.39**						
Sowing date	2	2	25.13*	22.03**	44.06**	69.23**	31.02*	94.94**	3257053.40**	2019251.20**	5185051.69**	150.08**	105.94**	78.49**	68.71**	5159.69**	2056.87**
Season x sowing date		2			3.10**			5.31**			91252.86**						
Error(a)	4	8	1.85	0.36	1.10	3.35	4.44	3.89	12915.53	1587.14	7251.33	1.35	0.96	0.98	0.47	1.16	1.25
Cultivar	5	5	20.57**	15.91**	33.09**	6.03*	6.91**	9.58**	541967.68**	460441.51**	991134.15**	23.32**	36.23**	22042.17**	16307.9**	2178.08**	1611.45**
Season x cultivar		5			3.39**			3.36**			11275.04**						
Sowing date x cultivar	10	10	5.18**	2.12**	4.37**	4.64*	3.95*	4.94**	208434.30**	186510.68**	370368.46**	14.85**	23.92**	20460.22**	13978.8**	2270.83**	1551.48**
Season x sowing dates x cultivar		10			2.93**			3.95**			24576.51**						
Error(b)	30	60	0.91	0.99	0.95	2.05	1.35	1.70	15647.82	1435.11	8541.46	1.99	0.95	302.74	4.06	0.70	0,89

* and ** significant at 0.05 and 0.01 levels of probability respectively. ns: not significant C: combined

c. Interaction effect:

Data in Table 9 indicated that spike length, number of spikelets/spike, straw yield/m^{2,} and harvest index differ significantly in all tested wheat cultivars across all sowing dates. Sids14 and Misr2 had the longest spikes (15.67 cm) under the recommended sowing date. In contrast, Sakha 95 recorded the shortest spike (9.33 cm) under the 20 Jan sowing date. Misr2 and Sakha95 were sown on 20 Nov and had the highest numbers of spikelets/spike (22.84 and 22.83), respectively. On the other hand, Sakha95 was sown on 20 Jan and had the lowest number of spikelets/spike (16.67). However, Giza171, which was sowed on 20 Nov, had the highest Straw yield/m2 (2927.50 g), while Giza168, which was sowed on 20 Jan, had the lowest Straw yield/m^2 (1281.17 g). Wheat cultivars sowing in the late sowing dates had the highest harvest index compared to the recommended dates. Sowing Giza168 on 20 Jan recorded the highest harvest indexes (33.16 and 34.49). In contrast, Misr2 was sown on 20 Nov and recorded the lowest harvest indexes (21.17 and 22.60) in the first and second seasons, respectively. Data in Table 10 cleared that 1000-grain yield and grain yield/ha differ significantly in all tested wheat cultivars across all sowing dates in both seasons. Giza171 had the highest 1000-grain yield (52.51 and 52.23 g) under the recommended sowing date in the first and second seasons, respectively. In contrast, Misr1 recorded the lowest means (31.67 and 32.20 g) under heat stress in the first and second seasons, respectively. Giza171 had the highest grain yields/ha (9.45 and 9.20 tons) with 20 Nov, in the first and second seasons, respectively. In contrast, Giza168 was sown on 20 Jan and Giza171 was sown on 20 Dec recorded the lowest means of grain yield/ha (6.30 ton) in the first season, while Giza168 and Giza171were sown on 20 Jan. recorded the lowest grain yields/ha (6.80 and 6.81 ton) in the second season, respectively.

4. Effect of sowing date, wheat cultivar, and their interaction on physiological traits.

4.1. Analysis of variance:

The obtained results in Table 11 showed that mean squares due to sowing date, wheat cultivar, and their interactions for canopy temperature and proline content were highly significant. The Hartley test for homogeneity of variance showed homogenous variances in the two seasons for canopy temperature.

Table (9): Means of spike length, number of spikelets per spike, straw yield, and harvest index as affected by sowing date, wheat cultivar, and their interaction.

Factors		Spike length (cm)	No. Spikelets per spike	Straw	Harvest index (%)	
		Combined	Combined	Combin	1st season	2nd season
20-Nov		13.49 a	21.42 a	2467.75	24.65 b	25.52 c
20-Dec		12.26 b	20.25 b	1825.72	29.82 a	30.13 a
20-Jan		11.28 c	18.21 c	1796.11	29.46 a	29.12 b
LSD 5%		0.56	1.06	46.65	1.07	0.91
Cultivars						
Giza171		11.81 bc	20.06 bc	2154.39	26.25 c	26.51
Sids14		14.06 a	19.50 cd	2030.17	28.10 b	27.12 c
sakha95		10.86 d	19.78 bcd	2079.00	27.54	29.07 b
Misr1		11.33 cd	18.95 d	1826.50	30.09 a	30.37 a
Misr2		13.97 a	21.03 a	2372.89	26.31 c	25.93 d
Giza168		12.03 b	20.44 ab	1716.22	29.57 a	30.55 a
LSD 5%		0.66	0.89	63.94	1.36	0.94
Interaction						
20-Nov	Giza1	13.25	20.84	2927.50	23.74	24.60
	Sids1	15.67	21.00	2067.50	28.83	29.06
	sakha	12.75	22.83	2340.00	24.60	25.11
	Misr1	11.75	20.17	2212.67	25.72	26.70
	Misr2	15.67	22.84	2921.84	21.17	22.60
	Giza1	11.84	20.84	2337.00	23.83	25.03
20-Dec	Giza1	11.50	20.00	1703.67	26.87	29.31
	Sids1	14.33	19.83	2053.67	28.44	26.75
	sakha	10.50	19.84	2031.84	28.55	29.28
	Misr1	11.00	19.17	1663.67	33.00	32.93
	Misr2	14.00	21.34	1971.00	30.36	30.40
	Giza1	12.25	21.33	1530.50	31.71	32.13
20-Jan	Giza1	10.67	19.34	1832.00	28.14	25.61
	Sids1	12.17	17.67	1969.33	27.04	25.53
	sakha	9.33	16.67	1865.17	29.48	32.82
	Misr1	11.25	17.50	1603.17	31.55	31.47
	Misr2	12.25	18.92	2225.84	27.39	24.81
	Giza1	12.00	19.17	1281.17	33.16	34.49
LSD 5%		1.31	1.77	127.11	2.35	1.63

Table (10): Means of 1000- grain weight and grain yield as affected by sowing date, wheat cultivar, and their interaction during 2021\2022 and 2022\2023 seasons.

Factors		1000- grain weight (g)		Grain yield (ton/ha)	
		1st Season	2nd Season	1st Season	2nd Season
20-Nov		44.24 a	44.43 a	8.21 a	8.15 a
20-Dec		43.15 b	43.25 b	7.78 b	7.78 b
20-Jan		40.20 c	40.62 c	7.23 c	7.54 b
LSD 5%		0.92	0.64	0.42	0.66
Cultivars					
Giza 171		50.87 a	51.28 a	7.45 bc	7.68 bc
Sids14		45.31 b	46.64 b	7.87 ab	7.54 bc
Sakha95		43.53 c	43.24 c	8.07 a	8.23 a
Misr1		38.42 e	38.60 e	7.73 ab	7.88 ab
Misr2		40.44 d	40.76 d	8.37 a	8.37 a
Giza 168		36.60 f	36.08 f	6.95 c	7.24 c
LSD 5%		0.68	0.45	0.70	0.52
Interaction					
20-Nov	Giza171	52.51	52.23	9.45	9.20
	Sids14	46.49	47.03	8.85	7.99
	sakha95	42.64	42.50	7.70	7.78
	Misr1	42.34	42.57	7.70	8.02
	Misr2	42.38	43.07	8.15	8.20
	Giza168	39.07	39.20	7.40	7.71
20-Dec	Giza171	49.83	51.50	6.30	7.02
	Sids14	47.73	47.90	7.98	7.61
	sakha95	45.55	45.03	8.60	7.91
	Misr1	41.25	41.03	8.15	8.21
	Misr2	39.90	40.00	8.50	8.70
	Giza168	34.63	34.03	7.15	7.20
20-Jan	Giza171	50.27	50.10	6.60	6.81
	Sids14	41.72	45.00	6.78	7.02
	sakha95	42.40	42.20	7.90	8.99
	Misr1	31.67	32.20	7.35	7.40
	Misr 2	39.05	39.20	8.45	8.20
	Giza168	36.10	35.00	6.30	6.80
LSD 5%		1.17	0.77	1.22	0.91

J. Agric. & Env. Sci. (Damanhour University) 2024, 23 (3): 45-76
Print: ISSN 1687-1464 Online: 2735-5098

Table (11): Mean squares due to sowing dates, wheat cultivars, and their interaction for physiological traits.

SOV	DF		Canopy temperature			Proline content	
	S	C	Season 1	Season 2	C	Season 1	Season 2
Rep.	2		0.50^{ns}	0.22^{ns}		0.000002^{ns}	0.009^{ns}
Season		1			0.01^{ns}		
Rep. / Season		4			0.36**		
Sowing date	2	2	6.14**	6.30**	12.42**	2.80**	2.43**
Season x sowing date		2			0.03**		
Error(a)	4	8	0.23	0.28	0.26	0.00001	0.01
Cultivar	5	5	2.89**	3.49**	6.36**	1.52**	1.58**
Season x cultivar		5			0.02**		
Sowing date x cultivar	10	10	1.03**	0.98**	1.93**	0.17**	0.14**
Season x sowing date x cultivar		10			0.09**		
Error (b)	30	60	0.13	0.10	0.12	0.00001	0.010

** significant at 0.01 level of probability. ns: not significant S: single season C: combined d

4.2. Mean performances:

a. Sowing date effect:

Data in Table 12 confirmed an increase in canopy temperature with delaying sowing date. Sowing wheat on 20 Dec recorded the highest canopy temperature (18.56 C^o), while sowing wheat on 20 Nov had the lowest canopy temperature (17.39 C^o). The leaf content of proline gradually increased with delayed sowing dates in both seasons. The highest proline contents were recorded in wheat on 20 Jan (1.71 and 1.72 mg/100 g fw). On the other hand, sowing wheat on 20 Nov recorded the lowest proline contents (0.93 and 0.99 mg/100 g fw) in the first and second seasons, respectively.

b. Cultivars effect:

All tested wheat cultivars significantly differ in their canopy temperature and proline content (Table 12). Giza171 and Sids14 had the highest canopy temperatures (18.73 and 18.56 C^o, respectively. On the other hand, the lowest canopy temperatures were recorded in Misr2 and Misr1 (17.28 and 17.41 Cº), respectively. The highest proline contents were recorded in Sakha95(1.86 and 1.87 mg/100 g fw) in the first and second seasons, respectively. On the contrary, the lowest proline contents were recorded in Misr2 (0.88 mg/100 g fw) in both seasons.

Table (12): Means of canopy temperature (Cº) and proline content (mg/100g fw) as affected by sowing date, wheat cultivar, and their interaction during 2021\2022 and 2022\2023 seasons.

Factors		Canopy temperature	Proline content	
		Combined	1st season	2nd season
20-Nov		17.39 c	0.93 c	0.99 c
20-Dec		18.56 a	1.36 b	1.33 b
20-Jan		18.07 b	1.71 a	1.72 a
LSD 5%		0.28	0.003	0.09
Cultivars				
Giza171		18.73 a	1.02 e	0.99 d
Sids14		18.56 a	1.11 d	1.14 c
sakha95		17.86 c	1.86 a	1.87 a
Misr1		17.41 d	1.35 c	1.38 b
Misr2		17.28 d	0.88 f	0.88 e
Giza168		18.20 b	1.79 b	1.81 a
LSD 5%		0.24	0.003	0.10
Interaction				
20-Nov	Giza171	18.00	0.64	0.62
	Sids14	17.67	0.97	0.97
	sakha95	16.42	1.16	1.52
	Misr1	17.42	1.13	1.13
	Misr2	17.00	0.56	0.57
	Giza168	17.84	1.11	1.12
20-Dec	Giza171	18.75	0.85	0.85
	Sids14	19.00	1.11	1.15
	sakha95	19.00	1.99	1.68
	Misr1	18.00	1.41	1.47
	Misr 2	17.84	0.95	0.95
	Giza168	18.77	1.85	1.86
20-Jan	Giza171	19.44	1.56	1.50
	Sids14	19.00	1.25	1.31
	sakha95	18.17	2.43	2.42
	Misr1	16.82	1.51	1.52
	Misr2	17.00	1.12	1.13
	Giza168	18.00	2.41	2.45
LSD 5%		0.19	0.01	0.41

c. Interaction effect:

Data in Table 12 indicated that canopy temperature and proline content differ significantly in all tested wheat cultivars across all sowing dates. Giza171 was sown on 20 Jan and had the highest canopy temperature (19.44 C^{o}). In contrast, Sakha95 was sown on 20 Nov and recorded the lowest canopy temperature (16.42 C^{o}. Additionally, under the 20 Jan sowing date, Giza168 had the highest proline content (2.45 mg/100g fw) in the second season, while Sakha95 had the highest contents (2.43 and 2.42 mg/100 g fw) in the first and second seasons, respectively. On the other hand, the lowest proline contents (0.56 and 0.57 mg/100 g fw) were obtained from sowing Misr2 on 20 Nov in the first and second seasons, respectively.

DISCUSSION

In the present study, delaying the sowing date to early Jan. resulted in a significant decrease in heading and maturity date, leading to a significant shortening of the grain filling period. In previous studies, delaying the sowing date led to a large increase in heat stress during and after the grain-filling period. This increase in air temperature caused rapid maturity of grains. In this regard, (**Dias and Lidon 2009)** found that bread wheat exposure to high temperatures significantly hastens heading and physiological maturity (shortening the grain filling period). **Tawfelis *et a*l., (2011)** showed that delaying the sowing date reduced days to heading and physiological maturity compared with the recommended sowing date. Also, (**Hakim *et al*., 2012)** confirmed that all genotypes were significantly affected by high-temperature stress in late and very late sowing conditions, resulting in a decrease in heading and maturity date. Substantial genetic variability was observed among wheat genotypes for their ability to cope with heat stress **(Shah and Paulsen 2003)**. (**Hossain *et al*., 2017 and 2018)** revealed that days to heading and physiological maturity were significantly influenced by sowing dates and varieties. (**Singh *et al*., 2021)** showed that delaying sowing dates experienced higher temperatures during flowering and had shorter vegetative and maturation periods than timely sowing dates.

Plants grown under heat stress exhibited early senescence, indicating a shorter grain filling period compared to control

(Bergkamp *et al*., 2018) where, for every 1°C rise in temperature above wheat's optimal growing temperature range of 20–25°C, there is a decrease in 2.8 days and 1.5 mg in the grain filling period **(Ahlawat *et al*., 2021). (Dwivedi *et al*., 2017)** heat stress induced an 8.6-day reduction in average grain filling duration compared to the optimal sowing date. Our results indicated that delaying the sowing date led to a significant shortage in the grain filling period. These findings are harmonic with those of (**Menshawy 2007), (Dias and Lidon 2009), (Modarresi *et al*., 2010), and (Ullah *et al*., 2022)** reported that late sowing led to a significant reduction in grain filling period.

In this study, the late sowing date was associated with a significant decrease in plant height, flag leaf area, and chlorophyll content. Heat stress may have contributed to reducing chlorophyll concentration on the late planting date by lowering the plant's photosynthetic ability through metabolic restrictions and oxidative damage to chloroplasts **(Farooq *et al*., 2011)**. Additionally, the degradation of chlorophyll caused by high temperatures likely decreased photosynthetic capacity (Dwivedi et al., 2017); hence, the length of heat stress largely impacted photosynthetic activity (Balla et al., 2019). Tawfelis *et al*., (2011) showed that postponing the sowing date decreased the area of flag leaves.

Additionally, Balla et al. (2019) found that the duration of heat stress largely impacted the flag leaf area. The decrease in plant height under heat stress was previously documented by Abdel-Nour and Hayam (2011), who discovered that the ideal planting date had the highest plant height when compared to the late and early planting dates. Similarly, Mumtaz et al. (2015) found that wheat planted on November 11th fared better regarding plant height. The genotypes Millat-11, Meraj-08, and Sehar-06 displayed the tallest plants. According to Hossain et al., (2017), sowing dates and cultivars substantially impacted plant height.

In every instance, the ideal sowing date (15 November) yielded a larger grain production than 20 December and 20 January. Grain yield has been nearly lowered by 302 kg ha^{-1} $^{o}C^{-1}$ for each day with a maximum temperature above 30°C during anthesis and by 161 kg ha−1 ^{o}C-1 for each day with a maximum temperature above 30°C during grain fill due to the increase in heat stress caused by postponing sowing dates (Telfer et al., 2018). Fleitas et al. (2021) showed that grain yield and yield components were negatively impacted when heat stress rose. Grain yield was significantly lower under post-flowering heat stress than under control. When exposed to extreme heat stress in controlled settings, the yield was reduced by 6–51%, and when field-based tents were used, the yield was reduced by 2–27% (Bergkamp *et al*., 2018). Additionally, Schittenhelm et al. (2020) discovered that, in comparison to nearby non-stressed control, the 14-day post-anthesis heat stress treatment resulted in an average drop of 57.3% in grain production. Grain yield/m^2 showed a significant decrease in both seasons under heat stress, according to Shenoda et al. (2021). Similar findings were made by Abdel-Nour, Nadya, and Hayam et al. (2011), who discovered that the optimal date of November 20th had the maximum biological yield and grain production compared to the late and early planting dates.

Singh et al. (2011) also found that high temperatures harmed each plant's biological yield. In the current study, a delayed sowing date led to a notable increase in the harvest index, but heat stress caused a significant decrease in biomass production and plant straw yield. In contrast to our findings, Hossain et al. (2017) discovered that sowing dates and types substantially impacted the harvest index.

The optimum sowing date (15 November) produced the highest harvest index out of the three sowing dates, whereas the late sowing date (December 30) produced the lowest. Regarding the harvest index, "BARI Gom 28" was discovered to be noticeably better than all other types. Similarly, Bergkamp et al. (2018) found that heat stress after flowering significantly decreased the harvest index compared to the control.

Our findings demonstrated that postponing the planting date led to a considerable rise in canopy temperature and proline concentration. Our findings are consistent with those of Madal et al. (2013) and Mahdavi et al. (2021), who discovered a relationship between canopy temperature and grain yield. This suggests that cooler canopies could produce higher grain yields in normal and high-temperature stress situations. Additionally, Abou Gabal and Tabl (2014) discovered that the HT cultivar had a greater relative value proline content than the HS cultivar, Giza168, which was observed to be an HS cultivar yet had a high relative value proline content.

CONCLUSION

The results indicated that wheat performance was significantly influenced by sowing date, cultivar, and their interaction. Generally, heat stress harmed all studied traits. Sids14 recorded the highest spikes and flag leaf area, while Sakha95 was the tallest cultivar in both seasons. Misr2 outperformed other tested cultivars of No. of spikelets/spike, harvest index, and grain yield/ha. Misr1 had the highest straw yield. Moreover, Giza171 and Sids14 had the highest canopy temperatures. Sakha95 had the highest proline content. Giza 171 had the highest 1000-grain weight and grain yield/ha under the recommended sowing date, but under heat stress conditions, Sakha95 had the highest value of proline content. Additionally, Giza171 recorded the highest straw yield under the recommended sowing date. Moreover, the cultivars “Misr2 and Giza171” were more suitable for the late sown conditions. This study was conducted in Egypt; similar overall performance patterns in other Mediterranean basin regions are expected to occur.

REFERENCES

Abdel Nour, Nadya, A.R. and S.A. Hayam (2011). Influence of sowing date and nitrogen fertilization on yield and its components in some bread wheat genotypes. Egypt J. Agric. Res., 89(4): 1413-1432.

Abou Gabal, A. A.,and K.M. Tabl (2014). Heat tolerance in some Egyptian wheat cultivars as measured by membrane thermal stability and proline content. *Middle East J Agric Res, 3*(2), 186-193

Ahlawat, O. P.; D. Yadav; P.L. Kashyap; A. Khippal and G. Singh (2022). Wheat endophytes and their potential role in managing abiotic stress under changing climate. *J. of App. Microbiology*, *132*(4):2501-2520.

Akter, N., and I.M. Rafiqul (2017). Heat stress effects and management in wheat. A review. *Agron. for sustainable dev., 37*, 1-17.

Asseng, S.; P. Martre; A. Maiorano; R.P. Rötte; G.J. O’Leary; G.J. Fitzgerald and F. Ewert (2019). Climate change impact and adaptation for wheat protein. *Global change biology, 25*(1), 155-173

Bavec,M.; Vukovic´, K.; GrobelnikMlakar, S.; Rozman, Cˇ .; Bavec, F (2007). Leaf area index in winter wheat: response on seed rate and nitrogen application by different varieties. J. Cent. Eur. Agric., 8, 337–342. [CrossRef]

Balla, K.; I. Karsai; P. Bónis; T. Kiss; Z. Berki; A. Horvath and O. Veisz (2019). Heat stress responses in a large set of winter wheat cultivars (Triticum aestivum L.) depend on the timing and duration of stress. *PLoS One*, *14*(9), e0222639.

Bergkamp, B.; S.M. Impa; A.R. Asebedo; A.K. Fritz and S.K. Jagadish (2018). Prominent winter wheat varieties response to post-flowering heat stress under controlled chambers and field-based heat tents. *Field Crops Res.*, *222*, 143-152.

Braun, H.J.; Atlin, G.; Payne, T.; Reynolds, M.P. Climate Change and Crop Production; CABI:Wallingford, UK, 2010; pp. 115–138.

Dahal, K. R., Puri, R. R., & Joshi, A. K. (2015). Effect of climate change and associated factors on the production and productivity of wheat (*Triticum aestivum* L.) over last years in the Terai Region of Nepal.

Dias, A.S. and F.C. Lidon (2009). Evaluation of grain filling rate and duration in bread and durum wheat, under heat stress after anthesis. *Journal of Agronomy and Crop Science*, *195*(2), 137-147.

Dwivedi, S.K.; S. Basu; S. Kumar; G. Kumar; V. Prakash; S. Kumar and A. Arora (2017). Heat stress-induced impairment of starch mobilisation regulates pollen viability and grain yield in wheat: Study in Eastern Indo-Gangetic Plains. *Field Crops Research*, *206*, 106-114.

Elbasyoni, I. S. (2018). Performance and stability of commercial wheat cultivars under terminal heat stress. *Agronomy*, *8*(4), 37.

FAOSTAT (2022). The annual report of wheat production. Food and Agriculture Organization of the United Nations, May, 2023.

Farooq, M.; H. Bramley; J.A. Palta and K.H. Siddique (2011). Heat stress in wheat during reproductive and grain-filling phases. *Critical Reviews in Plant Sciences*, *30*(6), 491-507.

Fleitas, M. C.; S. Mondal; G.S. Gerard; N. Hernández-Espinosa; R.P. Singh; J. Crossa and C. Guzmán (2020). Identification of CIMMYT spring bread wheat germplasm maintaining superior grain yield and quality under heat stress. *Journal of Cereal Science*, *93*, 102981.

Gheith, E.M.S.; M.M. Shafik; Ola Z. Elradry and B.M. Abdulkareem (2018). Growth and productivity of maize (*Zea mays* L.) as affected by nitrogen and zinc fertilizer levels. Gorwth. Bioscience Res., 15(1):54-59.

Gol, L., Tomé, F., & von Korff, M. (2017). Floral transitions in wheat and barley: interactions between photoperiod, abiotic stresses, and nutrient status. Journal of Experimental Botany, 68(7), 1399-1410.

Gomez, K.A. and A.A. Gomez (1984). Statistical procedures for Agricultural Research. (2nd ed). An International Rice Research Institute J. Wiley and Sons, New York, USA. pp. 377-434.

Hakim, M.A.; A. Hossain; J.A. Teixeira da Silva; V.P. Zvolinsky and M.M. Khan (2012). Yield, Protein and Starch Content of Twenty Wheat (*Triticum aestivum* L.) Genotypes Exposed to High Temperature under Late Sowing Conditions. *J. of Sci. Res.*, *4*(2): 178-191.

Hartley, H.O. 1950. The Maximum F-Ratio as a Short Cut Test for Heterogeneity of Variances. Biometrika, 37:308-312.

Hossain, A.; M.R. Islam; K.A.M.M. Rahman; M.H. Rashid and A. Anwari (2017). Comparative performance of three wheat (*Triticum aestivum* L.) varieties under heat stress. *Inter. J. of Natural and Social Sci.*, *4*(3), 26-42.

Hossain, M.M.; A. Hossain; M.A. Alam; A.E.L. Sabagh; K.F.I. Murad; M.M. Haque and S. Das (2018). Evaluation of fifty irrigated spring wheat genotypes grown under late sown heat stress conditions in multiple environments of Bangladesh. *Fresen. Environ. Bull*, *27*(9), 5993-6004.

Kumar, R.R.; S. Goswami; S.K. Sharma; K. Singh; K.A. Gadpayle; S.D. Singh; H. Pathak and R.D. Rai (2013). Differential expression of heat shock protein and alteration in osmolyte accumulation under heat stress in wheat. *Journal of Plant Biochemistry and Biotechnology*, *22*, 16–26. https://doi.org/10.1007/s13562-012-O1596.

Mohamed, N. E. M., & Said, A. A. (2014). Stability parameters for comparing bread wheat genotypes under combined heat and drought stress. *Egypt J Agron*, *36*(36), 123-146.

Mahdavi, S.; A. Arzani; S.A.M. Maibody and A.A. Mehrabi (2021). Photosynthetic and yield performance of wheat (Triticum aestivum L.) under sowing in hot environment. *Acta Physiologiae Plantarum*, *43*(7), 106.

Menshawy, A.M.M., (2007). Evaluation of some early bread wheat genotypes under different sowing dates:1. Earliness character. Fifth Plant Breeding Conference (May). Egypt J. Plant Breed., 11(1): 25-40.

Modarresi, M.; V. Mohammadi; A. Zali and M. Mardi (2010). Response of wheat yield and yield related traits to high temperature. *Cereal Research Communications*, *38*(1), 23-31.

Mondal, S.; R.P. Singh; J. Crossa; J. Huerta-Espino; I. Sharma; R. Chatrath and A.K. Joshi (2013). Earliness in wheat: a key to adaptation under terminal and continual high temperature stress in South Asia. *Field crops research*, *151*, 19-26.

Mumtaz, M.Z.; M. Aslam; H.M. Nasrullah; M. Akhtar and B. Ali (2015). Effect of various sowing dates on growth, yield and yield components of different wheat genotypes. American-Eurasian J. Agric. & Environ. Sci., 15 (11): 2230-2234.

Pimentel, A.J.B.; J.R.D.A.S.D.C. Rocha; M.A.D. Souza; G. Ribeiro; C.R. Silva and I.C.M. Oliveira (2015). Characterization of heat tolerance in wheat cultivars and effects on production components. *Revista Ceres*, *62*, 191-198.

Poudel, P. B. and M.R. Poudel (2020). Heat stress effects and tolerance in wheat: A review. *J. Biol. Today's World*, *9*(3), 1-6.

Poudel, P.B.; M.R. Poudel and R.R. Puri (2021). Evaluation of heat stress tolerance in spring wheat (*Triticum aestivum* L.) genotypes using stress tolerance indices in western region of Nepal. *Journal of Agriculture and Food Research*, *5*, 100179.

Riaz, M. W., Yang, L., Yousaf, M. I., Sami, A., Mei, X. D., Shah, L., ... & Ma, C. (2021). Effects of heat stress on growth, physiology of plants, yield and grain quality of different spring wheat (Triticum aestivum L.) genotypes. *Sustainability*, *13*(5), 2972.

Shenoda, J. E., Sanad, M. N., Rizkalla, A. A., El-Assal, S., Ali, R. T., & Hussein, M. H. (2021). Effect of long-term heat stress on grain yield, pollen grain viability and germinability in bread wheat (*Triticum aestivum* L.) under field conditions. *Heliyon*, *7*(6).

Shah, N.H.; Paulsen, G.M. Interaction of drought and high temperature on photosynthesis and grain-filling of wheat. Plant Soil 2003, 257, 219–226.

Saboon, M.A.A.; E.M.S. Gheith; S.A. Safina and Ola Z. El-Badry (2022). Response of three wheat varieties to nitrogen levels, seeding rates and their combination; 2: spike characters. INDIAN J. RES., 11(04): 144-147.

Shahbandeh,M. 2024.Major importing countries of wheat, flour, and products 2014/15-2023/24 https://www.statista.com/aboutus/our-research-commitment/1239/m-shahbandeh

Sharma, D., Singh, R., Rane, J., Gupta, V. K., Mamrutha, H. M., & Tiwari, R. (2016). Mapping quantitative trait loci associated with grain filling duration and grain number under terminal heat stress in bread wheat (Triticum aestivum L.). *Plant Breeding*, *135*(5), 538-545.

Sihag, P.; U. Kumar; V. Sagwal; P. Kapoor; Y. Singh; S. Mehla and O.P. Dhankher (2023). Effect of terminal heat stress on osmolyte accumulation and gene expression during grain filling in bread wheat (Triticum aestivum L.). *The Plant Genome*, e20307.

Singh, K.; S.N. Sharma and Y. Sharma (2011). Effect of high temperature on yield attributing traits in bread wheat. *Bangladesh Journal of Agricultural Research*, *36*(3), 415-426.

Singh, N.; A.S. Virdi; M. Katyal; A. Kaur; D. Kaur; A.K. Ahlawat and R. K. Sharma (2021). Evaluation of heat stress through delayed sowing on physicochemical and functional characteristics of grains, whole meals and flours of Indian wheat. *Food Chemistry*, *344*, 128725.

Tawfelis, M.B.; K.A. Khieralla; M.A. El Morshidy and Y.M. Feltaous (2011). Genetic diversity for heat tolerance in some bread wheat genotypes under Upper Egypt conditions. *Egyptian Journal of Agricultural Research*, *89*(4), 1463-1480.

Ullah, A.; F. Nadeem; A. Nawaz; K. H. Siddique and M. Farooq (2022). Heat stress effects on the reproductive physiology and yield of wheat. *Journal of Agronomy and Crop Science*, *208*(1), 1-17.

Ullah, S.; R. Trethowan and H. Bramley (2021). The Physiological Basis of Improved Heat Tolerance in Selected Emmer-Derived

Hexaploid Wheat Genotypes. *Frontiers in Plant Science*, *12*, 739246.

Vignjevic, M.;Wang, X.; Olesen, J.E.;Wollenweber, B(2014). Traits in Spring Wheat Cultivars Associated with Yield Loss Caused by a Heat Stress Episode after Anthesis. *J. Agron. Crop Sci*.201(1), 32-48

Worldometer (2023). African Countries by Population—(2023) Worldometer**.** **https://www.worldometers.info/population/countries-in-africa-by-population/**

Zhongfu Ni, Hongjian Li, Yue Zhao, Huiru Peng, Zhaorong Hu, Mingming Xin, and Qixin Sun (2018). Genetic improvement of heat tolerance in wheat: Recent progress in understanding the underlying molecular mechanisms. *The crop Journal*,6(1),32-41.

الملخص العربى

تأثيرات الاجهاد الحراري على الأداء لبعض أصناف القمح المصرية

صباح مرسى عبد المجيد، ايمان نايف حامد، محمد عبد الله فودة ويسرى السيد سلامة

قسم المحاصيل كلية الزراعة جامعه دمنهور

تمت زراعة ستة أصناف تجارية من القمح في منطقة أبو المطامير، محافظة البحيرة، جمهورية مصر العربية خلال موسمين زراعيين 2022/2021 و2023/2022 تحت ثلاثة مواعيد من الزراعة، 20 نوفمبر (الموصى به)، ديسمبر، و20 يناير (متأخرة أو اجهاد حراري). تم استخدام القطع المنشقة مرة واحدة في تصميم مكررات عشوائية كاملة باستخدام ثلاث مكررات. تم وضع مواعيد الزراعة في القطع التجريبية الرئيسية والأصناف في القطع التجريبية الصغيرة. كان الهدف العام من التجربة هو تحديد أفضل الأصناف من حيث موعد الزراعة الموصى به وكذلك أفضل الأصناف في الزراعات المتأخرة أو تحت ظروف الإجهاد الحراري. أظهرت النتائج أن الإجهاد الحراري كان له تأثير معنوي عكسي على الغالبية العظمى من الصفات المدروسة. من بين النتائج المتحصل عليها، سجل صنف سدس14 أعلى ارتفاع للسنبلة وأعلى مساحة ورقية خلال موسمي الدراسة. أوضحت النتائج أيضاً أن سخا95 كان أعلي الأصناف من حيث صفة طول النبات خلال موسمي الدراسة، بينما صنف مصر2 تفوق على كل الأصناف المدروسة في عدد السنيبلات للسنبلة الواحدة، ودليل الحصاد وكذلك محصول الحبوب للهكتار. كما سجل صنف مصر1 أعلى محصول للقش. سجلا صنفي جيزة171 وسدس14 أعلى درجة حرارة للغطاء النباتي. أعلى محتوى للحمض الأميني برولين تم تسجيله مع صنف سخا95. أعطى صنف جيزة 171 أعلى

محصول للقش ووزن الألف حبة ومحصول الحبوب للهكتار وذلك تحت ميعاد الزراعة الموصى به. إضافة إلى ذلك، أعطى صنف سخا95 أعلى متوسط للحمض الأميني برولين تحت ظروف الإجهاد الحراري. ومن بين النتائج الهامة التي تم الحصول عليها أن صنفي مصر2 وجيزة171 كانا أفضل الأصناف أداءً تحت ظروف الزراعات المتأخرة.

من خلال هذه الدراسة والنتائج المتحصل عليها يمكن القول أن تقييم أصناف محصول القمح تحت ظروف الإجهاد الحراري في مصر مهم وذلك لمواجهة ظاهرة الاحتباس الحراري وتقليل استيراد القمح.

الكلمات المفتاحية: القمح، الإجهاد الحراري، موعد الزراعة، المحصول.