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Evaluation of Local Bread Wheat Cultivars for Grain Yield and Its Attributes at Different Sowing Dates under Assiut Conditions

Mohammed A. Sayed[(1)#], Mohamed T. Said[(1)], Mahmoud A. Elrawy[(2)]

[(1)]*Agronomy Department, Faculty of Agriculture, Assiut University, 71526 Assiut, Egypt;* [(2)]*Genetic Department, Faculty of Agriculture, Assiut University, 71526 Assiut, Egypt.*

THE CURRENT research aimed to evaluate and select bread wheat stable cultivars with high productivity across diverse sowing dates. Fourteen wheat cultivars were grown in a randomized complete block design with three replicates at six sowing dates during two successive seasons of 2018/2019 and 2019/2020 representing twelve environments. The cultivars were evaluated for grain yield and its attributes. Highly significant differences were obtained among the wheat cultivars, sowing dates, and their respective interaction for all measured traits. The highest grain yield (2.992-ton fed^{-1}) was recorded on 30th November, after this date, each day delay in sowing of wheat onward decreases grain yield at the rate of 21kg fed^{-1} day^{-1}. Overall, the cultivar Gemiza 11 gave the highest grain yield with an average of 2.861 ton fed^{-1}, recorded the highest 1000-GW with an average of 47.73 g, highest straw yield with an average of 8.303-ton Fed^{-1}, and was the earliest cultivar with a mean heading date of 92.9 days. According to GGE biplot results, Gemiza 11, Gemiza 9, and Sakha 94 ranked in the first order as high-yielding cultivars and had greater stability level overall sowing dates under. Assiut conditions. The most adequate cultivars for sowing in the first half of November (1st -15th) are Misr 2, Sids 12, Sakha 95, Gemiza 9, and Gemiza 11. Also, Sakha 94, Gemiza 9, and Gemiza 11 can be sown after 30th November because they produce a satisfied yield, have good stability, and can be considered as late sowing tolerant.

Keywords: GGE, Planting dates, Stability, Wheat (*Triticum aestivum* L.).

Introduction

Wheat (*Triticum* spp. L) is one of the earliest domesticated food crops and considers the basic staple food of the major civilizations of the world. Bread wheat (*Triticum asetivum* L) is the dominant wheat type produced in Egypt and the most major food grain source for Egyptians. Based on grain acreage, it leads all crops, including rice, maize and potatoes, and is ranked second when it comes to the total production volume. In the marketing year 2020/2021, global wheat production reached approximately 772 million tons (Shahbandeh, 2021). As of 2020, Egypt produced approximately 8.9 milion tons of wheat come from total area harvested 1.39 million hectares, and is one of the largest wheat importers in the world (USDA, 2020; Statista, 2021).

Egypt Vision 2030 takes into account the obstacles that the country's growth is facing. However, the rapid population growth led to the surge in wheat demand because of the increased gap between production and consumption. Therefore, increasing wheat production is a high demand to reduce this gap in food productivity and consumption. Climate change poses a serious threat to Egypt., since it affects food systems in several ways ranging from direct effects on crop production especially in temperatures leading to changes in the length of the growing season

#Corresponding author email: mohamed.sayed5@agr.au.edu.eg
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(Gregory et al., 2005). The climate change may bring about substantial reductions in the national grain production (El-Marsafawy et al., 2012).

Sowing time is one of the most critical considerations and agronomic factor involved in producing high yield of wheat. Sowing at the right time is very important for optimum production. A genotype is considered stable if it has high mean yield associated with low fluctuations under diverse environments. Early or late sowing increases the risk of grain yield losses (Ehdaie et al., 2001; Gul et al., 2012), due to extreme variations in temperatures during growth period from sowing to harvesting (Liaqat et al., 2018). Also, biomass accumulation, number of spikes m^{-2} and thousand grain weight of wheat were affected by early and late sowing dates than optimum time (Wajid et al., 2004; Gul et al., 2012), due to limited growth period in the season (Anapalli et al., 2005). Therefore, choosing the suitable wheat cultivar along with optimum sowing time for an area guarantees higher yield.

Plant breeders carry out multi-environment trials (MET) to evaluate improved genotypes or cultivars across diverse environments (such as locations, sowing dates, and over years). They do that before a specific genotype is recommended for commercial production especially under climate change (Abate et al., 2015). The genetic effect of a genotype is not independent of the environmental effects and varies from one environment to another. Therefore, understanding the GE interaction is important to improve the prediction of the genotype performance (Moragues et al., 2006; Akcura et al., 2009; Zahia et al., 2010). Various multivariate statistical methods have been developed to measure the response of genotypes under different environmental conditions. The analysis of GGE biplot method can visually check the relationship between the test environment, genotype, and GE interaction. It gives information about: (i) mega-environment analysis (e.g., "which, won and where" pattern), whereby specific genotypes can be recommended to specific mega-environments (ii) the mean performance and stability of the genotype, and (iii) environmental evaluation (Yan & Kang, 2003; Yan & Tinker, 2006; Ding et al., 2007). The present study aimed at determining the best suitable wheat cultivar (s) for the most appropriate sowing time (period) that maximizes the total grain yield under Assiut condition.

Materials and Methods

Plant material and description of the experimental site

The present study was carried out at the Experimental Farm of Assiut University during the two growing seasons 2018/2019 and 2019/2020 using fourteen local bread wheat cultivars (*Triticum aestivum* L.), i.e., Gemiza 11, Gemiza 12, Gemiza 9, Giza 168, Giza 171, Misr 1, Misr 2, Misr 3, Sakha 94, Sakha 95, Shandaweel 1, Sids 1, Sids 12 and Sids 14. All fourteen cultivars were sown in six cultivation dates *i.e.* 1st of November, 15th November, 1st December, 15th December, 1st January and 15th January (D1, D2, D3, D4, D5 and D6, respectively) for evaluation for grain yield and its attributes.

Table 1 shows the soil type and its mechanical and chemical properties, annual precipitation, and monthly average minimum and maximum temperature of Assiut site from October to May of seasons 2018/2019 and 2019/2020. The soil's mechanical and chemical analyses were carried out by the Agricultural Research Center Soil, Water & Environment Res. Institute, Unit of Analysis & Studies. Nitrogen, P and K used at 220, 75 and 120kg ha^{-1} based on the recommendation, from sources of urea (with 46% N), triple super phosphate (with 46% P_2O_5) and potassium sulfate (with 50% K_2O), respectively, were added to all treatments (plots). 120kg ha^{-1} seeding rate were used in each planting date.

Here, it should be noted that daily records of maximum and minimum temperatures were recorded from the meteorological station at the Farm of the Faculty of Agriculture in Assiut Univ. The monthly average temperature was calculated as reported in Table 1. Assiut lays out the middle of Egypt and represents a hot temperature-dry environment with clay loam soil and is classified as desert climate. Since the average annual temperature is 24.0°C and precipitation is about 1mm per year in Assiut (https://en.climate-data.org , March 2021).

Data collection, sampling and measurement

Observations on grain yield, and its attributes were taken from the middle rows per plot. Plant height (PH; cm) was measured as an average of five middle plants per cultivar in each plot. Number of spikes/m^2 (SN m^2) was counted on the middle-squared meter in each plot. Heading date (HD), straw yield ton/feddan (SY/F), Grain yield ton/feddan (GY/F) were measured on the whole field plot basis. Days to heading represents days required for heading of 50% plants in a plot from the date of sowing. The number of grains per spike (NG/S) was determined by selecting randomly five spikes. Thousand grain weight (TGW; g), 1000 grains from each entry was weight and recorded in grams. Harvest index was calculated from the ratio between grain and biological yields. All cultural practices were done according to standard recommendations for sowing wheat in Upper Egypt.

Experimental design and statistical analysis

The experiment was carried out using randomized complete block design with three replications in the two main cultivation seasons in the years of 2018/2019 and 2019/2020. Seeds were sown in six rows per entry which are 20 cm apart from each other, with plot size 2.5m ×1.2m= 3m^2 at the seed rate of 50kg feddan^{-1} for each replication.

Data were analyzed by Proc Mixed of SAS package version 9.2 (SAS, 2008). Separate analysis of variance using randomized complete block design (RCBD) with a split plot arrangement of treatments with three replicates. Sowing dates were assigned in main plots, while wheat cultivars were arranged in the sub plots, for each season. Bartlett's test was used to examine the variance homogeneity as reported by Snedecor & Cochran (1989), then combined analysis for data from the two growing seasons was also analyzed for each year as stated by Gomez & Gomez (1984). Means were compared by revised Least Significant Difference (RLSD) at 0.05 level of significant (Steel & Torrie, 1981). The genotype-genotype by environment (abbreviated as GGE) biplot approach (Yan & Tinker, 2006) was conducted to assess relationships among testing environments as well as among genotypes and environments. The GGE biplot method was carried out using Genstat software version 15 (Payne et al., 2013).

TABLE 1. Summary description of the experimental sites

Location	Assiut			
Latitude	27° 18' N	Longitude	32° 40' E	
Sea level	62m	Climate	Desert climate	
Season	**2018-2019**		**2019-2020**	
Mechanical analysis				
Sand	26.10		26.50	
Slit	24.50		24.10	
Clay	49.80		49.40	
Soil type	Clay loam		Clay loam	
Chemical analysis				
pH	7.75		7.79	
Organic matter %	1.72		1.70	
Total N%	0.08		0.07	
Total CaCO3%	1.17		1.20	
Rainfall (mm)	1mm		2mm	
Temperature*	**Maximum**	**Minimum**	**Maximum**	**Minimum**
October	32.3	18.2	33.3	19.6
November	26.2	12.9	28.5	14
December	20.5	8.3	21.1	8.4
January	19.0	6.1	18.1	6.0
February	21.4	7.9	23.4	7.7
March	24.4	10.0	25.6	11.5
April	29.6	14.1	29.8	15.2
May	37.4	22.4	35	19.7

* Monthly average minimum and maximum temperature of Assiut site from October to May of seasons 2018/2019 and 2019/2020.

Results and Discussion

Trait means and analysis of variance

Data in Table 2 show the analysis of variance and the main effect of the two successive seasons across sowing dates and wheat cultivars for all studied traits. ANOVA revealed no significant difference between the two seasons for all studied traits. The second season was higher in GY/F compared to the first one and this may be due to the increase in TGW, HI, G/S and NS/m^2. Data in Table 3 illustrate the main effect of the sowing dates on the studied traits across seasons and cultivars. The ANOVA revealed highly significant differences among the sowing dates for all studied traits. Highest grain yield (2.992-ton fed^{-1}) was recorded on 30th November sowing while late sowing on 30th December and 15th January (2,076-ton fed^{-1}) decreases the grain yield. After the 30th of November, each day of delay in sowing wheat reduces grain yield by 21kg fed^{-1} day^{-1}. Several authors have reported variations caused by sowing dates (Abate et al., 2015; Ahmed et al., 2020).

The D1 (1st November) gave the longest period to heading with an average of 104.8-day while D6 (15th January) recorded the shortest period to heading with an average of 77.4 day. Furthermore, tallest plant height was observed in D2 (15th November) with an average of 108.1cm whereas the shortest plant height was obtained by D6 with an average of 90.9cm. Highest number of spikes m^{-2} was recorded in D2 with an average of 506.4 while D6 gave the lowest number of spikes m^{-2} with an average of 295.2 spike. In addition, highest number of grains per spike was recorded by D5 with an average of 70.4 while the lowest number was obtained by D3 with an average of 59.4. For straw yield, the D1 gave the maximum straw yield with an average of 8.667ton fed^{-1} while D6 gave the lowest straw yield with an average of 6.212 ton fed^{-1}. Highest harvest index was obtained by D3 which recorded 37.18% while D1 gave the lowest harvest index and registered 32.15%. D3 gave the heaviest 1000-GW and recorded 45.82 g while D6 recorded the lowest TGW with an average of 36.81 g. These findings indicated that sowing in the second half of November (15-30th) may be considered as the optimum time for obtaining high production of grains. Similar observations were reported by several authors (Ali et al., 2010; Abate et al., 2015).

TABLE 2. Main effect of seasons 2018/2019 and 2019/2020 on the studied traits overall sowing dates and wheat cultivars

Seasons	HD	PH (cm)	SN m^2	NG/S	SY/F (ton)	HI (%)	TGW (g)	GY/F (ton)
2018/2019	96.0	101.9	361.8	62.0	7.406	34.86	40.78	2.555
2019/2020	95.0	101.5	371.9	61.9	7.366	34.99	43.00	2.586
F test	NS	NS	NS	NS	NS	NS	NS	NS

Ns= Non-significant. HD: Heading date, (PH; cm): Plant height, SN: Number of spikes/m^2, NG/S: Number of grains per spike, SY/F: Straw yield ton/feddan, GY/F: Grain yield ton/feddan, TGW(g): 1000-grain weight.

TABLE 3. Main effects of the six sowing dates on the studied traits over seasons and wheat cultivars

Sowing dates	HD	PH (cm)	SN (m^2)	NG/S	SY/F (ton)	HI (%)	TGW (g)	GY/F (ton)
D1	104.8	105.0	313.2	60.4	8.667	32.15	41.44	2.691
D2	102.9	108.1	506.4	58.6	7.559	36.26	43.33	2.783
D3	101.0	106.9	385.8	59.4	7.682	37.18	45.82	2.992
D4	97.8	99.6	438.0	59.8	7.254	35.32	44.20	2.505
D5	89.2	99.7	262.2	70.4	6.942	34.92	39.74	2.376
D6	77.4	90.9	295.2	63.1	6.212	33.72	36.81	2.076
F test	**	**	**	**	**	**	**	**
LSD REV.	0.87	0.49	36.45	4.04	0.45	0.85	0.18	2.18

** highly significant at 0,01 probability level. D1, D2, D3, D4, D5 and D6: The six cultivation dates, i.e. 1st of November, 15th November, 1st December, 15th December, 1st January and 15th January, respectively.

Data in Table 4 show the analysis of variance and the main effect of the tested cultivars for all studied traits across sowing dates and seasons. Highly significant differences were obtained among the wheat cultivars for all measured traits. This result indicates the presence of a remarkable degree of genetic variation that may contribute the most to adaptation and flexibility to diverse environmental conditions. Gomaa et al. (2018) reported that such significant main effects of the genotypes and their inteactions with environments like sowing dates and growing seasons) indicate) that these genotypes carry genes with different additives and additives by additives effects which seemed unstable and tended to rank differently from the environment to another. Overall seasons and sowing dates, the cultivar Gemiza 11 gave the highest grain yield with an average of 2.861 ton fed^{-1}, recorded highest 1000-GW with an average of 47.73g, highest straw yield with an average of 8.303-ton fed^{-1} and was the earlist cultivar with mean heading date of 92.9 day. The cultivar Giza 168 gave the lowest grain yield which recorded 2.111-ton fed^{-1} coupled with lowest 1000-GW with an average of 36.75g. It also, gave the lowest straw yield with an average of 6.430ton fed.-1, had smallest number of grains/ spike with an average of 56.9 grain, and was the shortest cultivar with plant height of 93.7 cm. In addition, the cultivar Sids 14 had a long period to heading with an average of 101 day and was the tallest cultivar with plant height of 106.3cm. Similar results were reported by Ali (2017), Gomaa et al. (2018).

Table 5 shows the interaction effects of sowing dates and growing seasons on the studied traits across all cultivars. The ANOVA revealed non-significant effects of sowing dates and growing seasons interaction on all studied traits except plant height. Sowing after 30th November led to decrease most of the studied traits in both seasons. Sasani et al. (2020) indicated that negative effects of late planting on crop performance through poor germination, which causes reduction in growth of individual plants and reduces tiller production under low temperatures when compared to early planting.

TABLE 4. Main effects of the tested wheat cultivars for all studied traits across seasons and sowing dates

Cultivar	HD	PH (cm)	SN m^2	NG/S	SY/F (ton)	HI (%)	TGW (g)	GY/F (ton)
Gemiza 11	92.9	98.4	367.7	60.3	8.303	35.03	47.73	2.861
Gemiza 12	94.2	98.9	333.4	61.2	7.387	33.00	39.23	2.359
Gemiza 9	96.0	105.5	416.8	60.4	7.601	35.39	40.78	2.725
Giza 168	93.2	93.7	385.5	56.9	6.430	33.30	36.75	2.111
Giza 171	96.8	102.5	354.1	58.8	7.162	35.07	42.77	2.439
Misr 1	95.7	101.4	419.8	58.8	7.258	35.77	44.73	2.677
Misr 2	94.9	104.8	359.2	69.5	7.809	36.25	40.51	2.814
Misr 3	95.9	103.0	366.9	63.6	7.395	36.05	43.37	2.735
Sakha 94	94.2	103.0	402.5	66.6	7.385	36.46	40.58	2.715
Sakha 95	96.6	104.4	369.8	64.9	7.332	35.60	42.96	2.627
Shandaweel 1	94.4	95.7	326.9	58.7	6.722	33.41	41.15	2.264
Sids 1	96.6	105.5	312.1	64.4	7.716	35.38	42.27	2.580
Sids 12	94.8	100.9	372.4	65.8	7.749	34.73	41.03	2.734
Sids 14	101.0	106.3	348.4	57.6	7.157	33.52	42.59	2.345
F test	**	**	**	**	**	**	**	**
LSD REV.	0.36	0.85	37.81	3.48	0.45	1.19	0.15	1.52

** highly significant at 0,01 probability level.

TABLE 5. The interaction effects between seasons and sowing dates for all studied traits across wheat cultivars

Seasons	Sowing dates	HD	PH (cm)	SN m²	NG/S	SY/F (ton)	HI (%)	TGW (g)	GY/F (ton)
2018/2019	D1	105.0	104.1	307.8	59.8	8.826	32.14	42.28	2.700
	D2	103.4	106.3	494.8	58.8	7.731	36.02	42.95	2.766
	D3	101.3	107.2	387.7	59.4	7.648	37.29	44.25	2.988
	D4	97.9	100.5	427.6	60.1	7.166	35.30	42.97	2.447
	D5	90.0	100.7	256.9	70.5	6.979	34.49	37.32	2.368
	D6	78.6	92.7	295.7	63.4	6.086	33.91	34.93	2.060
2019/2020	D1	104.6	105.8	318.6	61.0	8.509	32.17	40.61	2.682
	D2	102.4	110.0	518.1	58.4	7.387	36.50	43.71	2.800
	D3	100.6	106.6	383.9	59.3	7.716	37.07	47.39	2.996
	D4	97.7	98.8	448.4	59.5	7.342	35.35	45.43	2.563
	D5	88.5	98.8	267.5	70.4	6.906	35.34	42.16	2.385
	D6	76.3	89.2	294.7	62.9	6.338	33.53	38.69	2.091
F test		NS	**	NS	NS	NS	NS	NS	NS
LSD REV.		-	0.69	-	-	-	-	-	-

** highly significant at 0,01 probability level, Ns= Non-significant.

The interaction between wheat cultivars and sowing dates had a highly significant effect on all studied traits in both seasons (Table 6). The cultivar Misr 1 gave the highest values of grain yield, harvest index and number of grains per spike in the first season. While in the second season, the cultivar Gemiza 11 recorded the highest values of the traits grain yield, straw yield and 1000-GW. Gemiza 11 was the earliest cultivar in both seasons, while Sids 14 was the latest one in both seasons. The cultivar Gemiza 9 had the highest number of spikes m^{-2} in the first season, whereas Misr 1 gave the highest number of spikes in the second season. The results are similar to those reported by Ali et al. (2010), Gomaa et al. (2018).

Table 7 shows the interaction effects between the sowing dates and the wheat cultivars across years on all studied traits. Figure 1 shows the mean values of grain yield for the investigated cultivars in each sowing date. The ANOVA revealed highly significant effects of this interaction on all studied traits. It could be observed that Gemiza 9 was the highest cultivar in grain yield on the first sowing date (D1) and recorded 3.354 to fed^{-1} followed by Gemiza 11 (3.076-ton fed^{-1}).

While the lowest one was Shandaweel 1 which gave 2.102-ton fed^{-1}. In D2, Misr 2 gave the highest grain yield and recorded 3.758-ton fed^{-1} followed by Sids 12, whereas the lowest cultivar was Misr 3 which gave 2.195 ton fed^{-1}. In D3, Gemiza 11 produced the highest grain yield and registered 3.431-ton fed^{-1} followed by Sakha 94 which gave 3.431-ton fed^{-1}, while Giza 171 was the lowest one in grain yield and gave 2.330-ton fed^{-1}. In D4, Misr 3 was the best cultivar which gave 3.338-ton fed^{-1} followed by Sids 1 which gave 2.825-ton fed^{-1}, while the lowest one was Giza 168 which recorded 1.448-ton fed^{-1}. In D5, Sakha 94 gave the highest grain yield (2.679-ton fed^{-1}), while Shandaweel 1 was the worst one. In D6, Misr 3 had the highest grain yield which gave 2.588-ton fed^{-1}, while the lowest one was Gemiza 12 which gave 1.590-ton fed^{-1}. Similar results were reported by Gomaa et al. (2018).

Table 8 shows the interaction effects between seasons, sowing dates and cultivars on all studied traits. This interaction had non-significant effect on all studied traits except plant height which was highly significant. The cultivars varied in response to the diverse sowing dates in both seasons. The D1, D2 and D3 registered increase in grain yield and its attributes compared to D4, D5 and D6. This increase especially in D3, may be due to a prolonged vegetative growth stage resulting in more tillers formation, leaf numbers and leaf area, which resulted in more photosynthetic production and consequently increased yield attributes (number of spikes m^{-2}, number of grains $spike^{-1}$, 1000-grain weight) and in turn increased grain yield. Therefore, delaying sowing suppressed the yield caused by reduction in the yield contributing traits; number of productive tillers, grains $spile^{-1}$ and grain yield. These findings are in accordance with those obtained by El-Nakhlawy et al. (2015), Mumtaz et al. (2015), El Sayed et al. (2018), Ahmed et al. (2020).

TABLE 6. The interaction effects between seasons and wheat cultivars for all studied traits across sowing dates

Seasons	Cultivar	HD	PH (cm)	SN m²	NG/S	SY/F (ton)	HI (%)	TGW (g)	GY/F (ton)
2018/2019	Gemiza 11	93.4	96.9	350.7	61.2	8.370	35.04	46.58	2.848
	Gemiza 12	94.8	99.1	339.6	60.7	7.483	32.35	38.45	2.315
	Gemiza 9	96.7	106.6	429.4	60.7	7.498	35.54	39.66	2.773
	Giza 168	93.6	96.7	374.2	56.9	6.636	33.57	36.70	2.129
	Giza 171	97.1	102.6	351.8	58.1	7.307	35.62	41.75	2.439
	Misr 1	96.1	101.9	416.7	60.7	7.394	35.39	43.60	2.728
	Misr 2	95.7	106.7	376.9	68.9	7.748	36.32	39.62	2.871
	Misr 3	96.5	98.4	364.4	64.2	7.436	35.61	41.75	2.685
	Sakha 94	94.6	101.9	404.6	67.1	7.115	36.05	39.20	2.669
	Sakha 95	97.1	107.6	338.8	63.4	7.253	35.17	40.81	2.495
	Shandaweel 1	94.9	96.4	326.6	59.8	6.617	33.47	40.34	2.269
	Sids 1	97.2	105.6	294.3	64.3	7.810	35.75	42.19	2.558
	Sids 12	95.2	99.8	352.7	64.9	7.851	34.32	39.50	2.657
	Sids 14	101.5	106.6	343.8	57.1	7.165	33.81	40.81	2.327
2019/2020	Gemiza 11	92.4	100.0	384.7	59.3	8.236	35.02	48.89	2.873
	Gemiza 12	93.7	98.8	327.3	61.7	7.291	33.64	40.00	2.403
	Gemiza 9	95.3	104.5	404.2	60.2	7.704	35.23	41.90	2.676
	Giza 168	92.8	90.7	396.9	56.9	6.224	33.03	36.81	2.092
	Giza 171	96.4	102.5	356.3	59.5	7.017	34.51	43.80	2.440
	Misr 1	95.3	100.9	422.8	56.9	7.122	36.15	45.86	2.626
	Misr 2	94.2	102.9	341.5	70.1	7.869	36.19	41.40	2.757
	Misr 3	95.3	107.5	369.3	62.9	7.354	36.49	44.99	2.785
	Sakha 94	93.7	104.0	400.3	66.1	7.655	36.87	41.97	2.760
	Sakha 95	96.2	101.1	400.7	66.4	7.410	36.04	45.11	2.760
	Shandaweel 1	93.9	95.0	327.3	57.6	6.828	33.35	41.96	2.258
	Sids 1	96.1	105.5	329.9	64.6	7.623	35.00	42.36	2.602
	Sids 12	94.3	102.0	392.1	66.7	7.646	35.13	42.55	2.810
	Sids 14	100.6	105.9	353.0	58.1	7.150	33.23	44.38	2.363
F test		NS	**	NS	NS	NS	NS	NS	NS
LSD REV.		-	1.21	-	-	-	-	-	-

** highly significant at 0,01 probability level.

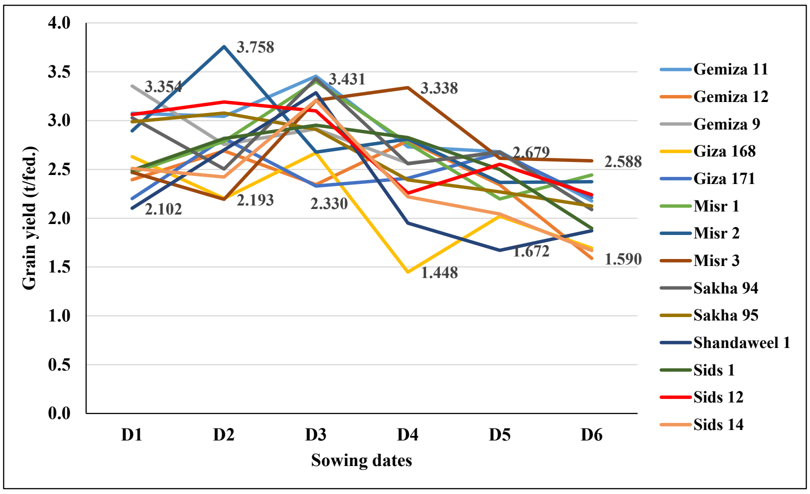

Fig. 1. Average of grain yield (ton/fed) for all testetd wheat cultivars in each sowing date acros growing seasons

TABLE 7 The interaction effects between sowing dates and wheat cultivars for all studied traits across seasons

Sowing dates	Cultivar	HD	PH (cm)	SN m²	NG/S	SY/F (ton)	HI (%)	TGW (g)	GY/F (ton)
D1	Gemiza 11	104.8	100.0	315.8	60.2	12.173	28.09	50.53	3.076
	Gemiza 12	104.2	109.8	245.2	61.3	9.719	25.63	38.76	2.395
	Gemiza 9	107.7	108.7	488.7	55.0	9.248	34.57	42.63	3.354
	Giza 168	104.0	97.6	391.7	46.5	7.973	34.84	36.74	2.630
	Giza 171	102.5	101.9	238.0	51.0	7.374	30.13	41.76	2.200
	Misr 1	102.5	106.5	284.8	51.5	7.889	32.21	47.40	2.466
	Misr 2	104.8	107.5	322.3	72.8	8.504	35.61	39.44	2.895
	Misr 3	103.0	106.4	231.8	59.3	8.223	32.72	41.39	2.471
	Sakha 94	104.7	105.3	330.5	77.2	8.734	34.83	38.91	3.029
	Sakha 95	105.0	112.6	359.3	71.0	7.898	35.42	42.41	2.989
	Shandaweel 1	104.2	101.3	242.0	45.0	7.391	29.25	42.21	2.102
	Sids 1	106.7	106.5	208.7	66.0	8.425	32.19	37.45	2.492
	Sids 12	103.8	98.9	433.0	68.7	7.976	36.22	39.29	3.063
	Sids 14	108.8	106.8	293.2	60.2	9.817	28.40	41.29	2.510
D2	Gemiza 11	102.7	103.2	503.8	68.5	7.739	37.35	44.24	3.044
	Gemiza 12	102.0	107.1	494.8	47.5	7.327	33.87	33.97	2.690
	Gemiza 9	105.8	116.7	509.5	58.8	7.660	37.11	41.13	2.756
	Giza 168	100.0	94.6	567.5	54.8	6.546	33.67	40.21	2.202
	Giza 171	102.0	110.2	545.0	61.0	7.116	38.70	45.90	2.819
	Misr 1	102.0	111.2	573.5	58.5	7.168	35.87	40.99	2.787
	Misr 2	103.8	117.4	559.8	76.5	8.758	38.40	45.53	3.758
	Misr 3	100.8	101.3	451.2	46.3	6.593	34.10	47.19	2.193
	Sakha 94	104.0	108.3	454.5	53.5	6.919	35.97	46.31	2.505
	Sakha 95	103.8	114.2	522.3	63.3	8.033	36.87	44.06	3.077
	Shandaweel 1	102.3	99.5	490.0	58.3	7.726	35.76	41.27	2.700
	Sids 1	103.7	112.8	471.0	56.8	7.773	39.47	49.14	2.816
	Sids 12	100.7	102.2	563.5	61.3	9.296	33.29	42.62	3.190
	Sids 14	106.7	115.2	383.7	54.7	7.176	37.19	44.06	2.422
D3	Gemiza 11	96.0	105.1	395.5	58.8	8.365	38.08	57.84	3.455
	Gemiza 12	99.7	98.5	262.2	55.0	7.442	33.07	42.27	2.343
	Gemiza 9	105.0	109.8	400.2	54.3	7.948	35.79	42.16	2.915
	Giza 168	97.5	96.0	327.8	45.7	7.644	37.32	47.61	2.669
	Giza 171	100.8	109.6	344.0	51.5	6.847	34.91	43.63	2.330
	Misr 1	101.5	106.7	557.8	52.0	7.531	38.97	48.43	3.401
	Misr 2	102.0	103.5	263.2	50.2	7.623	35.80	43.51	2.677
	Misr 3	100.0	112.6	416.8	70.7	6.987	38.86	45.08	3.207
	Sakha 94	102.0	107.5	392.8	76.3	8.254	38.19	42.59	3.431
	Sakha 95	102.8	108.7	412.3	60.3	7.794	36.69	47.82	2.911
	Shandaweel 1	99.0	101.8	477.7	66.3	8.199	38.30	40.00	3.285
	Sids 1	102.7	114.4	328.0	62.8	8.276	37.48	43.28	2.953
	Sids 12	99.5	105.8	399.0	66.8	7.188	38.46	45.55	3.100
	Sids 14	105.2	116.6	423.7	60.2	7.456	38.60	51.67	3.206

TABLE 7. Cont.

Sowing dates	Cultivar	HD	PH (cm)	SN m²	NG/S	SY/F (ton)	HI (%)	TGW (g)	GY/F (ton)
D4	Gemiza 11	94.0	99.8	406.8	56.7	7.638	38.00	48.11	2.732
	Gemiza 12	96.2	94.7	569.5	59.3	7.751	37.75	46.79	2.794
	Gemiza 9	97.0	103.5	501.3	55.8	7.282	35.80	45.44	2.564
	Giza 168	95.0	91.7	453.8	59.3	5.259	27.45	34.12	1.448
	Giza 171	99.5	98.8	458.5	60.3	7.179	36.06	39.58	2.408
	Misr 1	98.8	96.2	459.8	56.8	7.480	38.30	48.32	2.768
	Misr 2	98.7	98.9	497.0	61.0	7.611	37.47	45.81	2.812
	Misr 3	98.0	99.6	464.2	73.2	7.942	38.30	45.99	3.338
	Sakha 94	96.2	104.3	367.5	59.7	7.351	39.05	42.74	2.557
	Sakha 95	99.2	102.1	409.5	58.0	7.187	34.97	41.02	2.393
	Shandaweel 1	97.8	91.1	267.8	64.8	6.175	31.68	50.44	1.950
	Sids 1	99.2	111.9	419.5	62.3	8.448	34.00	44.72	2.825
	Sids 12	97.8	97.6	349.0	54.0	7.637	31.29	46.72	2.257
	Sids 14	102.0	104.6	507.7	56.5	6.619	34.36	38.99	2.220
D5	Gemiza 11	86.0	96.1	311.8	61.5	7.781	34.54	46.66	2.682
	Gemiza 12	87.3	99.4	226.2	69.2	7.212	34.03	36.32	2.342
	Gemiza 9	87.2	102.0	355.0	70.8	7.037	36.48	38.60	2.666
	Giza 168	87.5	93.7	231.8	83.2	6.088	33.12	28.13	2.021
	Giza 171	91.3	99.1	260.0	69.8	7.610	37.45	45.74	2.666
	Misr 1	90.2	96.9	235.2	72.2	6.601	33.30	42.76	2.198
	Misr 2	87.0	106.0	227.2	80.8	7.300	34.86	36.32	2.367
	Misr 3	91.2	103.0	331.7	62.7	7.431	34.97	42.10	2.613
	Sakha 94	85.5	101.5	419.5	73.5	6.684	37.03	38.12	2.679
	Sakha 95	90.5	100.1	194.5	83.0	6.807	35.77	43.22	2.270
	Shandaweel 1	88.5	91.4	213.0	62.3	5.107	32.65	34.73	1.672
	Sids 1	90.7	100.5	230.2	61.8	7.711	35.73	43.81	2.499
	Sids 12	89.2	102.3	217.7	74.2	7.668	35.80	35.83	2.553
	Sids 14	97.2	103.9	217.7	61.2	6.157	33.11	44.02	2.043
D6	Gemiza 11	73.8	86.3	272.2	55.8	6.123	34.10	39.02	2.176
	Gemiza 12	76.0	84.1	202.8	74.7	4.874	33.63	37.24	1.590
	Gemiza 9	73.2	92.3	246.2	67.7	6.431	32.57	34.72	2.094
	Giza 168	75.0	88.7	340.5	52.0	5.073	33.40	33.71	1.693
	Giza 171	84.3	95.3	279.0	59.2	6.844	33.13	40.04	2.212
	Misr 1	79.2	91.1	407.3	61.8	6.880	35.96	40.49	2.443
	Misr 2	73.3	95.5	285.8	75.7	7.058	35.38	32.47	2.375
	Misr 3	82.5	94.8	305.5	69.3	7.195	37.35	38.49	2.588
	Sakha 94	72.7	90.9	450.0	59.3	6.369	33.68	34.82	2.087
	Sakha 95	78.5	88.4	320.5	53.7	6.272	33.90	39.25	2.125
	Shandaweel 1	74.7	89.3	271.2	55.5	5.737	32.84	38.24	1.873
	Sids 1	77.0	87.2	215.3	76.7	5.666	33.39	35.22	1.896
	Sids 12	77.5	98.7	272.2	69.8	6.727	33.29	36.14	2.239
	Sids 14	86.3	90.5	264.5	52.8	5.718	29.46	35.53	1.668
F test		**	**	**	**	**	**	**	**
LSD REV.		0.89	2.15	95.19	8.78	1.24	3.06	4.01	0.4

TABLE 8. The interaction effects between seasons, sowing dates and wheat cultivars for all studied traits across

Seasons	Sowing dates	Cultivar	HD	PH (cm)	SN m^2	NG/S	SY/F (ton)	HI (%)	TGW (g)	GY/F (ton)
2018/2019	D1	Gemiza 11	105.3	93.3	277.0	58.7	12.076	27.76	49.05	2.919
		Gemiza 12	104.7	116.0	270.3	58.7	9.588	24.46	39.18	2.318
		Gemiza 9	107.7	104.0	542.7	53.3	8.905	35.00	43.26	3.424
		Giza 168	104.3	103.3	344.0	46.3	8.793	36.87	40.17	2.780
		Giza 171	102.7	96.7	233.0	50.0	7.948	30.04	44.48	2.354
		Misr 1	102.7	105.7	235.3	50.0	8.019	30.83	46.28	2.336
		Misr 2	105.3	104.0	383.0	74.0	8.157	37.03	42.09	3.133
		Misr 3	103.3	104.0	226.0	61.0	8.961	31.83	41.62	2.558
		Sakha 94	104.7	107.0	357.7	80.7	8.907	35.03	38.87	3.161
		Sakha 95	104.7	116.7	299.3	66.0	7.821	34.41	40.58	2.690
		Shandaweel 1	104.3	101.0	226.3	45.0	7.355	28.17	42.70	2.072
		Sids 1	105.7	101.7	231.3	64.3	8.617	33.35	39.95	2.572
		Sids 12	105.0	101.7	319.3	67.3	7.775	36.20	40.30	2.790
		Sids 14	109.0	103.0	363.7	61.7	10.641	28.90	43.40	2.688
	D2	Gemiza 11	103.3	99.3	510.0	68.0	8.029	36.63	47.02	3.229
		Gemiza 12	102.7	113.7	529.7	48.0	7.978	33.36	36.83	2.826
		Gemiza 9	106.3	112.3	524.7	61.7	8.087	37.51	40.76	2.855
		Giza 168	100.3	101.0	548.0	56.0	6.855	33.30	40.70	2.283
		Giza 171	102.3	111.0	481.3	59.0	7.796	38.41	44.00	2.604
		Misr 1	102.3	115.0	569.0	63.3	7.561	35.95	42.77	2.998
		Misr 2	104.3	116.0	593.3	70.0	8.590	38.06	44.87	3.664
		Misr 3	101.3	79.7	454.3	48.0	6.760	34.57	45.86	2.224
		Sakha 94	104.7	103.7	461.7	57.0	6.823	35.78	44.83	2.601
		Sakha 95	104.3	114.0	486.0	60.7	8.059	36.94	42.35	2.834
		Shandaweel 1	102.3	95.3	457.3	59.0	7.490	34.29	41.06	2.443
		Sids 1	104.7	115.0	453.7	56.7	7.764	40.76	48.58	2.775
		Sids 12	101.0	98.3	522.0	61.0	10.005	32.27	40.95	3.144
		Sids 14	107.3	114.0	336.0	54.7	6.437	36.43	40.73	2.238
	D3	Gemiza 11	96.3	104.0	361.7	58.7	7.837	38.25	53.84	3.162
		Gemiza 12	100.0	95.0	278.3	55.0	7.138	30.57	39.52	2.185
		Gemiza 9	105.3	111.3	405.3	55.0	7.805	37.45	41.62	3.078
		Giza 168	97.7	98.7	292.7	45.3	8.048	38.30	44.46	2.680
		Giza 171	101.0	115.0	364.7	51.0	6.852	35.64	43.37	2.324
		Misr 1	101.3	106.7	560.7	51.3	8.042	38.98	46.91	3.574
		Misr 2	102.3	101.3	286.3	55.3	8.011	36.63	40.93	2.945
		Misr 3	100.3	113.3	416.3	70.7	6.928	38.32	43.95	3.130
		Sakha 94	102.3	104.0	440.7	73.7	7.559	38.30	42.14	3.350
		Sakha 95	103.3	112.3	386.0	62.0	7.937	35.97	45.46	2.851
		Shandaweel 1	99.3	101.0	505.3	65.7	8.037	38.30	40.54	3.509
		Sids 1	104.3	108.3	326.7	63.7	8.262	38.42	44.03	3.039
		Sids 12	99.3	108.0	370.3	67.0	7.300	38.63	43.63	3.011
		Sids 14	105.7	121.7	432.3	57.7	7.319	38.30	49.06	2.992

TABLE 8. Cont.

Seasons	Sowing dates	Cultivar	HD	PH (cm)	SN m²	NG/S	SY/F (ton)	HI (%)	TGW (g)	GY/F (ton)
	D4	Gemiza 11	94.3	99.0	427.0	59.7	7.724	39.10	48.54	2.929
		Gemiza 12	96.3	94.0	524.7	57.7	7.859	38.00	44.74	2.594
		Gemiza 9	97.7	103.3	502.3	58.0	6.743	34.97	42.73	2.523
		Giza 168	94.7	96.0	505.7	58.0	5.130	26.62	34.81	1.380
		Giza 171	99.3	94.3	444.3	60.0	7.277	36.55	39.93	2.417
		Misr 1	99.0	93.3	451.3	57.7	7.434	38.30	47.27	2.753
		Misr 2	99.3	104.0	484.3	63.3	7.589	36.63	43.82	2.805
		Misr 3	98.0	98.3	423.3	70.7	7.352	38.30	43.25	3.003
		Sakha 94	96.3	105.3	370.7	59.3	6.958	39.13	41.80	2.490
		Sakha 95	99.3	107.7	369.0	59.0	7.019	34.97	39.24	2.337
		Shandaweel 1	98.3	90.3	280.3	67.0	5.850	32.95	49.46	1.919
		Sids 1	98.7	119.0	319.0	59.7	8.956	32.65	43.49	2.607
		Sids 12	97.3	99.7	417.7	54.0	7.733	30.54	43.76	2.236
		Sids 14	101.7	103.0	467.3	58.0	6.700	35.43	38.71	2.263
2018/2019	D5	Gemiza 11	86.3	96.7	225.3	61.3	8.303	33.51	43.24	2.491
		Gemiza 12	88.0	95.7	224.0	70.3	7.349	32.75	33.98	2.306
		Gemiza 9	88.0	105.3	346.0	72.7	7.155	35.89	37.27	2.721
		Giza 168	88.0	92.0	229.7	81.7	5.936	33.47	27.56	1.992
		Giza 171	92.0	100.0	289.0	69.0	7.337	39.48	42.54	2.806
		Misr 1	91.0	97.7	245.3	76.7	6.840	33.30	40.48	2.278
		Misr 2	88.0	112.3	239.3	76.3	7.290	33.29	34.54	2.312
		Misr 3	92.3	100.0	374.0	67.3	7.356	34.97	39.53	2.727
		Sakha 94	86.0	101.7	353.3	74.0	6.284	35.20	32.91	2.393
		Sakha 95	91.3	102.7	190.7	78.3	6.615	35.40	40.52	2.237
		Shandaweel 1	89.3	96.0	217.3	63.0	5.455	32.86	33.09	1.794
		Sids 1	91.7	105.7	227.3	64.0	7.819	34.91	42.27	2.472
		Sids 12	90.0	97.0	226.3	74.3	7.563	34.97	33.70	2.519
		Sids 14	98.0	106.7	209.3	57.7	6.402	32.86	40.80	2.103
	D6	Gemiza 11	74.7	89.0	303.0	61.0	6.251	34.97	37.77	2.359
		Gemiza 12	77.0	80.0	210.7	74.3	4.990	34.97	36.46	1.662
		Gemiza 9	75.0	103.0	255.3	63.3	6.293	32.42	32.34	2.040
		Giza 168	76.3	89.3	325.0	54.0	5.055	32.87	32.49	1.659
		Giza 171	85.3	98.3	298.7	59.7	6.630	33.60	36.20	2.129
		Misr 1	80.3	93.3	438.7	65.0	6.467	34.97	37.87	2.431
		Misr 2	74.7	102.7	275.3	74.7	6.854	36.26	31.49	2.367
		Misr 3	83.7	95.0	292.7	67.7	7.259	35.65	36.32	2.469
		Sakha 94	73.7	90.0	443.7	58.0	6.160	32.87	34.62	2.023
		Sakha 95	79.7	92.0	302.0	54.3	6.066	33.30	36.72	2.020
		Shandaweel 1	75.7	95.0	273.0	59.3	5.512	34.25	35.18	1.880
		Sids 1	78.3	84.0	207.7	77.3	5.442	34.39	34.80	1.885
		Sids 12	78.3	94.3	260.3	66.0	6.733	33.30	34.65	2.242
		Sids 14	87.3	91.3	254.0	52.7	5.487	30.92	32.15	1.676

TABLE 8. Cont.

Seasons	Sowing dates	Cultivar	HD	PH (cm)	SN m^2	NG/S	SY/F (ton)	HI (%)	TGW (g)	GY/F (ton)
2019/2020	D1	Gemiza 11	104.3	106.7	354.7	61.7	12.270	28.43	52.02	3.233
		Gemiza 12	103.7	103.6	220.0	64.0	9.850	26.80	38.35	2.472
		Gemiza 9	107.7	113.5	434.7	56.7	9.591	34.13	41.99	3.284
		Giza 168	103.7	91.9	439.3	46.7	7.152	32.82	33.30	2.480
		Giza 171	102.3	107.1	243.0	52.0	6.799	30.23	39.04	2.046
		Misr 1	102.3	107.3	334.3	53.0	7.758	33.58	48.51	2.596
		Misr 2	104.3	111.0	261.7	71.7	8.850	34.20	36.80	2.657
		Misr 3	102.7	108.8	237.7	57.7	7.484	33.61	41.16	2.385
		Sakha 94	104.7	103.6	303.3	73.7	8.560	34.63	38.94	2.897
		Sakha 95	105.3	108.5	419.3	76.0	7.975	36.42	44.25	3.287
		Shandaweel 1	104.0	101.5	257.7	45.0	7.427	30.33	41.72	2.133
		Sids 1	107.7	111.3	186.0	67.7	8.233	31.03	34.95	2.412
		Sids 12	102.7	96.1	546.7	70.0	8.177	36.24	38.27	3.335
		Sids 14	108.7	110.5	222.7	58.7	8.993	27.90	39.17	2.332
	D2	Gemiza 11	102.0	107.1	497.7	69.0	7.448	38.07	41.46	2.859
		Gemiza 12	101.3	100.5	460.0	47.0	6.676	34.38	31.11	2.555
		Gemiza 9	105.3	121.1	494.3	56.0	7.232	36.71	41.51	2.656
		Giza 168	99.7	88.3	587.0	53.7	6.236	34.04	39.72	2.122
		Giza 171	101.7	109.5	608.7	63.0	6.436	38.99	47.81	3.035
		Misr 1	101.7	107.3	578.0	53.7	6.774	35.79	39.21	2.576
		Misr 2	103.3	118.8	526.3	83.0	8.927	38.73	46.18	3.852
		Misr 3	100.3	122.9	448.0	44.7	6.427	33.63	48.51	2.162
		Sakha 94	103.3	112.9	447.3	50.0	7.015	36.16	47.80	2.409
		Sakha 95	103.3	114.5	558.7	66.0	8.006	36.79	45.76	3.320
		Shandaweel 1	102.3	103.7	522.7	57.7	7.962	37.23	41.47	2.957
		Sids 1	102.7	110.7	488.3	57.0	7.782	38.18	49.70	2.857
		Sids 12	100.3	106.0	605.0	61.7	8.587	34.30	44.30	3.236
		Sids 14	106.0	116.4	431.3	54.7	7.916	37.94	47.39	2.606
	D3	Gemiza 11	95.7	106.3	429.3	59.0	8.893	37.91	61.84	3.749
		Gemiza 12	99.3	102.0	246.0	55.0	7.745	35.57	45.02	2.502
		Gemiza 9	104.7	108.3	395.0	53.7	8.091	34.13	42.70	2.753
		Giza 168	97.3	93.3	363.0	46.0	7.240	36.33	50.75	2.658
		Giza 171	100.7	104.3	323.3	52.0	6.841	34.19	43.88	2.335
		Misr 1	101.7	106.7	555.0	52.7	7.020	38.96	49.96	3.227
		Misr 2	101.7	105.6	240.0	45.0	7.236	34.97	46.08	2.410
		Misr 3	99.7	111.9	417.3	70.7	7.047	39.39	46.22	3.283
		Sakha 94	101.7	110.9	345.0	79.0	8.950	38.09	43.04	3.513
		Sakha 95	102.3	105.0	438.7	58.7	7.650	37.41	50.17	2.970
		Shandaweel 1	98.7	102.6	450.0	67.0	8.361	38.30	39.46	3.062
		Sids 1	101.0	120.4	329.3	62.0	8.289	36.53	42.53	2.867
		Sids 12	99.7	103.6	427.7	66.7	7.076	38.30	47.46	3.189
		Sids 14	104.7	111.5	415.0	62.7	7.593	38.91	54.29	3.421

TABLE 8. Cont.

Seasons	Sowing dates	Cultivar	HD	PH (cm)	SN m²	NG/S	SY/F (ton)	HI (%)	TGW (g)	GY/F (ton)
2019/2020	D4	Gemiza 11	93.7	100.6	386.7	53.7	7.552	36.90	47.69	2.535
		Gemiza 12	96.0	95.5	614.3	61.0	7.644	37.50	48.85	2.994
		Gemiza 9	96.3	103.7	500.3	53.7	7.820	36.63	48.15	2.604
		Giza 168	95.3	87.5	402.0	60.7	5.388	28.29	33.43	1.515
		Giza 171	99.7	103.3	472.7	60.7	7.082	35.57	39.22	2.400
		Misr 1	98.7	99.1	468.3	56.0	7.526	38.30	49.37	2.784
		Misr 2	98.0	93.8	509.7	58.7	7.632	38.30	47.80	2.819
		Misr 3	98.0	100.9	505.0	75.7	8.531	38.30	48.72	3.673
		Sakha 94	96.0	103.2	364.3	60.0	7.744	38.97	43.68	2.624
		Sakha 95	99.0	96.5	450.0	57.0	7.355	34.97	42.79	2.449
		Shandaweel 1	97.3	91.9	255.3	62.7	6.499	30.41	51.41	1.981
		Sids 1	99.7	104.8	520.0	65.0	7.939	35.34	45.96	3.043
		Sids 12	98.3	95.6	280.3	54.0	7.541	32.05	49.68	2.277
		Sids 14	102.3	106.2	548.0	55.0	6.538	33.30	39.27	2.177
	D5	Gemiza 11	85.7	95.6	398.3	61.7	7.259	35.56	50.07	2.872
		Gemiza 12	86.7	103.1	228.3	68.0	7.075	35.31	38.66	2.379
		Gemiza 9	86.3	98.7	364.0	69.0	6.919	37.08	39.93	2.611
		Giza 168	87.0	95.3	234.0	84.7	6.240	32.77	28.70	2.050
		Giza 171	90.7	98.3	231.0	70.7	7.884	35.43	48.95	2.527
		Misr 1	89.3	96.1	225.0	67.7	6.362	33.30	45.03	2.118
		Misr 2	86.0	99.7	215.0	85.3	7.310	36.43	38.11	2.421
		Misr 3	90.0	105.9	289.3	58.0	7.505	34.97	44.67	2.499
		Sakha 94	85.0	101.4	485.7	73.0	7.083	38.85	43.33	2.964
		Sakha 95	89.7	97.6	198.3	87.7	6.999	36.14	45.91	2.302
		Shandaweel 1	87.7	86.9	208.7	61.7	4.759	32.43	36.37	1.549
		Sids 1	89.7	95.3	233.0	59.7	7.602	36.55	45.35	2.527
		Sids 12	88.3	107.6	209.0	74.0	7.773	36.63	37.97	2.588
		Sids 14	96.3	101.1	226.0	64.7	5.911	33.35	47.24	1.983
	D6	Gemiza 11	73.0	83.6	241.3	50.7	5.995	33.24	40.27	1.993
		Gemiza 12	75.0	88.1	195.0	75.0	4.758	32.29	38.02	1.518
		Gemiza 9	71.3	81.7	237.0	72.0	6.570	32.72	37.09	2.149
		Giza 168	73.7	88.0	356.0	50.0	5.091	33.93	34.94	1.728
		Giza 171	83.3	92.3	259.3	58.7	7.059	32.66	43.88	2.295
		Misr 1	78.0	88.9	376.0	58.7	7.294	36.96	43.10	2.456
		Misr 2	72.0	88.4	296.3	76.7	7.261	34.49	33.45	2.382
		Misr 3	81.3	94.6	318.3	71.0	7.130	39.05	40.65	2.707
		Sakha 94	71.7	91.9	456.3	60.7	6.578	34.50	35.02	2.151
		Sakha 95	77.3	84.7	339.0	53.0	6.478	34.49	41.79	2.229
		Shandaweel 1	73.7	83.6	269.3	51.7	5.962	31.42	41.30	1.865
		Sids 1	75.7	90.3	223.0	76.0	5.890	32.39	35.64	1.907
		Sids 12	76.7	103.1	284.0	73.7	6.721	33.28	37.64	2.237
		Sids 14	85.3	89.7	275.0	53.0	5.948	28.00	38.92	1.661
F test			NS	**	NS	NS	NS	NS	NS	NS
LSD REV.			-	2.96	-	-	-	-	-	-

Genotype by environment interaction

The pooled ANOVA exhibited highly significant (P< 0.001) variation among the twelve environments (sowing dates), among the fourteen wheat cultivars and cultivars × sowing dates interaction (GEI) for grain yield per feddan (Table 9). The cultivars contributed to the total sum of squares by a value of 14.12%. The contribution of the sowing dates effects was 25.77%, approximately twice the contribution of the cultivars. Furthermore, GEI effects explained 29.43% from the total sum of squares. There still remains a large proportion of variance left unexplained by the model pooled into the residual term (30.69%). Presence of highly significant GE effects indicates the different responses of tested wheat cultivars towards sowing dates and may suggest the possible existence of different mega environments with different top-yielding cultivars. These results are in accordance with those obtained by Mohammadi & Amri (2012), Ayalew et al. (2014), Abate et al. (2015), Ahmed et al. (2020), Lozada & Carter (2020).

Mega environments and best cultivars

In a GGE biplot (Fig. 2) the cultivars and sowing dates are represented in the same plot with vectors connecting the sowing dates with the origin. The angles between sowing dates vectors provides information on the correlation between sowing dates. An acute angle indicates positive correlation, a right angle indicates no correlation, and an obtuse angle indicates negative correlation. Cultivars or sowing dates tend to cluster together. The origin represents a virtual cultivars that have an average performance of grain yield in each sowing date. Therefore, there are positive correlation between the sowing dates D1. D2, D7, and D8 which represent sowing dates on 1st and 15th November in both seasons, respectively. In addition, positive correlation was observed among the sowing dates D3, D4, D9 and D10 which represent the sowing dates on 30th November and 15th December in both seasons, respectively. Also, positive correlation was obtained between sowing dates D5, D6, D11, and D12 that represent the sowing date at the end of December and 15th January in both seasons, respectively. These findings are in accordance with those obtained by Ayalew et al. (2014), Gomaa et al. (2018), Kendal (2019), Bányai et al. (2020).

GGE biplot method explained 55.49 % of the total variance (35.67% for PC1 and 19.82% for PC2) of the grain yield for wheat cultivars across sowing dates. The polygon view of the GGE showed cultivars with relatively better performance at each sowing date. Figure 3 shows the ‘’which, won, and where’’ pattern of the GGE biplot, since the cultivars Giza 168, Misr 2 and Misr 3 had greatest distance to the origin of the biplot and are among the most reactive data. They produce low or high yield in one or more sowing dates. The cultivars in the center of the exploratory graph are less reactive and have the same rank in all sowing dates and therefore do not react to the environment. The GGE biplot method revealed two mega environments (sowing dates). Since the sowing dates or environments that are in the same area are similar, these sowing dates or environments are highly correlated, in this biplot. The first mega environment including the sowing dates D1, D2. D7, and D8 are located in one area in the biplot, indicating identical conditions. The most adequate cultivars for grain yield in these sowing dates are Misr 2, Sids 12, Sakha 95, Gemiza 9 and Gemiza 11 because they are located in the same sector. The second mega environment consisted of the other sowing dates, but it could be observed that D3 and D9 are closer to each other, D5, D6, D11 and D12 are clustered together. D4 and D10 are in the same mega environment but far from the other sowing dates. Cultivars Sids 1, Misr 1, Gemiza 12, Sakha 94, and Misr 3 are the most adequate cultivars to sowing dates D3 and D9 (represent optimum date) and produce high yield in these sowing dates. Also, Sakha 94, Gemiza 9 and Gemiza 11 can be sown after 30th November because they produce a satisfied yield and have good stability. Cultivars Giza 168, Giza 171, Shandaweel 1 and Sids 14 had grain yield lower than the average across all sowing dates. These findings are in accordance with those obtained by Ayalew et al. (2014), Gomaa et al., (2018), Kendal (2019), Bányai et al. (2020).

TABLE 9. Combined ANOVA for grain yield/ feddan (ton/fed)

Source	DF	Type III SS	Mean square	F value	Pr > F	Contribution %
Cultivars	13	24.30	1.87	11.89	<.0001	14.12
Sowing dates	11	44.35	4.03	25.65	<.0001	25.77
Cultivars × sowing dates	143	50.65	0.35	2.25	<.0001	29.43
Error	336	52.82	0.16	-	-	30.69
Corrected total	503	172.11				

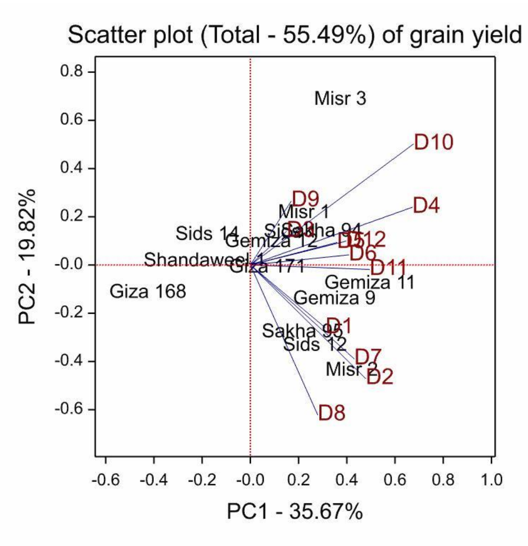

Fig. 2. GGE bipot based on mean grain yield (ton/fed) of 14 wheat cultivars across 12 sowing dates [The vectors and rug-plot indicate the correlations among tested sowing dates]

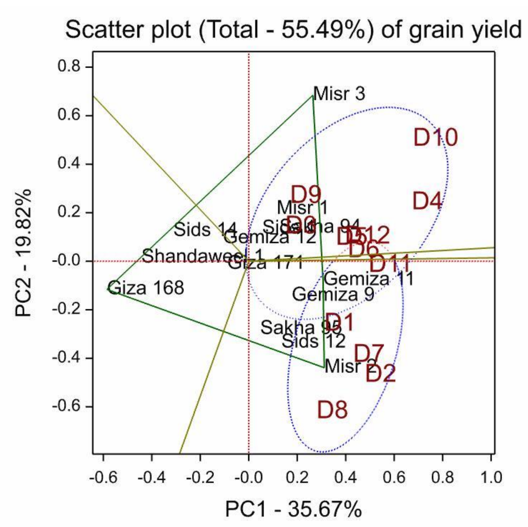

Fig. 3. Polygon views of GGE biplot based on environmental scaling for the 'which-won-where' pattern of 14 wheat cultivars and 12 sowing dates over two seasons [Six sowing dates each season]

Ranking biplot is used to show the best performance cultivar in a specific sowing date (Fig. 4). In this figure, the cultivars were ranked under all sowing dates. Gemiza 11, Gemiza 9 and Sakha 94 ranked in the first order as high-yielding cultivars and had a greater stability level as they were subtended by relatively low PC2 score. In addition, cultivars Misr3, Misr 2, Misr 1, Sids 12 and Sakha 95 produced high grain yield but had mean scores greater than the average environment coordinate point and are considered as unstable cultivars for grain yield. D3 shares more attributes with D9, and D5 than other sowing dates. In addition, the smaller the circle containing a cultivar the greater stability performance in sowing date D3. The cultivars Sids 1, Sakha 94, and Misr 1 are likely to be the ideal cultivars for sowing date D3 (30[th] November) in terms of achieving high mean grain yield and good stability. We used the comparison biplot to compare the performance of the tested environments with that of an ideal one (sowing date). The ideal sowing date was D3 based on the average of the grain yield of all cultivars (Fig. 5). Similar findings were reported by Mohammadi et al. (2011), Abate et al. (2015), Ahmed et al. (2020).

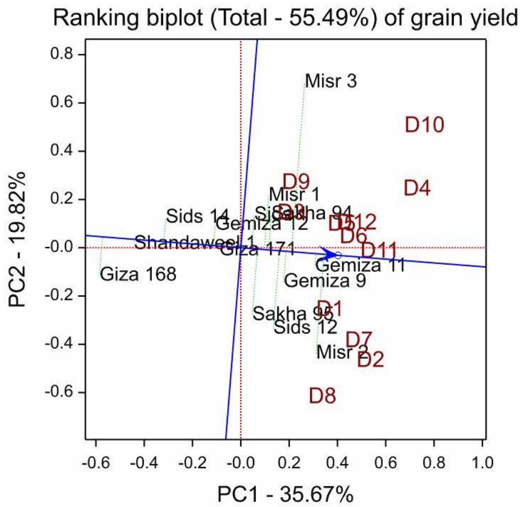

Fig. 4. GGE biplot shows the average environment coordination based on cultivars focused scaling for the means performance ranking and stability of cultivars

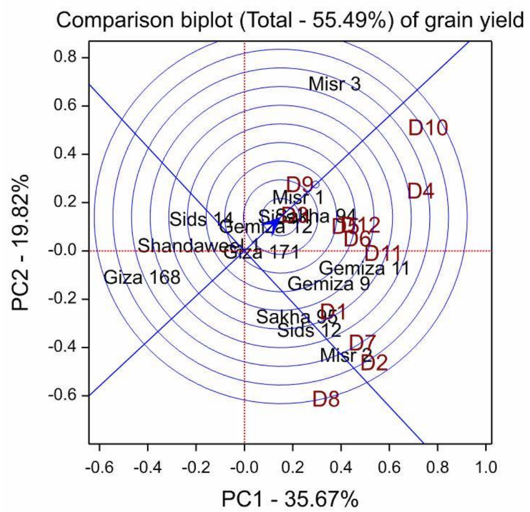

Fig. 5. GGE biplot based on environment focused scaling for comparison of the sowing dates with the optimum one

Conclusion

In conclusion, differences among the tested wheat cultivars, sowing dates and cultivars by sowing dates interaction were highly significant for all studied traits. The contribution of the sowing dates (12 environments) and GE interaction to the sum of squares exceeded the contribution of the cultivars, indicating the predominant influence of the environments on grain yield than genotypes. Highest grain yield (2.992-ton fed^{-1}) was recorded on 30th November, after this date each day delay in sowing of wheat onward decreases grain yield at the rate of 21kg fed^{-1} day^{-1}. The cultivar Gemiza 11 was superior cultivars than others in traits grain yield, 1000-GW, straw yield and was the earliest one. Based on GGE biplot results, Gemiza 11, Gemiza 9, and Sakha 94 ranked in the first order as high-yielding cultivars and had greater stability level over all sowing dates under Assiut conditions. The most adequate cultivars for sowing in the first half of November are Misr 2, Sids 12, Sakha 95, Gemiza 9 and Gemiza 11. Sakha 94, Gemiza 9, and Gemiza 11 can be sown after 30th November because they produce a satisfied yield, have good stability, and can be considered as late sowing tolerant. The GGE biplot succeeded to determine the best suitable wheat cultivar (s) for the most appropriate sowing time (period) for grain yield under Assiut condition.

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تقييم أصناف محلية من قمح الخبز لمحصول الحبوب ومكوناته في مواعيد زراعة مختلفة تحت ظروف محافظة أسيوط

محمد عبدالعزيز عبدالحليم سيد [1] ، محمد ثروت سعيد عبدالعال [1]، محمود ابوالسعود الراوي محمد [2]
[1]قسم المحاصيل – كلية الزراعة – جامعة أسيوط – أسيوط – مصر، [2]قسم الوراثة – كلية الزراعة – جامعة أسيوط – أسيوط – مصر.

يهدف البحث الحالي إلى تقييم وإنتخاب أصناف قمح الخبز ذات الثبات الجيد والإنتاجية العالية تحت مواعيد زراعة مختلفة. تمت زراعة أربعة عشر صنفًا من قمح الخبز في تصميم القطاعات العشوائية الكاملة باستخدام ثلاثة مكررات في ستة مواعيد زراعة خلال موسمين متتاليين من 2018/2019 و2019/2020 تمثل اثنتي عشرة بيئة. قيمت الأصناف لمحصول الحبوب ومكوناته. تم الحصول على فروق ذات دلالة إحصائية عالية بين أصناف القمح ومواعيد الزراعة والتفاعل بينها لجميع الصفات المقاسة. تم تسجيل أعلى إنتاج للحبوب (2.992 طن /فدان) في ميعاد الزراعة 30 نوفمبر، بعد هذا الميعاد، كل تأخير في زراعة القمح فصاعدًا يؤدى إلى انخفاض محصول الحبوب بمعدل 21 كجم/ فدان/يوم. بشكل عام، أعطى الصنف جميزة 11 أعلى إنتاج للحبوب بمتوسط 2.861 طن/فدان، وسجل أعلى متوسط وزن للألف حبة بمتوسط 47.73 جرام، وأعلى محصول من القش بمتوسط 8.303 طن/فدان. وكان أبكر الأصناف في طرد السنابل بمتوسط 92.9 يومًا. وفقًا لنتائج تحليل GGE biplot، احتلت كل من الأصناف جميزة 11، جميزة 9 و سخا 94 المرتبة الأولى كأصناف عالية الإنتاجية ولديها مستوى أعلى من الثبات على مستوى كل مواعيد الزراعة المختبرة تحت ظروف أسيوط. أنسب الأصناف للزراعة في النصف الأول من شهر نوفمبر (1 – 15 نوفمبر) هي مصر 2، سدس 12، سخا 95، جميزة 9، جميزة 11. أيضًا، الأصناف سخا 94، جميزة 9، جميزة 11 يمكن زراعتها بعد 30 نوفمبر لما لها من إنتاجية مرضية من محصول الحبوب كما أنها تتمتع بثبات جيد، ويمكن اعتبارها متحملة للزراعة المتأخرة.