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Research Article

Effect of Planting Dates and Planting Methods on Water Relations of Wheat

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Wheat (*Triticum aestivum* L.) is the uppermost cereal grain crop considered as a major stable food for the Egyptian people. Field experiments were conducted during two consecutive winter seasons of 2017-18 and 2018-19 to study the effect of two planting dates (PD) (20th of November and 20th of December) under four different planting methods (PM) (bed broadcast, flat broadcast, drill at 15 cm, and drill at 25 cm apart rows) on the productivity and water relations of wheat genotype (Egypt 1). The study is intended to assess the water relations for wheat planting dates and planting methods and determine the role of late planting date and planting methods on wheat productivity. Results showed that the values of grain yields and some attributed yields were highly significantly affected by planting dates and methods in the two growing seasons. Planting wheat at the optimal date (20th November) was better than sowing at the late date (20th December) for all values obtained from the studied parameters in both seasons of the study. The bed broadcast planting method gave the highest mean values for all studied parameters except the plant height which was recorded with drilling seeds at a 15 cm planting method in the two growing seasons. The highest values of water applied were recorded with the first date under the borders planting method (PD_1M_2), while the lowest of Aw recorded was from beds planting method with the second date. The highest mean values for WP were recorded with the bed broadcast planting method.

1. Introduction

Wheat (*Triticum aestivum* L.) is the uppermost cereal grain crop regarded as a major stable food for the Egyptian people. But the local production does not meet the consumption owing to the increased population with a limited cultivated area as well as water resources [1, 2]. So, improving the productivity of this crop is the main task due to its short supply. The most factors that lead to increasing wheat yield are breeding, producing new genotypes with high yielding ability, planting in recommended time and suitable method, and using all other ways such as fertilization, irrigation, weed control, pest control, and the best storage [3].

Wheat requires particular environmental conditions for better emergence and growth. Wherefore, seasonal temperature is an important climatic aspect that can have thoughtful effects on the yields of crops. Nowadays, obvious changes in temperature and rainfall in both the global and regional aspects were identified as climate change phenomena in terms of amount and time of occurrence and consequently have exerted different impacts on the inputs and agricultural production [4].

Previous research revealed that average global temperatures have increased and are predicted to stay rising, with an associated higher frequency of extremely hot days. These trends have already been reported in the major global wheat-producing regions [5–7]. Severe damage could be caused by climate change to agricultural productivity if no adaptation measures are taken especially in wheat [1]. Kalra et al. [8] and Hundal [9] noted that a 20 C increase in temperature in wheat or rice resulted in a 15–17% decline in grain yield for both crops, and the decrease was very high in wheat. Also, Zhang et al. [10] observed that the lesser temperature rise during the growing season would have a less adverse impact on wheat production because, for each degree increase in the mean growing season temperature, grain yield of wheat would decrease by some 10%.

Planting cereal crops at a proper time is one means of realizing higher economic yields as it allows crops to give their full yield potential. Belated planting of wheat has been recognized as a foremost bottleneck for high productivity. Subsequent delay in a day from optimum planting time has decreased 1% grain yield in general, and delay in sowing can also increase risks of yield loss or crop failure by diseasing attack, etc. [11]. So, late planting affects not only germination but also the no. of grains spike^{-1}, 1000-grain weight, and ultimately the grain yield [12–14]. In opposite to that, the normal planting date gave the higher grain yields [15]. Each day delay in sowing from 20th November decreases grain yield at 39 kg·ha^{-1} per day [16]. Growing degree day is a good estimator of wheat growth stages [17], and accumulation of degree days for each stage of growth is relatively stable and independent of planting date [18]. Therefore, to become accustomed to crop systems and to the changing climate and considering the growing population (at least till 2050), it is vital to know how climate change influences agricultural production and water productivity, and it is a need to produce more agricultural outputs under undesirable climatic conditions for more people [19].

On the other side, the unsuitable planting method could cause a low yield due to the seed rate and crop management. In Egypt, wheat is grown in broadcasting in a huge area. Broadcasting does not just require a higher seed rate but leads to lower plant density, whereas drill planting method and bed planting are recommended for the sake of their regular seed distribution [20]. Bed planting is one of the proven farming methods that improve water distribution and efficiency and fertilizer use efficiency and also reduce weed infestation and crop lodging. It also reduces the cost of planting, soil erosion, and degradation [21]. Therefore, raised beds and planting at the optimum time provide a means of better matching crop growth to the water supply. So, producing more food from less water should be one of the strategies, and this can be done among others through evolving better agronomic and water management approaches. Improving crop yield and per-unit water use has been considered among evaluation strategies in agricultural water management [22]. So, this study aimed to evaluate the water relations for wheat planting dates and planting methods and determine the role of late planting date and planting methods on wheat grain yield.

2. Materials and Methods

2.1. Experimental Site Description and Soil Properties. A field experiment was performed to evaluate the effect of two planting dates under four various planting methods on the yield and water relations of wheat genotype (Egypt 1) at El-Qarda Water Requirement Research Station (WMRI) (latitude: 31 6′N/longitude: 30 56′E, elevation of 6 meters above mean sea level), Kafr El-Sheikh governorate, Water Management Research Institute, National Water Research Center (Egypt). The experiments were conducted during the two succeeding seasons of 2017-18 and repeated in 2018-19.

Table 1: Physical analysis of soil experimental field.

Soil properties	1st season	2nd season
Soil texture		
Sand (%)	20.59	20.03
Coarse sand (%)	1.95	1.91
Fine sand (%)	18.64	18.12
Silt (%)	28.12	28.60
Clay (%)	51.29	51.37
Texture	Clay	Clay
Bulk density (g·cm^{-3})	1.26	1.15
Field capacity (%)	39.98	39.9
Wilting point (%)	21.7	21.60

Before sowing, soil samples were taken from the experimental site in both study seasons for estimating the physical and chemical analyses. Electrical conductivity (dS·m^{-1}) was measured using a conductivity meter in the soil paste extracts. Soluble cations and anions were determined in the soil paste extract following the method of Page et al. [23]. The particle size distribution of soil, in percent, was measured using the pipette method according to Gee and Bauder [24]. Soil bulk density was determined before the experiment by using the core method according to Klute [25]. The field capacity and permanent wilting point were calculated from soil moisture tension curves [26], as presented in Tables 1 and 2.

During the growing cycles of wheat from November to April, the meteorological data were obtained from the Sakha Agrometeorological Station in line with the experimental location. The climate of the North Delta (where the farm is located) is typically Mediterranean with dry mild summer and fairly cool and wet winter; see Table 3.

Growing degree days were proposed to clarify the relationship between growth duration and temperature, and they were calculated from (1) [27], during growing seasons:

$$\mathrm{GDD} = \sum\left(\frac{(T_{\max} + T_{\min})}{2}\right) - T_{\mathrm{b}}, \quad (1)$$

where GDD is growing degree days, T_{b} is a minimum temperature in which germination occurs (5), $T_{\max}$ is maximum air temperature, and $T_{\min}$ is minimum air temperature.

Also, the Agricultural Rainfall Index (ARI) was used to verify the severity and persistence of drought in the studied area. ARI represents a reliable indicator of monthly water balance and is used to determine agricultural droughts [28–30]. ARI is calculated using

$$\mathrm{ARI} = \left(\frac{P}{\mathrm{ET}_0}\right) \times 100, \quad (2)$$

where P is monthly precipitation. ARI values of <40 indicate that drought takes place in a specific month. When $40 < \mathrm{ARI} < 200$, the condition is favorable for vegetation and agricultural production. ARI above 200 demonstrates a wet month. And ET_0 is reference evapotranspiration; it was computed using CROPWAT 8.0. The software is introduced by Allen et al. [31]

Table 2: Chemical analysis of the soil experimental field.

Chemical analysis	Cations				Anions				
	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CaCo_3^{-}$	Hco_3^{-}	Cl^{-}	So_4^{-}	EC
1st season	1.82	2.10	6.36	0.13	0	2.64	4.67	3.09	0.83
2nd season	1.73	2.01	5.63	0.13	0	2.48	4.12	2.85	0.69

Table 3: Meteorological data for Kafr El-Sheikh governorate.

Month	Max. temperature (°C)		Min. temperature (°C)		Relative humidity (%)		Wind speed (km/day)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
November	23.7	25	19.9	17.4	72	71	53	24
December	21.5	19.5	18.4	13.9	77	76	43	25
January	19.3	18.9	13.9	12.3	76	98	49	33
February	21.6	19.7	14.6	14.3	75.5	73	35	29
March	25.4	21.7	16.6	17.6	65	72	46	46
April	27.8	25.1	20	21.3	62	65	74	45

2.2. Experimental Design and Layout. The experimental treatments were intended in a split-plot design with three replications. Two planting dates, 20^{th} of November (the common sowing date in the study site, PD_1) and 20^{th} of December (PD_2), were represented in the main plots, while four planting methods, bed broadcast (M_1), flat broadcast (the common sowing method in the study site, M_2), drill at 15 cm apart rows (M_3), and drill at 25 cm apart rows (M_4), were randomly distributed in the submain plots.

The plot area was $60\,m^2$ ($10\,m * 6\,m$). The beds on bed planting methods were 120 cm wide for the top and 30 cm for the bottom. Sowing by drill was by hand in rows 15 cm apart and 25 cm apart. To avoid the impact of the crosswise movement of irrigation water, the plots were isolated by levees 1.5 wide. Seeds were planted at a seeding rate of $142.8\,kg{\cdot}ha^{-1}$. All agronomic procedures were kept normal and the same for all treatments as suggested by Agriculture Research Center, Ministry of Agriculture, Giza, Egypt. Wheat was manually harvested at physiological maturity (harvesting date) on the 25^{th} of April and on 1^{st} of May in the first and second seasons, respectively.

2.3. Studied Characters and Measurements

2.3.1. Growth Traits, Yield, and Yield Components. At harvest time, plant height (cm) was recorded randomly by measuring the height of 10 tillers in an experimental unit. Grains $spike^{-1}$ was recorded on 10 selected spikes taken from each plot and averaged thereof by threshing and manually counting grains. Thousand grains weight (gm) was recorded on counting a thousand grains manually. Grain yield recorded from the central area of $1\,m^2$ and determination were at harvest to obtain grain per plot and adjusted to 14% moisture basis and then converted to $kg{\cdot}ha^{-1}$.

2.3.2. Irrigation Water Applied and Actual Water Consumptive Use ($m^3{\cdot}ha^{-1}$). Irrigation water is controlled and measured by a flow meter installed in the water delivery unit of the irrigation pump. Soil water storage was measured in each plot on a weight basis before and after each irrigation for the depths of 20, 40, and 60 cm, to calculate water consumptive use ($m^3{\cdot}ha^{-1}$) using [32]

$$Cu = \frac{(\theta_2 - \theta_1)}{100} \times B \cdot d \times D \times A, \quad (3)$$

where Cu is water consumptive use, θ_1 is initial moisture content, θ_2 is final moisture content (after irrigation), $B.d$ is bulk density, D is soil depth (cm), and A is area.

2.3.3. Water Relations. Water productivity (WP) ($kg{\cdot}m^{-3}$) and productivity of irrigation water (IWP) ($kg{\cdot}m^{-3}$) were calculated using (4) and (5) [33], and values of efficiency of water consumptive use (Ecu) were obtained using (6) [34]:

$$WP = \frac{Gy}{Cu}, \quad (4)$$

$$IWP = \frac{Gy}{Wa}, \quad (5)$$

$$Ecu = \frac{Cu}{Wa} \times 100, \quad (6)$$

where Gy is the grain yield ($kg{\cdot}ha^{-1}$), Wa is the irrigation water applied ($m^3{\cdot}ha^{-1}$), and Cu is the total water consumption ($m^3{\cdot}ha^{-1}$).

2.4. Statistical Analysis. The experiment was done in triplicate in a randomized split-plot design with planting dates as the main plots and planting methods as the subplots. Analyses of variance were performed with all data according to Steel and Torrie [35]. The differences amongst treatments were separated using the least significant difference (LSD) at the 0.05 probability level.

3. Results

3.1. Growing Degree Days (GDD) and Agricultural Rainfall Index (ARI). GDD was proposed to clarify the relationship

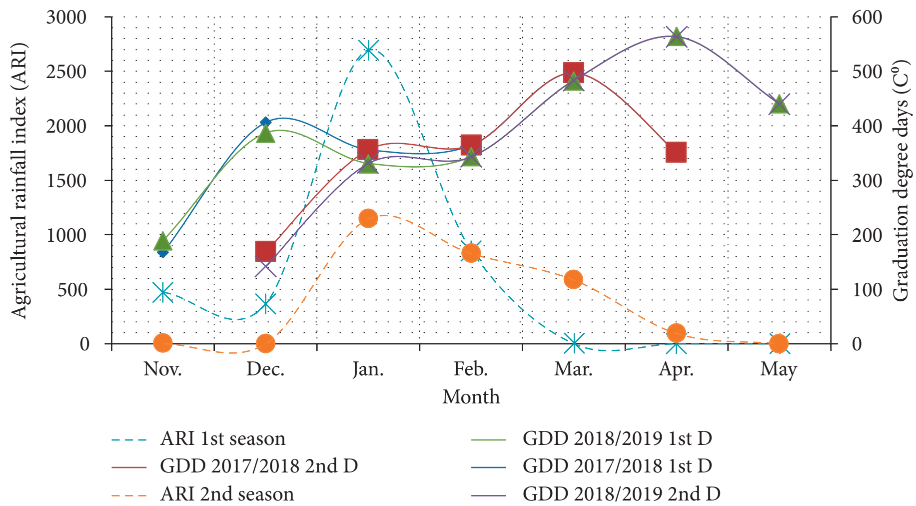

Figure 1: GDD for different planting dates and Agricultural Rainfall Index during the two seasons (2017/2018 and 208/2019).

Table 4: Rainfall ($mm{\cdot}day^{-1}$), reference evapotranspiration ET_0 ($mm{\cdot}day^{-1}$), Agricultural Rainfall Index, and standard deviation.

Month	Rainfall (mm/month)		Eto (mm/day)		ARI	
	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season
Nov.	9.4	0	1.99	1.86	472.36	0
Dec.	5.6	0	1.53	1.23	366.01	0
Jan.	36.4	14.9	1.35	1.3	2696.30	1146.15
Feb.	16.6	15.3	1.94	1.85	855.67	827.03
Mar.	0	17.3	3.13	2.96	0	584.46
Apr.	0	3.9	4.51	4.17	0	93.53
May	0	0	5.86	5.76	0	0
Standard deviation (SDEV)	13.29	8.10	1.70	1.69	966.58	473.27

between growth duration and temperature. The results showed that planting dates varied in the values of growing degree days (GDD) from planting to harvesting, where first date plants needed more accumulated heat units than the second date as shown in Figure 1. GDD was reduced by 18.94% and 15.88% in the late sowing date compared with normal sowing date through the two seasons, respectively. The severity and persistence of drought in the studied area over the 2017/2018 and 2018/2019 winter seasons were determined using the mean monthly ARI. Each month, the Agricultural Rainfall Index value less than 40 was considered as dry. Consequently, the dry months were November, December, April, and May 2018/2019, respectively, while in the 2017/2018 season the dry months were March, April, and May. The highest mean monthly ARI values (2696.30 and 1146.15) were found in January both seasons, while the lowest was obtained in November, December, April, and May,which can be attributed to the lowest precipitation (Figure 1 and Table 4).

3.2. Effect of Planting Dates, Planting Methods, and Their Interaction on Plant Height, Yield, and Yield Components. The results in Table 5 and Figures 2 and 3 show the combined interactions between planting dates and planting methods. The interaction between planting dates and planting methods executed nonsignificant effects on plant height and most of the yield and its components in the two growing seasons except grain yield and 1000-grain weight in the first season and no. of grains per spike in the second season which detected highly significant effects. The highest grain yield (7752.5, 6970 $kg{\cdot}ha^{-1}$) was obtained by sowing wheat on bed broadcast on 20^{th} November (PD_1M_1) in both seasons, respectively, while the lowest was observed with sowing wheat on flat broadcast method at the late sowing date, 20^{th} December (PD_2M_2). All planting methods achieved high 1000-grain weight values with sowing on 20^{th} November through the two growing seasons. The data concerning no. of grains spike^{-1} indicates that the highest no. of grains per spike value (55.4) was observed with bed broadcast with the first planting date (PD_1M_1).

3.2.1. Planting Dates. Planting dates showed highly significant effects on plant height, grain yield, and its components, i.e., 1000-grain weight, no. of grains per spike, and spike length, through the first season. But, the second season did not show a significant effect on grain yield and some of the yield components, i.e., no. of grains per spike and spike length; however, it had a highly significant effect on plant height and 1000-grain weight. In general terms, the first date has better values than the late date for grain yield and its components (Table 5).

3.2.2. Planting Methods. Significant differences were found between the four planting methods on the height of the

Table 5: Effect of planting dates and planting methods on plant height, grain yield, 1000-grain weight, no. of grain spike^{-1}, and spike length in the first and second growing seasons.

Treatments	Plant height (cm)		Grain yield (kg·ha^{-1})		1000-grain weight (g)		No. of grain spike^{-1}		Spike length (cm)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Main plots: planting dates (PD)										
Nov-20	76.35	91.03	6709.34	6502.13	46.12	38.59	44.69	50.75	8.65	10.98
Dec-20	63.96	74.98	5798.33	6241.33	38.2	31.82	42.59	48.38	8.39	11
F test	*	**	**	NS	**	**	**	NS	**	NS
LSD 5%	6.085	2.856	2.826	—	2.254	0.733	3.309	—	1.095	—
LSD 1%	—	6.589	6.519	—	5.201	1.69	7.634	—	2.525	—
Subplots: planting methods (PM)										
M_1	65.3	81.9	6984.43	6705.77	43.48	36.03	48.67	54.05	8.93	11.6
M_2	65.85	82.35	5991.25	6398.53	41.74	35.64	41.26	47.45	7.99	10.85
M_3	73.52	81.75	5901.94	5748.31	40.95	33.63	41.11	45.45	8.59	10.6
M_4	75.94	86	6141.3	6502.13	42.52	35.52	44.07	51.3	8.58	10.9
F test	*	**	**	**	**	NS	**	**	NS	*
LSD 5%	8.094	2.165	0.862	1.525	2.913	—	4.724	1.755	—	0.562
LSD 1%	—	3.035	1.208	2.139	4.084	—	6.623	2.46	—	—
Interaction										
PD × PM	NS	NS	**	NS	**	NS	NS	**	NS	NS

Note that *, **, and NS indicate $P < 0.05$, <0.01 and not significant, respectively.

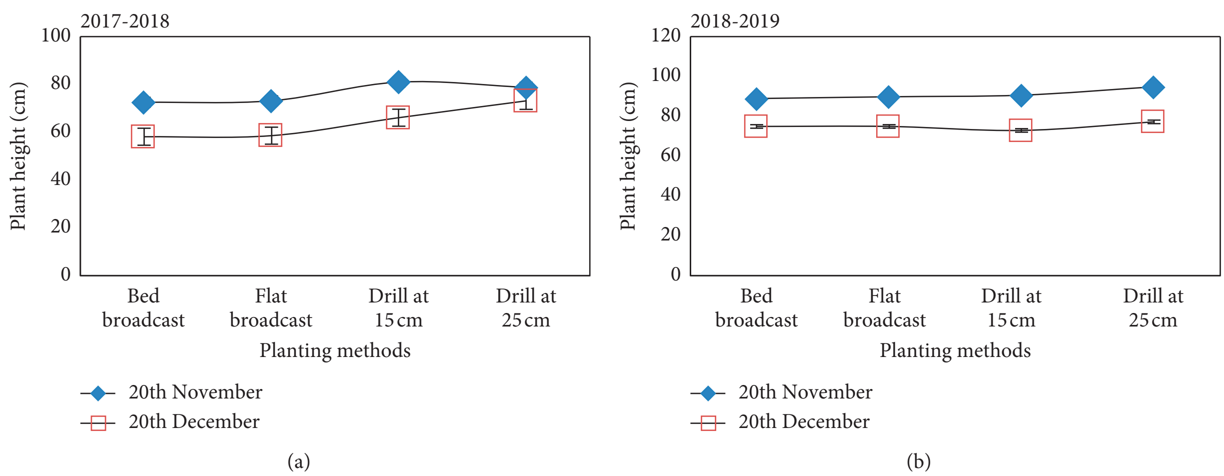

Figure 2: Plant height as affected by planting dates and planting methods during 2017-2018 and 2018-2019 seasons.

wheat plant; planting wheat with the drill at 25 cm apart rows gave the best values of plant height in comparison with the other planting methods (75.94 and 86.00 cm) in both seasons, respectively. Also, highly significant differences among the planting methods were found on the wheat grain yield for the two growing seasons; the bed broadcast (M_1) has the highest values of the grain yield (6984.43 kg·ha^{-1} in 2017/2018 and 6705.77 kg·ha^{-1} in the 2018/2019), which was 14.22%, 15.50%, and 12.07% higher than flat broadcast (M_2), drill at 15 cm apart rows (M_3), and drill at 25 cm apart rows (M_4) in 2017/2018 and 4.58%, 14.28%, and 3.04% for the previous methods for 2018/2019, respectively (Table 5).

The 1000-grain weight of flat broadcast was significantly higher than other methods in 2017/2018, while there was no significant difference between the four planting methods in the 2018/2019 growing season. As for the number of grains per spike, a high significant difference was observed in the two growing seasons, and the order from highest to the lowest values was the bed broadcast, drill at 25 cm apart rows, flat broadcast, and drill at 15 cm apart rows in both growing seasons. Concerning the spike length, there were significant and highly significant differences for the spike length among the four planting methods in the two growing seasons, respectively. The bed broadcast had the highest mean values for the spike length (8.93 and 11.60 cm) in the two growing seasons, respectively, while the lowest values were recorded with the drill at 15 cm apart rows in the two growing seasons, respectively (Table 5).

3.3. *Applied Irrigation Water (Aw).*

Applied water for wheat included irrigation water plus effective rainfall as shown in Figure 4. The results indicated that the highest values of

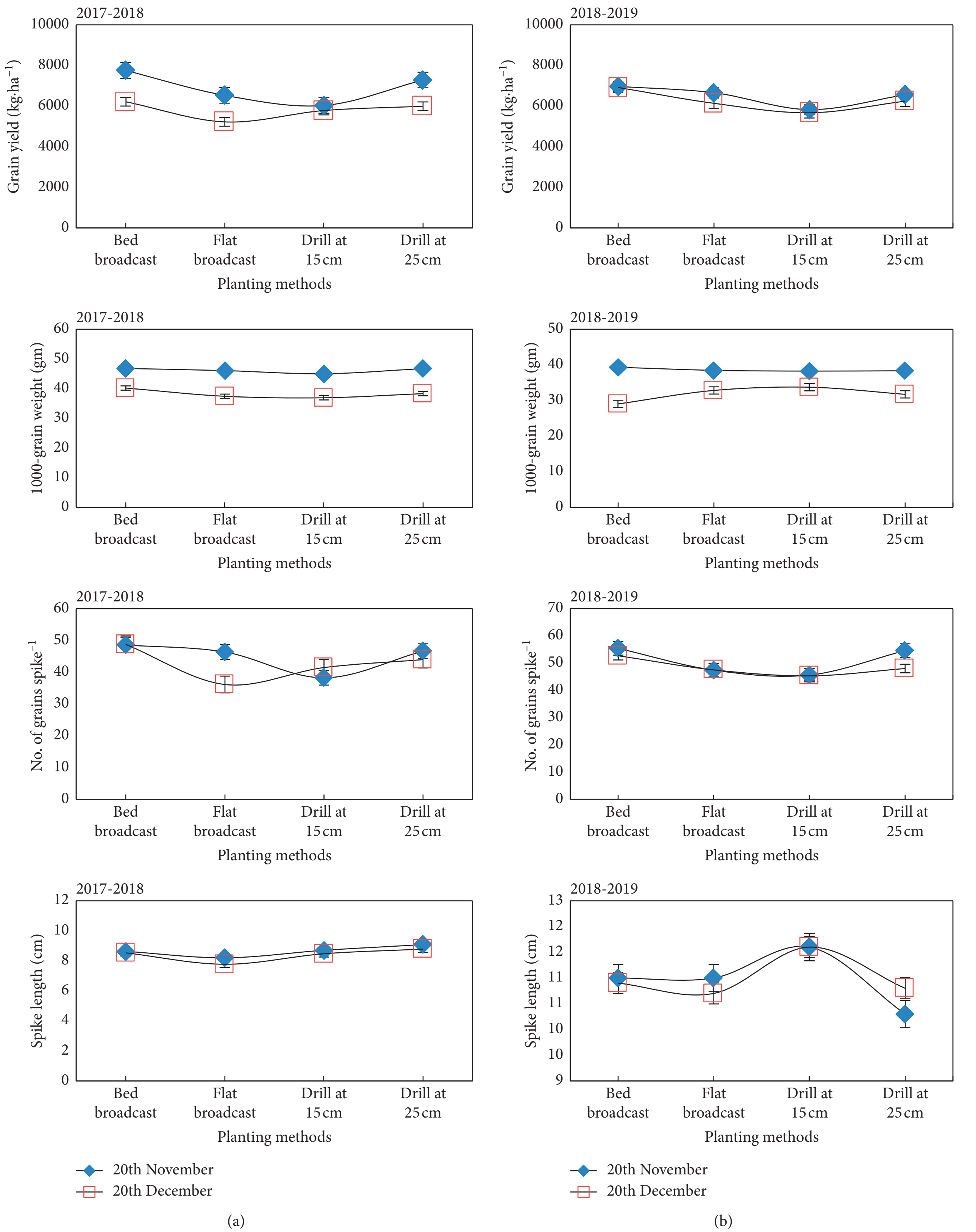

FIGURE 3: Wheat grain yield, 1000-grain weight, no. of grains per spike, and spike length as affected by planting dates and planting methods during 2017-2018 and 2018-2019 seasons.

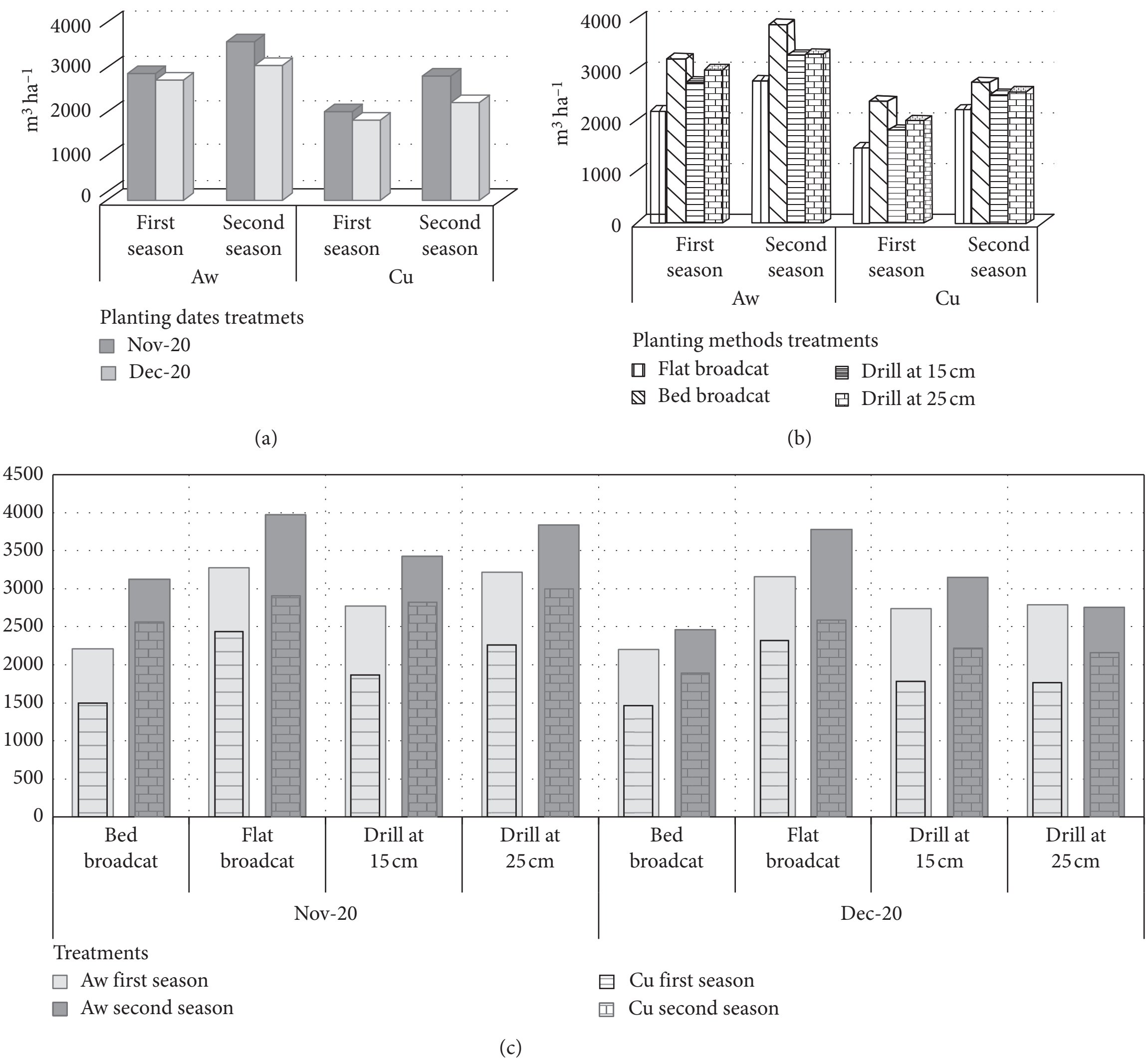

Figure 4: Applied water amounts and actual water consumptive use (m^3·ha^{-1}) as affected by (a) planting dates, (b) planting methods, and (c) the interaction between them in the two growing seasons.

water applied (3273.81 m^3·ha^{-1}, i.e., 32.74 cm and 3969.52 m^3·ha^{-1}, i.e., 39.70 cm) were recorded with the first date under the flat broadcast planting method (PD_1M_2) in the two growing seasons, respectively, while the lowest Aw was obtained from the bed broadcast planting method with the second date (PD_2M_1) (2202.38 m^3·ha^{-1}, i.e., 22.02 cm and 2460.00 m^3·ha^{-1}, i.e., 24.60 cm) in the two seasons, respectively.

Regarding the planting dates and the planting methods treatments, the data obtained showed that the mean values of applied irrigation water for the first date were higher than values obtained with the late date in the two growing seasons. The values of Aw for the planting methods can be arranged in the following descending order as $M_2 > M_4 > M_3 > M_1$. In other words, treatments M_4, M_3, and M_2 received 26.47, 19.92, and 31.37% higher than that applied to the bed broadcast planting method M_1.

3.4. Actual Water Consumptive Use (Cu). It is clear from Figure 4 that the actual water consumption in the first date (2017.9, 2822.5 m^3·ha^{-1}) is higher than that of the second date (1832.7, 2215.3 m^3·ha^{-1}) for the first and second seasons, respectively. On the other hand, the over means of the two seasons for planting methods treatments can be arranged in descending order as 2563.3 > 2296.1 > 2173.8 > 1855.3 m^3·ha^{-1} for M_2, M_4, M_3, and M_1, respectively.

Concerning the interaction between planting dates and planting methods, overall, the first date with all planting methods treatments under the study was better than that the others, and also, we can notice that the bed broadcast planting method gave good values of water consumptive use in the two planting dates in the study. On the other side, the first date and planting in beds gave the maximum value of Cu, and it is not far from the Cu value of the first date and planting with drilling at 25 cm apart rows, while the

Table 6: Effect of planting dates and planting methods treatments on the productivity of irrigation water (Paw, kg·m^3), water productivity (WP, kg·m^3), and efficiency of water consumptive use (Ecu, %) in the two growing seasons.

Planting dates	Planting methods	Paw (kg·m^{-3})			WP (kg·m^{-3})			Ecu (%)		
		1st season	2nd season	The average	1st season	2nd season	The average	1st season	2nd season	The average
Nov-20	M_1	3.62	2.31	2.97	5.34	2.81	4.08	67.89	82.13	75.01
	M_2	2.06	1.73	1.9	2.76	2.37	2.57	74.55	73.15	73.85
	M_3	2.25	1.76	2.01	3.33	2.13	2.73	67.38	82.31	74.85
	M_4	2.34	1.76	2.05	3.33	2.26	2.8	70.37	78.08	74.23
Dec-20	M_1	3.21	2.9	3.06	4.82	3.77	4.3	66.49	76.95	71.72
	M_2	1.71	1.68	1.7	2.32	2.45	2.39	73.58	68.45	71.02
	M_3	2.18	1.86	2.02	3.35	2.64	3	65.19	70.59	67.89
	M_4	2.22	2.34	2.28	3.51	2.99	3.25	63.25	78.24	70.75

minimum value of Cu was achieved with the late date in beds planting method.

3.5. Water Relations. Presented data tabulated in Table 6 clearly showed that, for the productivity of applied water (paw), the mean values of Paw for wheat for planting dates treatments are 2.23 and 2.27 kg·m^{-3}, for the first and the second date, respectively, and this indicates that Paw for the second date is better than the first date, and according to planting methods treatments, the highest value for Paw for planting methods treatments is 3.02 kg·m^{-3} which was recorded with M_1 (the bed broadcast planting method). The over mean values of Paw can be descended in order as 3.02 > 2.17 > 2.02 > 1.80 kg·m^{-3} under M_1, M_4, M_3, and $M_{2,}$ respectively.

Regarding water productivity WP, data show that WP took the same trend that achieved from the paw for planting dates treatments, which the mean values of WP for wheat under the second planting date 3.30 kg·m^{-3} were higher than the first date 3.04 kg·m^{-3}, and also for the planting methods treatments, where the highest mean values of WP (4.19 kg·m^{-3}) was recorded under treatment M_1 (bed broadcast), The mean values of WP can be descended in order as 4.19 > 3.03 > 2.87 > 2.48 kg·m^{-3} under M_1, M_4, $M_{3,}$ and $M_{2,}$ respectively.

Concerning efficiency of consumptive use (Ecu), the value of Ecu is the highest under the first planting date 74.49% in comparison with the second date 68.86%. In the point of view of planting methods, the same trend was obtained for Paw and WP where the highest mean value for Ecu was recorded under treatment M_1 of bed broadcast planting method, but the mean values of Ecu for planting methods treatments are different somewhat which can be descended in order as 73.37 > 72.49 > 72.44 > 71.37% for M_1, M_4, M_2, and M_3, respectively.

4. Discussion and Conclusions

According to the aims of our study, the results can conclude that delaying or postponing by the proper planting date for the wheat crop caused a reduction in wheat yield by 14%. This could be attributed to shortening the vegetative growth period, as well as weak vegetation, lack of spikes, and grain atrophy due to the expulsion of late spikes, which is counterbalanced by high temperature in the grain filling, and also makes the crop more susceptible to disease insects. These results are in harmony agreement with those obtained by [36–40], which reported that increasing mean temperatures during the growing season have been reported to reduce grain yields of irrigated wheat crops under field conditions and the authors also attributed this to a shortening of the growing season, less light interception, and fewer kernels per unit area. This is also in consensus with the study of Wieg and Cuellar [41], who reported that there was a 3.1-day shortening in the duration of grain filling for every 1°C increase in average daily air temperature above optimal temperature (15°C) during grain fullness. This decrease in the grain filling period was associated with a decrease in yield and weight of grain size. Also, Refay [42] pointed out that the delay in planting time was accompanied by significant losses of grain yield estimated at 7.98% compared with the early date. Baloch et al. [43] concluded that wheat cultivation on 25 October and 10 November produced the largest number of branches, plant height, the weight of 1000 grains, and grain yield and it decreased with the next planting dates. Delaying wheat sowing results in high temperature at anthesis and during grain filling stages, and this high temperature will reduce the final yield [41–45]. Also, Joshi et al. [46] reported heat stress as major abiotic stress due to delayed sowing affecting the wheat cultivation.

The grain yield was higher on the first date than the second date through the 2017/2018 season but they were approximately similar through the 2018/2019 season. This is may be attributed to rainfall distributions as measured by the size of SDEV which were higher than (±7.5) mm·d^{-1} in both seasons. The two years were close to each other in the amount of rainfall but very different in rainfall distribution. First year was with rainfall events occurring early and another in which they occur late. Rainfall distribution could be more important than rainfall amount, due to several reasons, such as inadequate water availability during critical growth stages and the ineffective storage capacity of soils during copious and infrequent rainfall events [47–51].

Limon-Ortega and Sayre [52] indicated that wheat grain yield was mostly determined by the amount of rainfall and distribution during the crop season. The work of Stephens and Lyons [51] showed that wheat yields in Australia are primarily a function of the amount of growing season rainfall; the relationship between rainfall and grain increased as the climate grows to be more water restrictive; despite this, the distribution of rainfall is furthermore important in the wetter areas.

With particular regard to the planting methods, from the study results, it can be concluded that the bed broadcast planting method gave the best values of grain yield and other yield attributes among the other studied planting methods. Better vertical distribution of photosynthetic active radiation in wheat canopies which cultivated on raised beds may be attributed to increasing wheat yield [53]. Weed germination is lower on drier bed surfaces than with the conventional flat layouts [54]. Decreasing mean values under drill at 15 cm apart rows in the study may have resulted from the small distance between plants in the unit area and increasing contribution on light for development spike stages [55–57].

Regarding the study aim of evaluating the water relations for wheat planting dates and planting methods, the study concludes that, among planting methods, bed planting methods saved amounts of irrigation water by 29.5% (1046.07 $m^3 \cdot ha^{-1}$, average irrigation applied water in both seasons) in comparison with flat planting method and consumed less water other than planting methods. These findings are in agreement with the results obtained by Aboelsoud et al. [58] who illustrated that the highest Aw values were obtained with the traditional flat planting method and the lowest Aw values were achieved with wheat planted with raised furrows, by Li et al. [53] who identified the advantage of bed technique from higher savings of irrigation water with less local machinery and labor costs, and by Fahong et al. [59] who showed that using furrow irrigation rather than flood irrigation could reduce irrigation by up to 30% and enhance water use efficiency.

Regarding the rate of water consumptive use, the value starts low at the beds planting method resulted in a decreasing number of canals irrigation and the lowest evaporation (E) due to the soil being almost bare and the vegetative cover. Therefore, the evapotranspiration (ET) value becomes the summation of the two components of $E + T$. Also, the bed planting method for wheat played a great role in water productivity, where beds planting method increases the yield of wheat about 1.22 kg, 1 kg, and 0.85 kg for 1 m^3 applied water to the field in comparison with flat broadcasting, drill at 15 cm apart rows, and drill at 25 cm apart rows, respectively. This may be because irrigation water moves faster to the crop root zone through undisturbed soil pores, whereas irrigation water takes longer time to move due to puddle formation in the subsurface layer in case of conventional tillage. These results agree with those obtained by Bian et al. [60], who reported that WUE was significantly higher (7.5%) in the wide-precision sowing system (width of sowing) than in the traditional-cultivation planting system, and Timlin et al. [61] clarify that water loss from evapotranspiration in the row position was significantly greater than that in the interrow position. Also, Wang et al. [62] showed that the furrow planting pattern significantly increased soil water content, 1000-grain weight, and grain yield of winter wheat relative to conventional and uniform row planting patterns. Bed planting significantly improved the yield of intercropped and improved the number of grains per spike and 1000-grain weight of wheat (19.2%) over conventional planting. Bed planting also reduced irrigation by 19–24% and hence improved water productivity by 30% [63]. Also, Limon-Ortega and Sayre [52] formulated that the use of bed planting systems has typically been associated with water management topics, which may be related to the borders of percolated water due to smaller areas exposed to the irrigation water and the cultivated area being irrigated in a shorter time. In light of the prediction of an increase in temperatures in the coming years as a result of climate change, the increase of air temperature represents a real risk on wheat production especially under the expected undesired changes in water and planting time and methods, plus the population increase and their demands. In addition, considering the ever-increasing competition among different water users, improving water use efficiency in agriculture is now a grave concern.

5. Recommendation

In the context analyzed in the paper, although the late date treatment received fewer amounts of irrigation water in comparison with the recommended date, the recommended date suppressed all values of studied parameters. On the other side, bed broadcast planting method also has the greatest values of the studied parameters and consumed the lower amounts of applied water compared to that of conventional flat method. Therefore, bed broadcast is more effectual when water is scarce. Finally, our results suggest that sowing wheat in the recommended date in bed broadcast should be used based on higher yields, irrigation water savings, increased water productivity, and higher profitability under the regions whose conditions are similar to the condition of the climate of Nile Delta, Egypt. As also shown, the method of planting wheat with the drill at 25 cm can be used (with the wide distance apart rows) for achieving higher productivity rather than traditional methods.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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