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RESEARCH ARTICLE

Identification of bread wheat (*Triticum aestivum* L.) genotypes tolerant to heat and low N stress

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Abstract

To identify the heat and low N-stress tolerant bread wheat genotypes, fifteen genotypes were evaluated in early, recommended and late dates under low and recommended N fertilizer rates. The experiments carried out during the two seasons of 2021/2022 and 2022/2023 at the experimental farm of Faculty of Agriculture, Minia University. Significant differences (P≤0.05 or 0.01) of sowing dates, N levels, genotypes, and their interactions were found for the mot studied traits in the two seasons. Early and late sowing dates resulted in a reduction in the most studied traits compared to the recommended sowing date. Low N fertilization caused a reduction in all studied traits compared to the recommended N level except harvest index. For grain yield under low N, Misr2 recorded the lowest heat stress sensitivity index HSI followed by lines 8, 20, 4 and 13, indicating, tolerance to heat stress. Misr2 gave the highest grain yield on the late sowing date with low N. Line 15, Giza168 and Gemmieza12 could be sowing on late date when providing recommended N fertilization to compensate the late of sowing date. Based on all N stress tolerance indices, lines 14, 15, 24 and 34 on early sowing date, lines 13, 17, 24, and 34 in recommended sowing date, lines 13, 17, 24 and Misr2 on late sowing date were the most N-stress tolerant genotypes.

Keywords: stress; tolerant; nitrogen; late; heat; sensitivity.

1. Introduction

Wheat production in Egypt is not sufficient to meet the population's needs due to the lack of area allocated for wheat cultivation as a result of decreased water resources and competition from other winter crops. Therefore, Egypt imports more than half of its wheat needs owing to the increasing population growth and the increase in the per capita consumption rate. Wheat production is affected by climate changes, especially temperature. The sowing date is considered one of the most important agricultural practices that is affected by temperature to which wheat is exposed during the growth stages. Wheat is one cereals respond significantly to high temperature and relative humidity that affect on their growth and grain development (Eslami *et al*., 2014). Delayed sowing date caused reduction in wheat yield and its components as a result of exposure of plants to high temperature, which decreased season length (Suleiman *et al.*, 2014). Wang *et al*. (2013) and He *et al.* (2015) found that rise of temperature increase crop growth rate, while late sowing date or sowing longer growing cultivars could lead to delayed growth. The elevated temperature has threatened crop production around the globe during the last few decades. Wheat yield is predicted to fall by 6% worldwide with a rise of 1 °C Asseng *et al.* (2015). The most important proposed adaptation strategies in this regard are 1- Developing new cultivars that can withstand high temperatures, 2- Developing new cultivars with a short growing season to reduce their water requirements. 3- Changing sowing dates to suit the new weather

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conditions, as well as planting suitable cultivars in suitable climatic regions to increase the crop yield per unit of water for each crop. Sood *et al*. (2017), Suresh *et al.* (2018) and Fouad (2019) used heat sensitivity index to determine the heat tolerant genotypes in wheat. Ali *et al*. (2016) found that the November 15th was the most favorable sowing date to achieve the highest grain yield and its attributes in wheat. Abdel Nour and Fateh (2013) and Madhu *et al*. (2018) showed that the recommended sowing date produced the highest biological yield, grain yield and its attributes compared to early and late sowing dates. Nitrogen is one of the essential elements that determine the grain yield of wheat (Huang *et al.*, 2018). It was observed that all determined traits of wheat were increased by adding 160 kg N/ha. (Chowdhury *et al.*, 2018) or 180 kg N/ha (Litke *et al.*, 2018) as nitrogen fertilizer rate. Awad *et al*. (2023) found that adding 70 kg N/fed significantly increased grain yield and its components of wheat compared to 50 kg N/fed. Significant increase in plant height of wheat plants owing to raise N fertilization to 90 kg N/fed in the two growing seasons. El-Seidy *et al*. (2017) found that adding 75 kg N/fed could be recommended to produce optimum grain yield per unit area. Ali *et al*. (2016) revealed that increasing N fertilization to 190.4 kg N/ha significantly gave an increase in grain yield and its components. Sowing Misr1 cultivar on November 15th using 190.4 kg N ha^{-1} gave the highest grain yield. Tyagi *et al.* (2020), Ivic *et al.* (2021) and Aga *et al.* (2022) used stress tolerance indices to identify tolerant genotypes under low and high nitrogen conditions. As stress sensitivity index, stress tolerance index, mean, geometric mean productivity, tolerance index, yield stability index, harmonic mean, sensitivity low of nitrogen index, low of nitrogen resistance index and relative low of nitrogen index. Tyagi *et al.* (2020) revealed that stress tolerance indices are considered suitable for the determination of high-yielding wheat genotypes under stress N conditions. The stress tolerant genotypes could be used as donors to incorporate the stress N-tolerant genes in wheat breeding programs to develop high-yielding wheat cultivars for stress nitrogen. The current study aims to evaluate some bread wheat genotypes in early, recommended and late sowing dates under low and recommended N fertilizer rates to evaluate the heat and low N stress tolerant genotypes. Where, our environment and wheat production is greatly affected by the exposure to the increasing temperature brought by climate change situation.

2. Materials and methods

Fifteen genotypes of bread wheat including twelve lines and three cultivars (Table 1) were evaluated during the two seasons of 2021/2022 and 2022/2023 in three sowing dates, 25th Oct. early date (ED), 20th Nov. recommended date (RD) and 15th Dec. late date (LD) under two nitrogen fertilization levels, 37.5 low N (LN) and 75 recommended N (RN) Kg. N/fed, in the form of Urea 46% N at the experimental farm (28.11°N-30.75°E) of Fac. Agric., Minia Univ., El-Minia, Egypt.

Table 1. Name and pedigree of the Egyptian bread wheat genotypes used in the study

Genotypes	Pedigree
L2, L4, L8, L13, L14, L15, L17, L20, L23, L24, L31 and L34	Giza168/Sids4
Misr2	SKAUZ/BAV 92
Giza168	MIL/Buc//Seri CM93046-8M-04-0M-2Y-0B
Gemmeiza12	OTUS/3/SARA/THB//VEE

The strip-split-plot design with 3 replications using the three sowing dates as the vertical factor, the two nitrogen fertilization levels as horizontal factor and the 15 bread wheat genotypes as the subplot factor. The plot size was five rows, 3 m in length, and 0.2 m in width. Grains were sown by hand drill 5 cm. apart. Other recommended cultural practices were applied for wheat production throughout the growing season. Mechanical and chemical properties of the experiment soil are shown in Table 2.

Table 2. Mechanical and chemical analyses of the soil

Mechanical analysis	Clay %	Silt %	Sand %	Texture
	54.74	35.34	9.92	Clay loam
Chemical analysis	pH	N%	P mg / 100 g	K ppm
	7.96	0.88	12.87	16.00

Source, The soil and water Lab., Fac. Agric., Minia Univ.

Data were taken on 2.00 m^2 middle of plot area for the following traits: Days to 50% heading (DH), plant height in cm (PH), flag leaf area in cm (FLA) according to Radford (1967), spike length in cm (SL), number of spikes $plot^{-1}$ (NS P^{-1}), number of grains $spike^{-1}$ (NG S^{-1}), 1000 grain weight in g. (TGW), grain yield $feddan^{-1}$ in ardab (GY fed^{-1}), biological yield in ton fed^{-1} (BY) and harvest index (HI%) = GY/BY*100. Air temperature and relative humidity for the two growing seasons are shown in Fig (1).

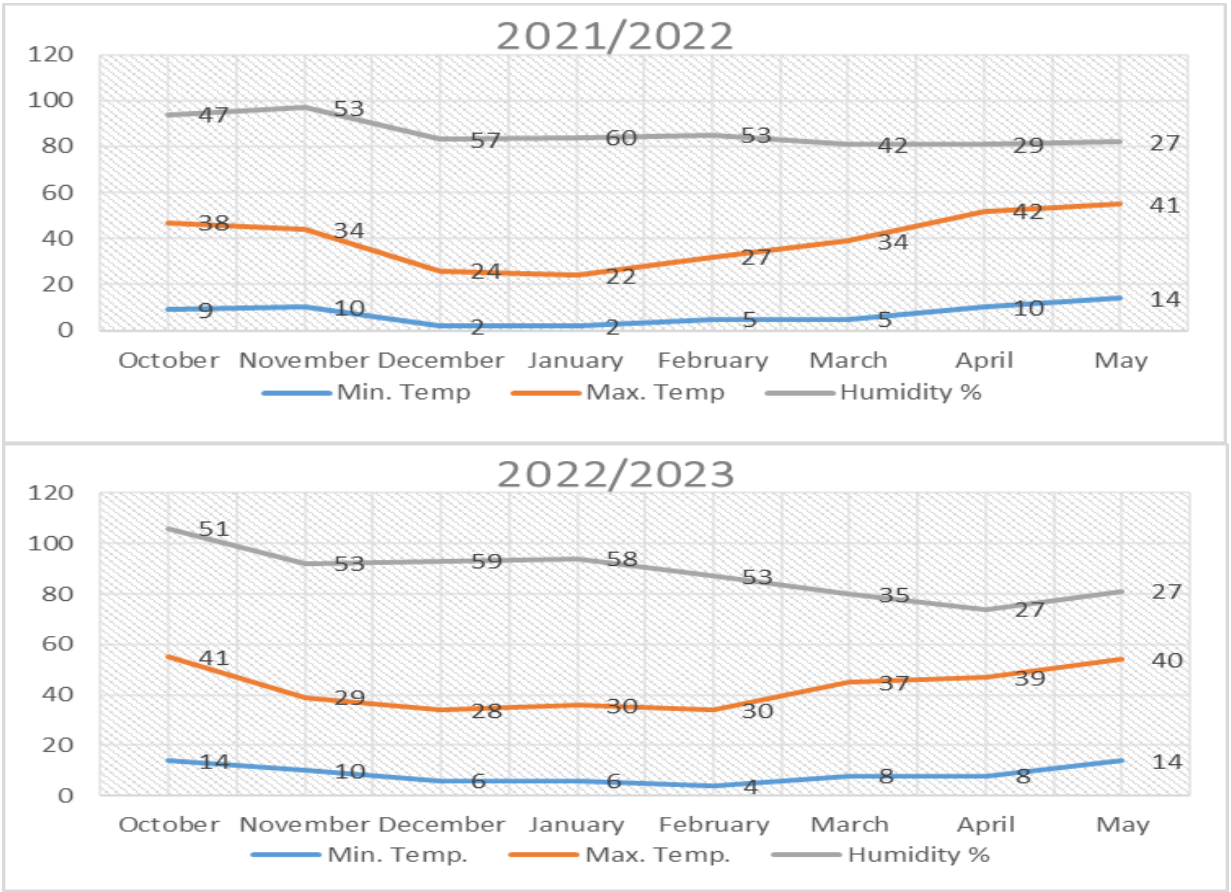

Figure 1. Mean air temperature (C°) and humidity (%) during 2021/2022 and 2022/2023 growing seasons at Minia conditions https://www.timeanddate.com/weather

Heat sensitivity index HSI = (1- Ys/Yp) ÷ (1- $\overline{Ys}/\overline{Yp}$) (Fisher and Maurer, 1978)

Where, Ys and Yp were trait means of an individual genotype under heat stress condition (late sowing date) and normal conditions (recommended sowing date), respectively. $\overline{Ys}$ and $\overline{Yp}$ were grand mean of all genotypes under heat and normal conditions, respectively.

Table 3. Ten nitrogen stress parameters were calculated based on grain yield fed^{-1} as follows:

	Parameter	Reference
	Stress intensity SI =1−($\overline{Ys}/\overline{Yp}$)	
1	Stress sensitivity index (SSI) = [1- (Ys/ Yp)]/SI	(Fischer and Maurer, 1978)
2	Stress tolerance index (STI) = Ys.Yp/($\overline{Yp}$)^2	(Fernandez, 1992)
3	Mean productivity (MP) = (Ys + Yp)/2	(Rosielle and Hamblin, 1981)
4	Geometric mean productivity (GMP) = $\sqrt{(Ys \times Yp)}$	(Fernandez, 1992)
5	Tolerance index (TOL) = Yp – Ys	(Rosielle and Hamblin, 1981)
6	Yield stability index (YSI) = Ys/Yp	(Bouslama and Schapaugh, 1984)
7	Harmonic mean (HM) = [2(Yp Ys)]/(Yp + Ys)	(Chakherchaman *et al*., 2009)
8	Sensitivity low of nitrogen index (SNI) =(Yp - Ys)/Yp	(Farshadfar and Javadinia, 2011)
9	Low of nitrogen resistance index (NI) =[Ys(Ys/Yp)]/ $\overline{Ys}$	(Farshadfar and Javadinia, 2011)
10	Relative low of nitrogen index (RNI) =(Ys/Yp) ($\overline{Ys}/\overline{Yp}$)	(Fischer *et al.*, 1998)

Where, Ys and Yp were trait mean of an individual genotype under low N stress and recommended N, respectively. $\overline{Ys}$ *and* $\overline{Yp}$ *were grand mean of all genotypes under low N stress and recommended N, respectively.*

2.1. Statistical analysis

The comparison means using revised least significant difference (RLSD) according to Gomez and Gomez (1984). Heritability in a broad sense (H%) was determined according to Walker (1960). The phenotypic (PCV%) and genotypic (GCV%) coefficients of variability were calculated according to Burton (1952). Phenotypic and genotypic correlation coefficients were calculated as outlined by Johnson *et al*. (1955). Rank sum (RS) = Rank mean ($\bar{R}$) + Standard deviation of rank (SDR) according to Farshadfar and Elyasi, 2012 to determine the best genotype across all stress nitrogen tolerance indices.

3. Results and discussion

Mean squares for the studied traits over the three sowing dates and two N fertilization levels in the first and second seasons are presented in Table 4. Significant differences (P≤0.05 or 0.01) of sowing dates, N levels, genotypes, dates x genotypes interaction, N levels x genotypes interaction, sowing dates x N levels x genotypes interaction were found all the studied traits in the two seasons except sowing dates x N levels x genotypes interaction for flag leaf area in 1st season and weight of grains/spike in 2nd season in addition N levels for harvest index in 2nd season. Significant differences (P≤0.05 or 0.01) of sowing dates x N levels interaction were detect for days to heading, biological yield and harvest index in the two seasons in addition plant height, spike length, 1000 grain weight, number of spikes/plot in 1st season and number of grain/spike and grain yield in 2nd season (Table 4). Similar results were obtained by Ali *et al.* (2016), Hefny and Mohammed (2018), Ahmed (2021) and Mohamed *et al.* (2022). The phenotypic coefficient of variability value was higher than genotypic coefficient of variation for all the determined traits in the two seasons. Values of G.C.V. and P.C.V. % were ranging from 2.60% and 3.38% for plant height to 17.91 and 18.50% for number of spikes/plot in 1st season. While in 2nd season ranging from 1.65 and 2.70% for plant height to 20.47 and 21.05% for number of grains/spike.

Table 4. Mean squares for the studied traits in the first and second seasons.

		First season (2021/2023)									
S.V.	DF	DH	PH	FLA	SL	NG/S	TGW	NS/Plot	GY/fed	BY/fed	HI
Rep	2	58.20	123.58	47.69	0.29	47.50	5.63	1029.00	3.68	0.79	0.24
Dates D	2	12680.80**	1358.04**	1285.53**	87.95**	14422.20**	7141.63**	1486331.00**	2060.56**	175.19**	1857.69**
Error D	4	3.40	9.16	6.50	0.07	48.70	11.51	8604.00	0.94	0.20	1.71
Nitrogen N	1	2647.70**	4280.97*	2306.57*	100.69**	2014.70**	493.99**	816465.00**	903.07**	376.35**	204.62*
Error N	2	7.70	80.32	6.67	0.04	10.50	4.04	5466.00	3.32	0.18	10.88
D x N	2	421.00**	58.96*	2.91	0.79*	13.80	28.85*	17777.00**	27.74	11.85**	307.17**
Error c	4	15.70	8.07	16.21	0.11	3.70	1.89	1305.00	4.55	0.30	14.66
Genotypes G	14	978.20**	196.95**	336.27**	20.34**	1202.20**	221.96**	264599.00**	103.69**	9.22**	140.09**
D x G	28	150.50**	110.30**	108.12**	3.65**	167.10**	116.51**	34655.00**	15.94**	6.35**	74.93**
N x G	14	49.20**	43.71**	29.84**	1.26**	75.30**	38.7**	40143.00**	18.37**	1.65**	86.13**
D x N x G	28	54.80**	48.28**	17.25	0.67**	53.70**	38.59**	22822.00**	13.22**	1.97**	62.33**
Error d	168	8.10	9.81	9.96	0.24	19.50	17.20	2567.00	3.33	0.29**	16.38**
GCV%		7.89	2.60	10.56	8.64	17.26	5.52	17.91	14.98	5.37	6.13
PCV%		8.11	3.38	11.86	9.00	18.21	7.76	18.50	16.59	6.80	9.71
H%		94.45	59.55	79.24	92.12	89.84	50.54	93.72	81.45	62.26	39.87
		Second season (2022/2023)									
S.V.	DF	DH	PH	FLA	SL	NG/S	TGW	NS/Plot	GY/fed	BY/fed	HI
Rep	2	38.10	0.56	15.73	0.60	2.10	18.02	1152.00	1.04	0.24	11.22
Dates D	2	1513.60**	1251.69**	1429.34**	86.10**	17291.00**	7673.03**	1851030.00**	1765.99**	205.912**	1619.64**
Error D	4	26.40	23.22	10.37	0.36	19.40	3.28	1933.00	4.10	0.36	18.94
Nitrogen N	1	3073.80**	4608.01**	217.94**	89.02**	1589.80**	2273.66**	542944.00**	944.76**	350.30**	142.18
Error N	2	9.70	5.05	12.11	0.04	4.60	4.78	42.00	2.07	0.02	18.58
D x N	2	205.50*	45.09	5.49	0.95	88.70**	297.82	19330.00	37.58*	6.76**	203.85**
Error c	4	23.10	28.05	10.57	0.83	3.40	104.47	4832.00	3.55	0.08	6.11
Genotypes G	14	904.40**	156.40**	349.26**	20.54**	1699.90**	184.35**	300102.00**	88.87**	9.07**	112.32**
D x G	28	167.30**	121.42**	105.21**	4.32**	198.60**	113.35**	28689.00**	12.79**	8.02**	74.21**
N x G	14	73.80**	18.87*	21.15**	1.32**	96.50**	88.43**	19880.00**	30.98**	1.84**	92.81**
D x N x G	28	49.80**	50.42**	24.02**	0.54*	37.10**	84.40**	20184.00**	13.12**	2.63**	68.61**
Error d	168	8.00	9.90	9.15	0.32	14.30	20.82	2070.00	3.23	0.19	14.30
GCV%		7.45	1.65	10.96	8.49	20.47	4.48	19.07	14.11	3.23	4.91
PCV%		7.69	2.70	12.14	8.98	21.05	7.44	19.50	15.81	4.67	8.85
H%		93.89	37.06	81.64	89.42	94.59	36.24	95.62	79.70	47.95	30.76

**, ** significance at 5 and 1% probability of levels.*

Values of phenotypic and genotypic coefficients of variability were close to each other, which resulted in high values of heritability in broad sense reached 95.45% for days to heading in 1st season and 95.6% for number of spikes/plot in 2nd season (Table 4). The wide difference between G.C.V. and P.C.V.% values resulted in low heritability values as weight of grains/spike and harvest index by 36.84 and 39.87% in 1st season and 17.81 and 30.76% in 2nd season, respectively. Similar results for PCV and GCV% were reported by El-Degwy (2013) and Fouad (2019) for DH, PH, SL, 1000GW and BY, NS. Sharaan *et al.* (2017) found high heritability for the most studied traits. Sarcevic *et al.* (2014) found that heritability for grain yield at high and low N were 82 and 77%, respectively.

3.1. Mean performance

Means of the studied traits in sowing dates, N levels and their interaction in first and second seasons are shown in Table 5. Early and late sowing dates resulted in a reduction in the most studied traits in comparison to the recommended sowing date in the two seasons. Early sowing subjected the wheat plants to high soil temperature, higher than optimal, resulting in restriction of proper growth of wheat plants. While, the late sowing date subjected the sown wheat grains to the low temperature of soil causing low emergence%, and at the end of the season the high temperatures, might adversely affect pollen grains and grain filling during the growth stage.

Table 5. Means of the studied traits in sowing dates, N levels and their interaction in first and second seasons

		First season (2021/2022)				RLSD5%		Second season (2022/2023)				RLSD5%	
Trait	N\D	ED	RD	LD	Mean	D	DxN	ED	RD	LD	Mean	D	DxN
DH	LN	91.97	90.60	66.83	83.13	0.78	2.38	91.21	89.20	67.27	82.56	2.18	2.89
	RN	95.57	95.85	77.41	89.61			94.32	94.94	77.74	89.00		
	Mean	93.77	93.22	72.12	86.37	N, F test**		92.77	92.07	72.51	85.78	N, F test**	
PH; cm	LN	83.60	82.13	75.01	80.25	1.9	1.71	83.80	81.16	76.77	80.58	2.05	NS
	RN	89.80	90.42	84.40	88.21			91.26	91.06	84.19	88.84		
	Mean	86.70	86.28	79.70	84.23	N, F test**		87.53	86.11	80.48	84.71	N, F test**	
FLA; cm^2	LN	28.26	35.30	28.82	30.79	1.08	NS	28.28	35.08	28.79	30.72	1.37	NS
	RN	34.05	40.82	35.05	36.64			33.46	41.23	34.65	36.45		
	Mean	31.16	38.06	31.93	33.72	N, F test*		30.87	38.16	31.72	33.58	N, F test**	
SL; cm	LN	9.37	11.38	10.85	10.53	0.11	0.2	9.46	11.57	10.78	10.61	0.25	NS
	RN	10.67	12.39	12.21	11.76			10.75	12.48	12.03	11.75		
	Mean	10.02	11.88	11.53	11.14	N, F test**		10.11	12.03	11.41	11.18	N, F test**	
NG/S	LN	33.40	56.18	34.04	41.20	2.96	NS	35.14	57.27	34.15	42.18	1.87	1.11
	RN	39.70	60.93	39.37	46.67			37.88	63.96	39.27	47.04		
	Mean	36.55	58.55	36.71	43.94	N, F test**		36.51	60.62	36.71	44.61	N, F test**	
TGW; g	LN	38.82	53.12	35.54	42.50	1.44	0.83	36.93	53.33	33.99	41.41	0.77	6.14
	RN	41.12	54.95	39.53	45.20			41.06	56.63	43.96	47.22		
	Mean	39.97	54.04	37.54	43.85	N, F test**		39.00	54.98	38.97	44.32	N, F test**	
NS/plot	LN	539.58	707.11	481.21	575.97	39.4	21.7	562.54	742.14	492.26	554.85	18.7	41.77
	RN	623.16	846.64	588.05	685.95			648.20	862.94	554.85	688.67		
	Mean	581.37	776.88	534.63	630.96	N, F test**		605.37	802.54	523.55	621.76	N, F test**	
GY/fed; ardab	LN	11.69	18.16	8.89	12.91	0.41	1.28	11.45	17.35	9.30	12.70	0.86	1.13
	RN	14.09	22.19	13.43	16.57			13.70	21.94	13.68	16.44		
	Mean	12.89	20.18	11.16	14.74	N, F test**		12.57	19.64	11.49	14.57	N, F test**	
BY/fed; tons	LN	6.12	7.82	4.83	6.26	0.19	0.33	6.38	7.93	4.68	6.33	0.25	0.17
	RN	9.27	9.55	7.03	8.62			9.20	9.66	6.96	8.61		
	Mean	7.69	8.69	5.93	7.44	N, F test**		7.79	8.79	5.82	7.47	N, F test**	
HI%	LN	29.18	34.89	35.06	33.04	0.56	2.3	27.61	33.16	30.31	30.36	1.85	1.49
	RN	23.18	35.06	28.91	29.05			22.81	34.17	29.76	28.91		
	Mean	26.18	34.98	31.98	31.05	N, F test*		25.21	33.67	30.03	29.64	N, F test ns	

Low N fertilization caused reduction in all the studied traits compared to the recommended nitrogen fertilization except harvest index in the two season. Jarecki (2024) found that the late sowing date of wheat by one month caused a reduction in grain yield could be compensated with increased N fertilization. The high yield potential was achieved with the addition of 150 kg N ha^{-1} at the favorable sowing date. Grain yield and yield attributes were the highest with the recommended sowing date and with fertilization of either 150 or 200 kg N ha^{-1}. Means of the studied traits for genotypes in first and second seasons are shown in Table 6. Line 15 gave the highest values for no. of spikes/plot and harvest index in both seasons in addition grain yield/fed and biological yield/fed in 1st season. Line 20 recorded the highest values for flag leaf area, no. of grains/spike in the two growing season. Line 23 was the earliest in days to 50% heading in the two seasons. Line 8 and 17 gave the heaviest 1000 grain weight in 2nd and 1st seasons, respectively.

Table 6. Means of the studied traits for genotypes in first and second seasons

Season	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
G\Trait	DH		PH; cm		FLA; cm^2		SL; cm		NG/S	
L2	79.67	77.67	84.37	85.35	35.79	34.09	10.42	10.68	42.11	43.75
L4	87.44	84.72	82.33	83.25	26.83	25.43	9.61	9.59	40.59	39.06
L8	84.31	83.33	87.44	85.41	41.09	41.04	11.17	11.17	41.97	42.82
L13	83.64	82.61	85.86	87.19	35.21	31.65	11.01	11.22	43.38	45.99
L14	93.39	94.03	87.96	87.31	29.61	30.21	11.57	11.58	37.82	37.69
L15	79.78	79.22	84.34	86.94	34.88	35.77	11.99	12.15	43.58	43.38
L17	94.83	95.00	87.21	86.19	27.93	28.72	10.13	10.38	33.34	32.96
L20	81.75	82.33	80.38	79.23	41.18	41.36	13.08	13.08	67.65	72.78
L23	74.33	75.31	79.73	82.79	36.36	36.10	11.91	11.90	54.85	56.16
L24	79.50	79.28	79.56	80.40	36.43	36.60	10.76	10.40	44.07	45.17
L31	93.67	91.67	86.01	85.82	34.25	35.79	11.48	11.31	35.57	36.73
L34	81.03	81.58	84.90	86.76	34.19	33.88	13.14	13.23	46.44	51.39
Misr2	95.61	94.19	89.93	86.82	32.05	32.80	9.91	9.96	42.80	39.96
Giza168	89.61	89.81	79.71	82.42	29.78	29.46	10.33	10.25	41.19	38.19
Gemmeiza12	97.00	95.97	83.67	84.75	30.16	30.85	10.66	10.79	43.68	43.15
RLSD5%	1.83	1.82	2.08	2.09	2.03	1.95	0.31	0.36	2.84	2.43
G\Trait	TGW; g		NS/Plot		GY/fed; ardab		BY/fed; tons		HI%	
L2	46.48	44.97	669.35	640.72	16.20	14.71	7.74	7.85	33.14	28.09
L4	45.59	42.91	559.92	605.53	13.18	12.93	7.37	7.48	27.15	26.70
L8	45.39	48.19	407.19	382.88	10.66	9.67	6.29	6.20	29.72	26.78
L13	38.53	44.12	681.31	737.61	16.57	15.53	8.19	7.73	32.31	30.79
L14	46.21	46.39	754.17	751.02	14.26	16.31	7.20	7.51	31.26	33.62
L15	39.77	40.96	839.47	858.49	19.89	17.85	8.69	7.85	35.74	33.79
L17	48.10	47.06	789.53	820.64	17.01	15.35	7.30	7.81	34.93	29.73
L20	37.35	38.53	444.46	474.25	12.65	12.99	7.53	7.61	26.52	25.88
L23	39.39	43.57	504.46	478.43	12.28	11.56	5.97	5.74	32.39	30.65
L24	43.08	46.50	583.55	586.73	14.74	15.01	6.92	6.90	32.31	32.35
L31	43.13	45.04	615.07	615.48	13.10	14.41	7.68	7.84	25.57	28.13
L34	47.86	44.78	599.93	672.02	17.87	18.11	8.37	8.57	34.04	31.93
Misr2	45.62	42.13	655.33	675.63	13.65	13.59	7.10	7.36	30.11	28.04
Giza168	46.88	46.22	720.03	708.62	14.52	15.93	7.70	7.96	29.43	29.48
Gemmeiza12	44.36	43.37	640.61	649.31	14.56	14.57	7.51	7.60	31.07	28.59
RLSD5%	2.88	3.33	32.59	29.27	1.17	1.16	0.35	0.28	2.95	2.76

Means of the studied traits for sowing dates x genotypes interaction are shown in Tables 7, 8 and 9. Line 23 was the earliest in DH on the late sowing date in the two seasons. Lines 4 and 23 were recorded the shortest in PH on the late date in 2nd and 1st seasons, respectively (Table 7). Line 20 gave the highest FLA, SL and NG/S in the recommended date in the two seasons (Tables 7 and 8). Lines 14 and 34 gave the heaviest 1000 grain weight in the recommended date in 1st and 2nd sowing date, respectively. Line 17 recorded the highest NS/Plot in the recommended date in the two seasons (Table 8). Lines 15 and 34 gave the highest values for each of grain yield/fed and biological yield/fed in the recommended sowing date in 1st and 2nd seasons, respectively (Tables 8 and 9).

Table 7. Days to heading, plant height, flag leaf area and spike length for sowing dates x genotypes interaction in first and second seasons

Season	S1 (2021/2022)			S2 (2022/2023)			S1 (2021/2022)			S2 (2022/2023)		
Dates	ED	RD	LD	ED	RD	LD	ED	RD	LD	ED	RD	LD
G\Trait	Days to heading						Plant height; cm					
L2	88.42	93.77	56.83	87.67	85.17	60.17	89.85	83.52	79.75	91.68	83.67	80.70
L4	93.50	89.17	79.67	90.33	86.00	77.83	89.58	83.45	73.98	92.12	86.63	71.01
L8	90.83	90.83	71.25	90.83	88.83	70.33	93.60	85.70	83.03	92.63	81.59	82.01
L13	91.50	91.58	67.83	93.17	89.33	65.33	85.77	84.90	86.93	86.07	87.67	87.83
L14	101.50	102.17	76.50	100.92	104.50	76.67	90.27	90.27	83.36	84.68	92.10	85.13
L15	84.67	86.33	68.33	85.33	85.17	67.17	84.50	87.63	80.88	85.28	91.52	84.03
L17	93.00	100.00	91.50	92.17	99.42	93.42	91.87	93.60	76.17	92.50	86.52	79.57
L20	91.92	86.33	67.00	91.17	87.92	67.92	80.46	78.93	81.74	80.26	78.10	79.32
L23	86.50	82.50	54.00	87.25	83.67	55.00	79.68	86.25	73.27	88.50	83.83	76.03
L24	91.50	85.00	62.00	90.50	86.00	61.33	77.15	80.20	81.33	78.78	80.43	81.98
L31	99.83	105.67	75.50	95.50	102.33	77.17	89.93	90.75	77.34	88.99	91.18	77.28
L34	92.17	88.17	62.75	92.33	88.33	64.08	85.80	91.02	77.89	86.60	94.03	79.63
Misr2	99.50	106.17	81.17	96.83	105.42	80.33	96.84	93.27	79.68	92.35	89.75	78.35
Giza168	100.17	91.17	77.50	99.25	91.25	78.92	82.84	81.18	75.10	86.07	82.31	78.87
Gemmeiza12	101.50	99.50	90.00	98.25	97.75	91.92	82.40	83.48	85.13	86.48	82.30	85.47
RLSD5%	3.07			3.07			3.51			3.52		
	Flag leaf area; cm^2						Spike length; cm					
L2	30.98	46.79	29.59	30.29	44.33	27.64	10.03	10.95	10.27	10.88	11.09	10.08
L4	25.42	26.69	28.37	22.92	25.59	27.79	8.89	10.13	9.82	8.68	10.23	9.88
L8	37.38	46.23	39.66	41.40	44.05	37.67	9.68	11.64	12.19	9.73	11.83	11.96
L13	35.41	37.16	33.06	29.77	34.67	30.50	9.08	12.62	11.33	9.35	13.15	11.17
L14	27.76	32.49	28.58	28.91	31.41	30.31	10.96	11.48	12.26	11.15	11.13	12.48
L15	32.32	44.02	28.31	30.89	45.63	30.79	11.60	11.64	12.74	11.65	12.00	12.80
L17	31.96	29.09	22.73	31.77	30.70	23.71	9.60	10.80	9.99	9.95	11.08	10.12
L20	34.52	52.67	36.34	36.34	51.22	36.51	10.75	15.68	12.82	10.38	15.80	13.06
L23	28.16	43.52	37.41	26.15	43.83	38.31	9.28	13.38	13.08	9.74	13.63	12.32
L24	31.29	40.50	37.51	29.84	43.83	36.13	9.39	11.59	11.31	9.05	11.74	10.40
L31	30.05	40.85	31.84	32.62	43.59	31.16	11.04	11.67	11.74	10.80	11.28	11.85
L34	35.07	37.58	29.92	32.40	38.23	31.02	11.98	13.73	13.69	11.85	14.08	13.77
Misr2	32.88	32.89	30.39	33.13	35.24	30.02	9.29	10.67	9.78	9.40	10.70	9.78
Giza168	26.26	28.92	34.14	27.96	27.22	33.20	9.00	11.08	10.90	9.11	11.20	10.43
Gemmeiza12	27.90	31.47	31.13	28.69	32.85	31.01	9.75	11.20	11.03	9.93	11.47	10.99
RLSD5%	3.53			3.39			0.55			0.63		

Table 8. Number of grains/spike, 1000 grain weight, number of spikes/plot and grain yield/fed for sowing dates x genotypes interaction in first and second seasons

Season	S1 (2021/2022)			S2 (2022/2023)			S1 (2021/2022)			S2 (2022/2023)		
Dates	ED	RD	LD	ED	RD	LD	ED	RD	LD	ED	RD	LD
G\Trait	Number of grains/spike						1000 grain weight; g					
L2	36.58	58.70	31.06	36.81	62.40	32.04	44.35	56.23	38.85	45.88	56.67	32.37
L4	35.06	51.73	34.98	33.58	52.07	31.55	44.01	56.25	36.51	35.69	54.80	38.24
L8	35.01	55.02	35.88	37.39	58.30	32.76	33.69	60.82	41.68	39.02	60.63	44.94
L13	36.06	55.88	38.20	38.95	63.30	35.74	34.39	48.06	33.14	39.06	53.03	40.28
L14	33.22	50.11	30.12	32.80	47.65	32.60	36.09	61.48	41.06	36.64	60.96	41.56
L15	31.92	66.25	32.59	29.37	68.00	32.76	33.49	47.42	38.40	35.91	51.93	35.03
L17	29.66	44.33	26.04	26.78	45.40	26.72	45.46	59.55	39.28	43.78	56.35	41.05
L20	58.14	95.33	49.48	63.25	102.90	52.20	33.08	49.15	29.84	30.71	45.92	38.97
L23	46.37	74.78	43.41	48.92	75.83	43.72	31.80	45.11	41.27	36.27	50.24	44.19
L24	36.38	56.59	39.24	40.32	55.20	40.00	36.42	54.03	38.80	38.25	59.08	42.16
L31	33.49	44.75	28.48	32.36	48.03	29.80	40.22	48.88	40.30	44.60	53.95	36.58
L34	40.69	53.75	44.87	43.27	65.70	45.19	44.98	59.28	39.31	35.14	63.08	36.12
Misr2	30.89	59.72	37.81	25.61	55.53	38.73	46.65	54.95	35.25	40.80	50.66	34.94
Giza168	29.32	55.00	39.25	26.12	52.92	35.52	48.41	57.32	34.91	45.94	57.30	35.43
Gemmeiza12	35.47	56.38	39.19	32.11	56.01	41.33	46.57	52.06	34.44	37.25	50.10	42.75
RLSD5%	5.18			4.24			4.86			5.69		
G\Trait	Number of spikes/plot						Grain yield/fed; ardab					
L2	608.98	809.17	589.92	656.75	704.58	560.81	16.13	21.89	10.57	13.51	19.89	10.74
L4	475.71	673.33	530.71	495.83	752.08	568.67	12.54	16.58	10.42	11.64	16.19	10.95
L8	430.60	414.17	376.81	381.58	447.50	319.54	9.02	13.49	9.46	9.42	11.82	7.77
L13	710.58	822.08	511.25	770.17	933.54	509.13	16.04	22.34	11.33	13.61	19.55	13.43
L14	677.29	908.13	677.08	780.08	816.67	656.31	14.15	17.86	10.77	14.54	22.23	12.16
L15	810.10	978.33	729.98	816.26	1013.44	745.77	15.62	27.26	16.79	15.73	22.87	14.95
L17	680.58	1040.83	647.19	745.17	1087.08	629.67	15.07	24.74	11.22	12.40	22.89	10.76
L20	394.42	479.79	459.17	446.25	606.25	370.25	11.01	17.67	9.29	11.38	17.71	9.88
L23	425.79	716.46	371.13	387.45	707.92	339.92	9.69	18.77	8.37	9.94	16.16	8.59
L24	604.71	636.46	509.48	587.58	737.08	435.51	11.65	20.30	12.26	13.26	21.03	10.75
L31	527.13	818.75	499.33	526.67	749.46	570.31	10.55	18.49	10.28	14.18	19.40	9.65
L34	499.38	768.13	532.29	606.13	830.83	579.10	14.46	24.58	14.58	14.20	25.34	14.78
Misr2	637.50	827.92	500.58	604.75	868.75	553.38	11.04	19.21	10.69	10.24	18.32	12.20
Giza168	751.88	879.58	528.63	723.07	893.75	509.04	14.33	18.54	10.69	13.63	21.25	12.91
Gemmeiza12	485.92	880.00	555.92	552.83	889.17	505.92	12.05	20.94	10.69	10.91	20.00	12.81
RLSD5%	56.75			50.96			2.28			2.24		

Table 9. Biological yield/fed and harvest index for sowing dates x genotypes interaction in first and second seasons

Season	S1 (2021/2022)			S2 (2022/2023)			S1 (2021/2022)			S2 (2022/2023)		
Dates	ED	RD	LD	ED	RD	LD	ED	RD	LD	ED	RD	LD
G\Trait	Biological yield/fed; tons						Harvest index%					
L2	9.37	8.67	5.18	9.58	8.57	5.39	25.73	37.75	35.94	20.92	34.50	28.85
L4	7.24	9.14	5.72	7.01	9.72	5.70	27.34	27.41	26.70	26.89	24.88	28.34
L8	8.57	5.71	4.60	9.32	5.26	4.01	18.16	35.17	35.82	16.47	34.25	29.61
L13	8.34	8.99	7.23	8.51	7.79	6.90	29.86	37.58	29.49	24.47	37.77	30.13
L14	8.72	7.75	5.12	8.21	9.43	4.89	26.52	35.05	32.22	27.45	35.52	37.87
L15	7.78	10.52	7.76	7.08	9.91	6.55	30.95	38.89	37.37	34.23	33.65	33.49
L17	7.94	9.62	4.35	8.48	9.45	5.51	29.15	38.90	36.74	22.95	36.51	29.72
L20	8.54	7.73	6.32	8.54	7.90	6.40	19.09	34.42	26.04	20.14	33.87	23.62
L23	6.32	6.89	4.69	6.48	6.73	4.01	23.10	40.98	33.10	22.88	35.72	33.36
L24	5.84	8.89	6.02	6.03	8.83	5.85	30.40	34.28	32.24	33.41	35.96	27.68
L31	8.41	8.89	5.75	8.42	10.09	5.02	19.59	31.79	25.32	25.98	28.89	29.51
L34	7.60	10.26	7.26	7.39	11.06	7.28	28.77	35.77	37.59	30.06	34.93	30.81
Misr2	5.98	8.98	6.35	6.67	8.63	6.78	29.74	31.88	28.72	23.51	31.70	28.90
Giza168	7.33	9.33	6.45	7.68	9.35	6.83	29.32	29.62	29.37	26.13	33.97	28.34
Gemmeiza12	7.44	8.93	6.18	7.43	9.17	6.19	24.96	35.15	33.11	22.65	32.87	30.23
RLSD5%	0.58			0.47			5.05			4.72		

Means of the studied traits for N levels x genotypes interaction are shown in Tables 10 and 11. Line 23 recorded the earliest in days to heading in low N in both seasons. Line 20 and Giza168 were the shortest genotypes in low N level in 1st and 2nd seasons, respectively. Line 8 gave the highest FLA in the recommended N fertilization in both seasons in addition highest 1000GW in 2nd season. Line 20 recorded the highest values for spike length and no. of grains/spike under the recommended N fertilization in both seasons (Table 10). Line 15 under the recommended N level gave the highest no. spikes/plot in 2nd season and grain yield/fed in the two seasons. Moreover, this line 15 recorded the highest BY/fed in the recommended N in 1st season and highest HI% in low N level in st season and under the recommended N level in 2nd season (Table 11)

Means of the studied traits for dates x N levels x genotypes interaction in the first and second seasons are shown in Tables 12, 13, 14, 15 and 16.

For days to 50% heading (Table 12), the late sowing date with low N resulted in earliness in heading date compared to the early and recommended dates with recommended N fertilization in both seasons. Line 15 was the earliest in early date under two N levels in the two seasons. Line 23 was the earliest on the recommended and late dates under two N levels in 1st season in addition the late date under two N levels in 2nd season. In 2nd season in the recommended date, line 15 under low N and line 23 under the recommended N were the earliest genotypes (Table 12). It was observed that under both two N levels, the late sowing date resulted in earliness in days to 50% heading by 25.08 and 18.44% compared to the recommended sowing date under low and recommended N levels, respectively over the two seasons. Ahmed (2021) found that the late sowing date recorded the earliness in heading days.

For plant height (Table 12), Giza168 was the shortest in plant height in 1st season in the recommended and late dates under low N level. Line 4 recorded the lowest plant height in 2nd season on the late date under two N levels (Table 13). Increasing nitrogen application gave increasing cell division and elongation leads to an increase in plant height (Dogan and Bilgili, 2010).

Table 10. Days to heading, plant height, flag leaf area and spike length, spike length, no. of grains/spike and 1000 grain weight for N levels x genotypes interaction in first and second seasons

Season	S1		S2		S1		S2		S1		S2	
N level	LN	RN	LN	RN	LN	RN	LN	RN	LN	RN	LN	RN
G\Trait	Days to heading				Plant height; cm				Flag leaf area; cm^2			
L2	77.71	81.63	76.11	79.22	79.48	89.27	80.07	90.63	34.04	37.53	32.10	36.07
L4	84.56	90.33	81.22	88.22	78.74	85.92	78.91	87.60	25.04	28.61	23.77	27.10
L8	83.11	85.50	82.22	84.44	85.49	89.40	81.14	89.69	35.61	46.57	37.07	45.00
L13	81.61	85.67	80.44	84.78	80.94	90.79	83.16	91.21	30.96	39.46	27.28	36.01
L14	88.17	98.61	88.06	100.00	86.53	89.40	84.09	90.52	26.96	32.25	27.19	33.23
L15	77.00	82.56	76.56	81.89	80.22	88.46	83.40	90.49	32.92	36.85	33.65	37.89
L17	91.17	98.50	92.28	97.72	83.19	91.23	80.83	91.56	25.38	30.47	25.91	31.53
L20	79.56	83.94	80.06	84.61	77.31	83.44	73.92	84.54	38.25	44.10	38.75	43.96
L23	71.67	77.00	72.33	78.28	74.38	85.09	77.44	88.13	32.56	40.17	32.24	39.95
L24	78.39	80.61	78.67	79.89	76.62	82.50	77.93	82.87	31.93	40.93	32.19	41.01
L31	87.67	99.67	84.78	98.56	81.64	90.38	82.44	89.20	31.80	36.70	32.67	38.91
L34	78.83	83.22	79.78	83.39	81.72	88.08	84.36	89.16	32.56	35.82	32.31	35.46
Misr2	88.78	102.44	88.39	100.00	85.72	94.14	82.33	91.30	30.31	33.79	31.48	34.11
Giza168	85.33	93.89	84.33	95.28	71.64	87.78	77.36	87.47	25.11	34.44	25.25	33.67
Gemmeiza12	93.44	100.56	93.17	98.78	80.08	87.26	81.27	88.23	28.46	31.87	28.88	32.82
RLSD5%	2.94		2.92		3.48		4.03		3.51		3.88	
	Spike length; cm				No. of grains/spike				1000 grain weight; g			
L2	9.75	11.09	9.95	11.42	38.46	45.77	39.59	47.91	43.60	49.36	43.55	46.40
L4	9.27	9.96	9.07	10.12	40.72	40.46	39.39	38.74	45.03	46.15	42.57	43.24
L8	10.49	11.85	10.56	11.78	38.26	45.68	37.56	48.08	41.58	49.21	40.20	56.19
L13	9.84	12.17	9.90	12.54	39.83	46.92	41.92	50.07	37.76	39.30	39.55	48.69
L14	11.36	11.77	11.17	12.00	35.72	39.92	34.78	40.59	45.05	47.36	44.49	48.29
L15	11.23	12.76	11.57	12.73	39.27	47.90	41.38	45.38	37.73	41.81	38.69	43.23
L17	9.80	10.46	9.99	10.78	29.76	36.93	31.28	34.65	47.34	48.85	47.48	46.64
L20	12.17	13.99	12.42	13.74	59.85	75.45	67.07	78.50	37.37	37.34	33.81	43.25
L23	11.10	12.73	11.03	12.77	53.43	56.27	55.29	57.02	40.97	37.81	38.09	49.04
L24	10.19	11.34	9.86	10.93	44.85	43.29	44.38	45.97	39.88	46.29	43.49	49.51
L31	10.92	12.05	10.81	11.80	32.21	38.93	36.14	37.32	40.54	45.73	42.31	47.78
L34	12.78	13.49	12.93	13.54	44.40	48.47	44.25	58.52	46.39	49.33	43.87	45.69
Misr2	9.61	10.21	9.78	10.14	41.45	44.16	39.85	40.06	45.25	45.99	40.92	43.34
Giza168	9.61	11.04	9.54	10.95	37.78	44.60	37.63	38.74	44.45	49.31	41.90	50.55
Gemmeiza12	9.90	11.42	10.52	11.07	42.08	45.28	42.27	44.03	44.52	44.19	40.30	46.43
RLSD5%	0.50		0.73		4.91		3.91		5.32		5.85	

Table 11. Number of spikes/plot and grain yield/fed, biological yield/fed and harvest index for N levels x genotypes interaction in first and second seasons

Season	S1		S2		S1		S2	
N level	LN	RN	LN	RN	LN	RN	LN	RN
G\Trait	No. of spikes/plot				Grain yield/fed; ardab			
L2	537.39	801.32	549.00	732.43	13.55	18.85	11.03	18.39
L4	548.03	571.81	544.39	666.67	12.35	14.01	11.38	14.47
L8	386.89	427.50	372.97	392.78	7.75	13.56	8.31	11.03
L13	587.89	774.72	700.22	775.00	15.07	18.07	13.50	17.56
L14	680.47	827.86	655.72	846.32	12.84	15.68	14.05	18.57
L15	802.83	876.11	840.39	876.58	17.28	22.50	13.50	22.20
L17	654.83	924.24	810.81	830.47	16.29	17.72	13.44	17.25
L20	443.06	445.86	468.56	479.94	11.24	14.07	12.98	13.00
L23	463.64	545.28	460.08	496.78	10.72	13.83	9.07	14.06
L24	546.75	620.35	530.92	642.53	13.63	15.85	15.07	14.96
L31	651.25	578.89	594.44	636.51	12.80	13.41	14.43	14.39
L34	527.44	672.42	637.52	706.53	13.89	21.85	16.61	19.60
Misr2	603.31	707.36	632.36	718.89	12.26	15.03	12.26	14.92
Giza168	661.03	779.03	644.88	772.36	11.52	17.52	12.50	19.36
Gemmeiza12	544.72	736.50	542.43	756.18	12.50	16.62	12.33	16.82
RLSD5%	49.68		46.97		1.88		1.86	
	Biological yield/fed; tons				Harvest index%			
L2	6.88	8.61	6.76	8.93	33.32	32.96	24.88	31.30
L4	6.18	8.55	6.26	8.70	29.51	24.79	28.08	25.33
L8	4.44	8.15	4.48	7.92	30.86	28.57	29.56	24.00
L13	6.77	9.60	6.09	9.38	36.37	28.25	33.09	28.48
L14	5.52	8.87	6.51	8.51	35.04	27.48	33.77	33.46
L15	7.49	9.89	6.66	9.04	37.20	34.28	31.18	36.40
L17	6.37	8.24	6.64	8.99	36.74	33.13	29.41	30.05
L20	6.51	8.55	6.84	8.39	28.60	24.43	28.66	23.10
L23	5.06	6.88	4.70	6.78	35.28	29.51	30.57	30.74
L24	6.19	7.65	6.29	7.51	33.86	30.75	35.07	29.63
L31	6.33	9.03	6.93	8.75	28.78	22.36	31.35	24.90
L34	7.21	9.54	6.97	10.18	33.79	34.30	35.39	28.48
Misr2	5.86	8.35	6.24	8.48	33.82	26.40	29.95	26.12
Giza168	6.53	8.88	6.78	9.13	29.45	29.42	27.34	31.62
Gemmeiza12	6.52	8.50	6.79	8.40	33.02	29.13	27.12	30.06
RLSD5%	0.56		0.45		4.18		3.90	

Table 12. Days to 50% heading and plant height for dates x N levels x genotypes interaction in the first and second seasons.

Days to heading												
Season	First season (2021/2022)						Second season (2022/2023)					
Dates	Early date		Recom. date		Late date		Early date		Recom. date		Late date	
Gen./N.	LN	RN	LN	RN	LN	RN	LN	RN	LN	RN	LN	RN
L2	87.50	89.33	91.97	95.57	53.67	60.00	87.33	88.00	83.33	87.00	57.67	62.67
L4	89.00	98.00	88.67	89.67	76.00	83.33	87.67	93.00	83.00	89.00	73.00	82.67
L8	90.67	91.00	89.67	92.00	69.00	73.50	90.67	91.00	87.33	90.33	68.67	72.00
L13	91.00	92.00	88.50	94.67	65.33	70.33	91.33	95.00	87.33	91.33	62.67	68.00
L14	100.00	103.00	100.00	104.33	64.50	88.50	100.50	101.33	103.00	106.00	60.67	92.67
L15	83.33	86.00	82.33	90.33	65.33	71.33	84.67	86.00	80.00	90.33	65.00	69.33
L17	92.00	94.00	93.00	107.00	88.50	94.50	90.00	94.33	97.33	101.50	89.50	97.33
L20	87.33	96.50	84.67	88.00	66.67	67.33	89.33	93.00	85.33	90.50	65.50	70.33
L23	85.67	87.33	81.33	83.67	48.00	60.00	87.00	87.50	81.33	86.00	48.67	61.33
L24	91.00	92.00	83.50	86.50	60.67	63.33	89.00	92.00	85.67	86.33	61.33	61.33
L31	97.00	102.67	103.67	107.67	62.33	88.67	92.00	99.00	99.67	105.00	62.67	91.67
L34	91.33	93.00	84.67	91.67	60.50	65.00	92.00	92.67	84.67	92.00	62.67	65.50
Misr2	97.00	102.00	103.33	109.00	66.00	96.33	94.67	99.00	102.50	108.33	68.00	92.67
Giza168	97.00	103.33	87.00	95.33	72.00	83.00	95.50	103.00	83.00	99.50	74.50	83.33
Gemmeiza12	99.67	103.33	96.67	102.33	84.00	96.00	96.50	100.00	94.50	101.00	88.50	95.33
RLSD5%	4.72						4.69					
Plant height; cm												
L2	81.20	98.50	79.13	87.90	78.10	81.40	82.20	101.17	79.00	88.33	79.00	82.40
L4	88.40	90.75	80.03	86.87	67.80	80.15	88.33	95.90	84.60	88.67	63.80	78.22
L8	92.80	94.40	81.73	89.67	81.93	84.13	88.20	97.07	74.19	89.00	81.02	83.00
L13	81.73	89.80	76.13	93.67	84.95	88.90	81.80	90.33	81.13	94.20	86.55	89.10
L14	88.00	92.53	89.73	90.80	81.85	84.87	79.40	89.97	91.00	93.20	81.87	88.40
L15	82.60	86.40	86.00	89.27	72.05	89.70	83.90	86.67	86.10	96.93	80.20	87.87
L17	87.93	95.80	91.00	96.20	70.63	81.70	87.10	97.90	79.40	93.63	76.00	83.13
L20	78.27	82.65	74.90	82.95	78.75	84.73	78.47	82.05	69.87	86.33	73.42	85.23
L23	75.13	84.23	83.40	89.10	64.60	81.93	80.53	96.47	81.20	86.47	70.60	81.46
L24	74.30	80.00	75.90	84.50	79.67	83.00	76.93	80.63	75.93	84.93	80.93	83.04
L31	88.27	91.60	89.03	92.47	67.61	87.07	88.66	89.32	90.10	92.27	68.55	86.00
L34	83.40	88.20	88.63	93.40	73.13	82.65	85.00	88.20	93.07	95.00	75.00	84.27
Misr2	93.75	99.93	86.20	100.33	77.20	82.15	90.70	94.00	80.80	98.70	75.50	81.20
Giza168	79.35	86.33	72.97	89.40	62.60	87.60	81.40	90.73	75.96	88.67	74.73	83.00
Gemmeiza12	78.87	85.93	77.10	89.85	84.27	86.00	84.40	88.57	75.07	89.53	84.33	86.60
RLSD5%	5.52						5.22					

Table 13. Flag leaf area and spike length for dates x N levels x genotypes interaction in the first and second seasons

Season	First season (2021/2022)						Second season (2022/2023)					
Dates	Early date		Recom. date		Late date		Early date		Recom. date		Late date	
Gen./N.	LN	RN	LN	RN	LN	RN	LN	RN	LN	RN	LN	RN
						Flag leaf area; cm^2						
L2	30.18	31.78	44.34	49.25	27.60	31.58	29.32	31.26	42.19	46.47	24.79	30.49
L4	24.26	26.58	25.23	28.14	25.63	31.11	21.34	24.50	23.33	27.85	26.65	28.94
L8	31.00	43.75	43.04	49.42	32.78	46.55	36.87	45.94	41.58	46.51	32.78	42.56
L13	33.95	36.87	33.46	40.85	25.47	40.65	28.94	30.60	32.22	37.11	20.68	40.33
L14	24.82	30.69	31.13	33.84	24.93	32.23	23.93	33.89	29.25	33.57	28.39	32.23
L15	30.88	33.77	41.35	46.68	26.54	30.09	29.74	32.05	42.78	48.48	28.44	33.14
L17	30.59	33.33	24.91	33.27	20.65	24.82	30.48	33.05	24.67	36.73	22.59	24.82
L20	32.31	36.74	49.47	55.87	32.98	39.69	35.19	37.49	48.08	54.36	32.98	40.04
L23	20.58	35.75	42.35	44.68	34.75	40.07	20.08	32.23	41.89	45.76	34.75	41.87
L24	24.90	37.68	36.40	44.60	34.49	40.52	23.66	36.01	38.41	49.24	34.49	37.77
L31	27.71	32.39	39.42	42.28	28.27	35.42	30.45	34.79	40.66	46.53	26.90	35.42
L34	32.51	37.64	36.17	38.99	29.01	30.84	30.99	33.82	36.47	40.00	29.48	32.56
Misr2	32.26	33.50	30.73	35.06	27.95	32.82	32.25	34.00	34.25	36.24	27.95	32.10
Giza168	21.99	30.54	22.08	35.77	31.27	37.02	23.54	32.38	20.95	33.50	31.27	35.14
Gemmeiza12	26.01	29.78	29.41	33.54	29.96	32.29	27.40	29.99	29.52	36.18	29.73	32.29
RLSD5%	NS						6.27					
						Spike length; cm						
L2	8.67	11.40	10.80	11.10	9.78	10.77	9.80	11.95	10.45	11.73	9.60	10.57
L4	8.45	9.33	10.03	10.22	9.32	10.33	8.00	9.35	10.15	10.31	9.07	10.69
L8	8.90	10.45	10.99	12.30	11.58	12.80	8.95	10.50	11.20	12.45	11.52	12.40
L13	8.00	10.17	11.53	13.70	10.00	12.65	7.95	10.75	12.15	14.15	9.60	12.73
L14	10.93	11.00	11.13	11.83	12.04	12.48	10.95	11.35	10.75	11.50	11.82	13.14
L15	10.50	12.70	11.05	12.23	12.13	13.35	10.70	12.60	11.50	12.50	12.50	13.10
L17	9.20	10.00	10.40	11.20	9.80	10.18	9.50	10.40	10.70	11.47	9.77	10.48
L20	10.00	11.50	15.35	16.00	11.17	14.48	9.60	11.17	15.50	16.10	12.15	13.97
L23	8.00	10.55	13.00	13.75	12.29	13.88	8.65	10.83	12.53	14.73	11.90	12.73
L24	9.05	9.73	11.33	11.85	10.20	12.43	8.90	9.20	11.38	12.10	9.30	11.50
L31	10.53	11.55	11.17	12.17	11.05	12.43	10.44	11.16	10.90	11.65	11.10	12.59
L34	11.57	12.40	13.13	14.33	13.63	13.75	11.55	12.15	13.60	14.57	13.63	13.90
Misr2	9.10	9.48	10.27	11.07	9.45	10.10	9.30	9.50	10.40	11.00	9.63	9.93
Giza168	8.35	9.65	10.42	11.75	10.07	11.73	7.93	10.30	10.97	11.43	9.73	11.13
Gemmeiza12	9.30	10.20	10.10	12.30	10.30	11.75	9.75	10.10	11.38	11.55	10.43	11.55
RLSD5%	1.01						1.40					

For flag leaf area (Table 13), the lowest flag leaf area recorded for L23 in early sowing date under low N level in the two seasons. While, the highest FLA recorded for line 20 on the recommended date under low and the recommended N level in both seasons. Line 17 recorded the lowest FLA in late sowing date by 21.62 and 24.82 cm^2 under low and recommended N fertilization, respectively over two seasons (Table 14). This indicating that this line could be heat stress tolerant this may be attributed to narrow leaf area consequently reduce of exposure to sunlight and thus reduced transpiration.

For spike length (Table 13), line 20 recorded the highest spike length on the recommended date under two N level and the late date under recommended N level in the two seasons. Line 34 gave the highest spike length on the early and late date under low N level in both seasons. Line 15 recoded the highest spike length on the early date

under the recommended N level in both seasons (Table 13).

For number of grains spike^{-1} (Table 14), line 20 gave the highest NG S^{-1} in the three sowing dates under two N levels in the two seasons. While, line 17 gave the lowest NG S^{-1} in the most of the interactions of sowing dates x N levels x genotypes in the two seasons (Table 14).

For 1000 grain weight (Table 14), line 20 gave the lowest 1000GW in the most of second order of the interaction of sowing dates x N levels x genotypes in the two seasons (Table 14). Line 2 gave the heaviest 1000GW in the early date under recommended N in 1st season, while gave the lowest 1000GW on the late date under the recommended N in 2nd season. Line 8 in 1st season on the recommended and late dates under the recommended N level gave the heaviest 1000GW. Line 14 in 2nd season recorded the heaviest 1000GW on the recommended date and N level in addition the late date with low N level. Line 34 recorded the highest 100GW on the recommended date under low N level in the two season.

For number spikes plot^{-1} (Table 15), line 15 recorded the highest NS/plot on the early and late dates under low N level in the two seasons in addition on the recommended conditions from date and N level in 2nd season. Line 14 gave the highest NS/plot on the late date under recommended N level in the two seasons. Line 17 recorded the highest NS/plot on the recommended date with low N level in both seasons in addition the early date with the recommended N level in 1st season. Line 8 gave the lowest NS/plot in with both N levels in the recommended sowing date in the two seasons and in late sowing date in 2nd season. Mahajan *et al.* (2018) and Abd Al-dahi and Al-Taweel (2021) indicated that the highest number of spikes m^{-2} was obtained when sowing dates on 10 and 25 November compared planting at the late date of 25 December. The recommended date allow increase the area of the flag leaf and thus increase the effectiveness of the process of photosynthesis and accumulation of dry matter, which led to an increase in the no. of spikes m^{-2}.

Regarding grain yield per fed in three dates under two N levels in the two seasons (Table 15), Line 15 recorded the highest GY/fed on the late date with the recommended N level in both seasons in addition the recommended date with low N level in 1st season and with the recommended N level in 2nd season. Line 34 gave the highest GY/fed in both seasons on the recommended date using the recommended and low N level in addition on the late date using low N level in 2nd season. Line 8 recorded the lowest GY/fed in the most cases of interaction of three dates x two N levels in the two seasons.

Mean biological yield fed^{-1} (Table 16), line 2 recorded the highest BY/fed on the early date with low N level in the two seasons. While, line 8 behaved the same trend of line 2 but under the recommended N level. Line 15 recorded the highest BY/fed in 1st season on the recommended date with low N level and on the late date with the recommended N level. Line 34 gave the highest BY/fed on the recommended conditions from date and N level in both seasons (Table 16).

For mean harvest index (Table 16), line 15 recorded the highest HI% on the recommended and late dates with the recommended N level in addition the early date with low N level in 2nd season. Line 17 gave the highest HI on the late date with the two N levels in addition on the recommended date with low N level in 1st season. Giza168 gave the highest HI% on the early date with the recommended N level in the two seasons (Table 16).

Table 14. Number of grains /spike and 1000 grain weight for dates x N levels x genotypes interaction in the first and second seasons

	No. of grains/spike											
Season	First season (2021/2022)						Second season (2022/2023)					
Dates	Early date		Recom. date		Late date		Early date		Recom. date		Late date	
Gen./N.	LN	RN	LN	RN	LN	RN	LN	RN	LN	RN	LN	RN
L2	33.11	40.05	53.90	63.50	28.37	33.75	33.60	40.02	57.80	67.00	27.37	36.70
L4	33.93	36.20	54.33	49.13	33.90	36.05	32.62	34.54	54.33	49.80	31.22	31.88
L8	29.59	40.43	51.85	58.20	33.36	38.40	30.15	44.63	51.30	65.30	31.22	34.30
L13	32.06	40.05	53.05	58.70	34.39	42.00	33.88	44.01	61.00	65.60	30.87	40.60
L14	30.29	36.15	52.27	47.95	24.59	35.65	29.19	36.41	47.50	47.80	27.66	37.55
L15	25.48	38.35	61.57	70.93	30.75	34.43	28.14	30.60	63.10	72.90	32.90	32.63
L17	28.37	30.95	39.35	49.30	21.56	30.53	27.30	26.25	43.80	47.00	22.73	30.71
L20	55.30	60.98	80.70	109.95	43.54	55.43	57.70	68.80	96.50	109.30	46.99	57.40
L23	44.59	48.15	71.05	78.50	44.66	42.15	47.88	49.95	74.67	77.00	43.34	44.10
L24	33.60	39.15	58.38	54.80	42.56	35.93	41.93	38.70	52.80	57.60	38.40	41.60
L31	28.28	38.70	44.20	45.30	24.15	32.80	34.16	30.55	46.47	49.60	27.79	31.80
L34	36.73	44.65	57.80	49.70	38.69	51.05	38.43	48.11	55.20	76.20	39.13	51.25
Misr2	29.12	32.65	59.80	59.63	35.42	40.20	26.74	24.48	54.40	56.67	38.41	39.05
Giza168	27.58	31.05	49.90	60.10	35.86	42.64	32.97	19.28	46.53	59.30	33.39	37.65
Gemmeiza12	32.95	38.00	54.50	58.25	38.78	39.60	32.34	31.89	53.67	58.35	40.81	41.85
RLSD5%	9.16						7.84					
	1000 grain weight; g											
L2	37.10	51.60	56.20	56.27	37.50	40.20	40.86	50.90	58.43	54.90	31.36	33.39
L4	43.42	44.60	58.80	53.70	32.85	40.16	39.04	32.34	57.57	52.03	31.12	45.36
L8	32.97	34.41	55.07	66.57	36.70	46.65	32.39	45.65	54.47	66.78	33.74	56.14
L13	35.40	33.38	46.55	49.57	31.33	34.95	37.44	40.68	50.23	55.82	30.98	49.58
L14	34.72	37.45	58.60	64.37	41.84	40.28	37.49	35.80	54.33	67.58	41.65	41.48
L15	33.76	33.23	43.63	51.20	35.81	41.00	34.79	37.03	48.17	55.70	33.11	36.95
L17	46.36	44.55	58.80	60.30	36.87	41.70	45.01	42.55	56.40	56.30	41.02	41.08
L20	29.98	36.18	54.07	44.23	28.07	31.60	26.32	35.10	46.87	44.97	28.26	49.68
L23	31.48	32.13	45.45	44.77	45.99	36.55	35.49	37.05	47.07	53.42	31.71	56.66
L24	35.61	37.24	52.43	55.63	31.59	46.00	38.08	38.43	59.45	58.72	32.95	51.38
L31	39.04	41.40	44.87	52.90	37.73	42.88	36.93	52.28	52.30	55.60	37.71	35.46
L34	41.60	48.35	60.07	58.50	37.50	41.13	35.91	34.38	60.40	65.75	35.30	36.94
Misr2	46.62	46.68	56.33	53.57	32.78	37.73	38.78	42.83	50.53	50.78	33.46	36.43
Giza168	46.53	50.30	53.80	60.83	33.02	36.80	37.73	54.15	55.28	59.32	32.69	38.18
Gemmeiza12	47.76	45.38	52.20	51.92	33.60	35.29	37.71	36.79	48.43	51.77	34.76	50.75
RLSD5%	8.60						8.05					

Table 15. Number of spikes/plot and grain yield/fed for dates x N levels x genotypes interaction in the first and second seasons

	No. of spikes/plot											
Season	First season (2021/2022)						Second season (2022/2023)					
Dates	Early date		Recom. date		Late date		Early date		Recom. date		Late date	
Gen./N.	LN	RN	LN	RN	LN	RN	LN	RN	LN	RN	LN	RN
L2	527.33	690.63	645.00	973.33	439.83	740.00	598.50	715.00	642.50	766.67	406.00	715.63
L4	470.17	481.25	695.00	651.67	478.92	582.50	449.17	542.50	656.67	847.50	527.33	610.00
L8	411.83	449.38	353.33	475.00	395.50	358.13	428.17	335.00	371.67	523.33	319.08	320.00
L13	596.17	825.00	730.00	914.17	437.50	585.00	677.83	862.50	873.33	993.75	549.50	468.75
L14	639.33	715.25	856.67	959.58	545.42	808.75	767.67	792.50	650.00	983.33	549.50	763.13
L15	775.83	844.38	923.33	1033.33	709.33	750.63	815.27	817.25	940.00	1086.88	765.92	725.63
L17	438.67	922.50	983.33	1098.33	542.50	751.88	718.08	772.25	1092.50	1081.67	621.83	637.50
L20	408.33	380.50	460.00	499.58	460.83	457.50	371.00	521.50	639.17	573.33	395.50	345.00
L23	397.83	453.75	648.33	784.58	344.75	397.50	400.40	374.50	645.00	770.83	334.83	345.00
L24	524.42	685.00	655.00	617.92	460.83	558.13	452.67	722.50	765.00	709.17	375.08	495.94
L31	544.25	510.00	883.33	754.17	526.17	472.50	478.33	575.00	753.75	745.17	551.25	589.38
L34	451.50	547.25	670.00	866.25	460.83	603.75	542.27	670.00	763.33	898.33	606.96	551.25
Misr2	630.00	645.00	680.00	975.83	499.92	501.25	602.00	607.50	750.83	986.67	544.25	562.50
Giza168	796.25	707.50	658.33	1100.83	528.50	528.75	621.13	825.00	796.67	990.83	516.83	501.25
Gemmeiza12	481.83	490.00	765.00	995.00	387.33	724.50	515.67	590.00	791.67	986.67	319.96	691.88
RLSD5%	83.98						75.41					
	Grain yield/fed; ardab											
L2	14.17	18.10	18.75	25.02	7.72	13.41	10.49	16.52	15.77	24.01	6.83	14.64
L4	12.83	12.25	15.74	17.43	8.49	12.35	12.17	11.10	13.80	18.59	8.18	13.71
L8	6.67	11.38	10.57	16.41	6.02	12.89	8.51	10.34	9.87	13.76	6.54	8.99
L13	14.40	17.69	21.10	23.58	9.71	12.95	10.92	16.31	17.63	21.46	11.95	14.91
L14	15.14	13.15	15.33	20.38	8.04	13.50	13.08	15.99	19.76	24.71	9.32	15.01
L15	13.34	17.91	27.46	27.05	11.04	22.55	15.74	15.72	14.53	31.20	10.23	19.67
L17	13.74	16.40	25.58	23.89	9.57	12.87	10.78	14.01	21.22	24.57	8.33	13.18
L20	8.46	13.55	15.73	19.61	9.52	9.05	11.91	10.85	16.84	18.57	10.19	9.57
L23	8.85	10.53	15.88	21.66	7.44	9.30	8.41	11.46	12.13	20.20	6.66	10.52
L24	10.48	12.82	19.13	21.47	11.28	13.25	12.51	14.00	22.73	19.33	9.95	11.55
L31	9.42	11.67	17.87	19.11	11.11	9.45	13.11	15.25	21.47	17.33	8.72	10.58
L34	12.04	16.88	20.78	28.39	8.87	20.30	13.62	14.78	23.20	27.48	13.02	16.53
Misr2	11.29	10.80	14.78	23.64	10.72	10.66	9.97	10.50	15.38	21.27	11.42	12.98
Giza168	12.76	15.90	15.18	21.91	6.63	14.75	9.71	17.56	18.43	24.07	9.36	16.45
Gemmeiza12	11.71	12.40	18.53	23.34	7.26	14.11	10.76	11.07	17.47	22.53	8.77	16.85
RLSD5%	3.22						3.17					

Table 16. Biological yield/fed and harvest index for dates x N levels x genotypes interaction in the first and second seasons

	Biological yield/fed; tons											
Season	First season (2021/2022)						Second season (2022/2023)					
Dates	Early date		Recom. date		Late date		Early date		Recom. date		Late date	
Gen./N.	LN	RN	LN	RN	LN	RN	LN	RN	LN	RN	LN	RN
L2	8.69	10.06	7.63	9.70	4.32	6.05	8.91	10.26	7.06	10.08	4.31	6.47
L4	5.71	8.76	8.07	10.22	4.75	6.68	5.39	8.64	8.65	10.79	4.74	6.66
L8	5.00	12.14	4.72	6.71	3.60	5.59	6.28	12.36	4.04	6.48	3.10	4.92
L13	6.38	10.31	8.27	9.70	5.67	8.79	6.25	10.77	6.78	8.79	5.23	8.58
L14	6.49	10.96	6.35	9.16	3.74	6.51	6.29	10.13	9.65	9.20	3.59	6.19
L15	5.91	9.65	10.62	10.43	5.94	9.58	6.10	8.06	8.41	11.41	5.45	7.65
L17	6.37	9.51	9.08	10.16	3.66	5.05	6.09	10.88	8.39	10.52	5.45	5.57
L20	7.49	9.59	6.62	8.83	5.42	7.23	7.98	9.10	6.99	8.82	5.55	7.25
L23	5.56	7.08	5.95	7.83	3.67	5.72	5.95	7.00	5.40	8.06	2.74	5.28
L24	4.74	6.93	8.23	9.55	5.59	6.45	5.26	6.80	8.42	9.24	5.19	6.50
L31	6.21	10.60	7.52	10.26	5.27	6.24	6.74	10.10	10.05	10.12	4.01	6.03
L34	6.06	9.14	9.05	11.47	6.51	8.00	5.75	9.03	9.13	12.98	6.02	8.53
Misr2	4.49	7.48	8.58	9.39	4.53	8.17	5.60	7.74	8.24	9.03	4.87	8.68
Giza168	6.59	8.07	8.11	10.55	4.89	8.02	6.90	8.46	8.48	10.23	4.96	8.71
Gemmeiza12	6.10	8.78	8.54	9.32	4.94	7.42	6.16	8.69	9.24	9.10	4.96	7.41
RLSD5%	0.89						0.72					
	Harvest index%											
L2	24.47	26.99	36.84	38.67	26.81	33.21	17.64	24.20	33.29	35.71	23.71	33.99
L4	33.71	20.96	29.25	25.57	26.79	27.83	34.46	19.33	23.93	25.83	25.87	30.81
L8	22.26	14.06	33.65	36.69	25.05	34.96	20.39	12.55	36.67	31.84	31.62	27.61
L13	33.95	25.77	38.27	36.88	25.61	22.09	26.20	22.73	38.92	36.62	34.17	26.10
L14	35.03	18.01	36.71	33.38	32.46	31.06	31.21	23.69	30.79	40.25	39.32	36.43
L15	33.82	28.08	38.78	39.01	27.85	35.74	39.21	29.24	26.07	41.23	28.26	38.73
L17	32.41	25.90	42.56	35.25	39.25	38.23	26.56	19.34	37.94	35.08	23.72	35.72
L20	16.97	21.21	35.52	33.32	26.32	18.76	22.39	17.89	36.13	31.60	27.45	19.80
L23	23.87	22.33	40.27	41.69	32.40	24.51	21.22	24.54	33.63	37.80	36.85	29.87
L24	33.03	27.77	34.86	33.71	30.31	30.78	35.99	30.83	40.51	31.41	28.71	26.65
L31	22.76	16.43	35.62	27.96	32.86	22.68	29.33	22.62	32.09	25.69	32.64	26.37
L34	29.83	27.72	34.43	37.11	20.47	38.08	35.54	24.57	38.17	31.70	32.45	29.17
Misr2	37.71	21.76	25.94	37.83	35.61	19.61	26.71	20.30	28.05	35.36	35.09	22.72
Giza168	29.11	29.53	28.08	31.15	20.35	27.59	21.12	31.14	32.64	35.30	28.25	28.43
Gemmeiza12	28.76	21.17	32.62	37.68	22.34	28.55	26.21	19.09	28.62	37.12	26.51	33.96
RLSD5%	7.14						6.67					

3.2. Heat sensitivity index

The heat sensitivity index (HSI) was calculated from the recommended and late (heat) sowing dates over two seasons in Table 17.

Under low nitrogen, L8 and 20 recorded an HSI lower than one for DH, PH, NS, BY and GY (Table 17). L17, L2, L24, Gemmieza12, L 23, L8, L20 and Misr2 gave the lowest HSI and lower than unity for DH, PH, FLA, (SL, NG), TGW, NS, BY and GY, respectively. Under recommended N, Gemmieza12 gave HSI lower than 1 for all studied traits except HI (Table 16). L24, L14, L23, L2, L13, L15 and L34 recorded the lowest HSI for (PH, SL), FLA, TGW, NS, BY, GY, (NG/S, HI), respectively (Table 16). For grain yield under low N, Misr2 recorded the

lowest HSI followed by lines 8, 20, 4 and 13, indicating these genotypes were tolerant to heat and nitrogen stress. Misr2 gave the highest grain yield on the late sowing date. Under the recommended N level, line 15 gave the lowest HSI (0.71) followed by line 4, Giza 168, Gemmieza12 and L34. Moreover, L15, 34, Giza168 and Gemmieza12 recorded grain yield higher than 15 ardab/fed. on the late sowing date under the recommended N of the two seasons (Table 11). Meaning, that these genotypes could be achieve high grain yield with sowing at a late date in case of adding recommended N fertilization to compensate for the late of sowing date. Moreover, lines 15 and L34 achieved the highest grain yield in recommended and late sowing dates. Jarecki (2024) found that the late sowing date of wheat by one moth caused a reduction in grain yield could be compensated with increased N fertilization. Sood *et al*. (2017), Suresh *et al.* (2018), Fouad (2019) and Fouad *et al.* (2022) indicated that some wheat genotypes were desirable for most of the determined traits and recorded HSI values less than unity, so considered a heat tolerant genotypes.

Table 17. Heat sensitivity index under low and recommended nitrogen fertilization averaged over two seasons

N					Low N					
G\Trait	DH	PH	FLA	SL	NG/S	TWG	NS/plot	BY/fed	GY/fed	HI
L2	1.26	0.09	2.17	1.54	1.26	1.15	1.04	1.04	1.19	2.01
L4	0.53	2.85	-0.42	1.56	1.00	1.30	0.78	1.09	0.89	0.07
L8	0.89	-0.64	1.24	-0.72	0.94	1.03	0.04	0.59	0.79	1.40
L13	1.08	-1.28	1.64	3.01	1.07	1.03	1.17	0.70	0.90	1.62
L14	1.53	1.34	0.65	-1.57	1.19	0.75	0.83	1.37	1.04	-0.46
L15	0.79	1.64	1.91	-1.61	1.23	0.72	0.63	1.01	1.01	0.97
L17	0.26	1.98	0.70	1.27	1.17	0.93	1.34	1.21	1.27	1.57
L20	0.89	-0.73	1.78	4.26	1.23	1.27	0.67	0.49	0.81	1.80
L23	1.62	2.53	0.96	0.92	0.99	0.46	1.45	1.10	1.02	0.45
L24	1.11	-0.82	0.43	2.46	0.68	1.22	1.25	0.89	1.01	1.56
L31	1.54	3.40	1.71	-0.07	1.07	0.64	1.04	1.19	1.02	0.24
L34	1.09	2.62	1.07	-0.35	0.78	1.14	0.78	0.78	1.03	1.95
Misr2	1.39	1.21	0.77	1.34	0.89	1.10	0.82	1.11	0.54	-2.23
Giza168	0.55	1.10	-2.50	1.29	0.71	1.15	0.86	1.02	1.08	1.44
Gemmeiza12	0.39	-1.53	-0.07	0.61	0.66	0.92	1.66	1.12	1.14	1.46
N					Recommended N					
L2	1.61	0.99	2.33	2.56	1.24	1.34	0.49	1.35	1.11	0.63
L4	0.38	1.38	-0.48	-0.93	0.85	0.76	0.62	1.34	0.72	-0.92
L8	1.10	0.91	0.47	-0.71	1.11	0.91	0.97	0.75	0.71	0.57
L13	1.39	0.74	-0.26	3.45	0.91	0.79	1.35	0.22	0.99	2.26
L14	0.75	0.82	0.29	-3.80	0.64	1.51	0.58	1.14	0.95	0.55
L15	1.20	0.65	2.23	-2.71	1.44	1.08	0.92	0.78	0.71	0.47
L17	0.43	1.85	1.93	3.45	0.98	1.15	1.09	1.79	1.20	-0.34
L20	1.24	-0.06	1.84	4.44	1.31	0.35	0.76	0.66	1.33	2.66
L23	1.54	0.98	0.62	2.57	1.20	0.20	1.58	1.13	1.36	2.07
L24	1.51	0.28	1.10	0.04	0.84	0.59	0.62	1.14	1.02	0.77
L31	0.82	0.89	1.34	-1.96	0.86	1.10	0.88	1.47	1.17	0.56
L34	1.57	1.61	1.31	1.69	0.51	1.48	1.04	1.19	0.88	0.15
Misr2	0.71	2.52	0.59	3.59	0.86	1.15	1.38	0.31	1.23	2.76
Giza168	0.79	0.59	-0.28	0.56	0.88	1.49	1.53	0.72	0.83	1.03
Gemmeiza12	0.32	0.53	0.49	0.90	0.81	0.68	0.86	0.72	0.84	1.08

It was observed negative values of HSI under low N for PH of lines L8, L13, L20, L24 and Gemmeiza12, for FLA for L4, Giza168 and Gemmeiza12, for SL of L8, L14, L15, L31 and L34, for HI of L14, Misr2, while under recommended N for PH for L20 and Gemmeiza12, for FLA for L4, L13 and Giza168, for SL for L4, L8, L14, L15, L31 and L34, for HI for L4, L14 and L17. This means that these genotypes showed an increase for these traits in heat stress (late sowing date) compared to normal conditions (recommended sowing date) under low and/or recommended N, referring that it was stable performance across different environments changing in climatic. Bhardwaj *et al.* (2018) and Suresh *et al.* (2018) found significant positive effects of heat stress in yield-related and physiological traits for wheat genotypes. Sharma *et al.* (2013) and Thakur *et al.* (2020) observed on increase in plant height and spike length of some genotypes by the negative HSI values.

3.3. Nitrogen stress tolerance indices

Based on grain yield, nitrogen stress tolerant parameters under early, recommended and late sowing dates are shown in Table 17. Based on STI, MP, GMP and HM, the four lines L2, L13, L14, and L15 were the most nitrogen stress tolerant under early sowing date (Table 18). While, L8, L23 and Misr2 were the most susceptible genotypes. Under recommended sowing date, L13, L15, 17 and L34 were the most tolerant to nitrogen stress, while, L4, L8 and L23 were the most susceptible to N stress. Based on STI, MP, GMP and HM, under early sowing date, L2, L13, L14 and L15 were the most N stress tolerant, while L8, L20, L23 and Misr2 were susceptible to N stress, under recommended sowing date, L13, L15, L17 and L34 were the most N stress tolerant, while L4, L8, L20 and L23 were susceptible to N stress, under late sowing date, L13, L15, L24 and L34 were the most N stress tolerant, while the genotypes L8, L20, L31, L23 were susceptible to N stress. L13 was the most tolerant to N stress in the three sowing dates while, L8, L20 and L23 were the most sensitive to N stress under the three sowing dates (Table 18). Similar results were obtained by Fouad, (2018).

Based on SSI, TOL and YSI, L4, L14 and Misr2 in the early date, L17, L24 and L31 in the recommended date and L20, L31 and Misr2 in the late sowing date were considered as N tolerant. Based on SSI, TOL and YSI, three wheat cultivars were identified as N stress tolerant under low nitrogen conditions in both years (Tyagi *et al.*, 2020). Ivic *et al.* (2021) revealed that based on the MP, GMP, HM, STI and YI indices, three wheat cultivars may be considered the high yield performances under stress and non-stress conditions. Aga *et al.* (2022) found that stress tolerance parameters GMP, STI, YI and SSI can be useful to in improve wheat performance under different N conditions.

Under the late sowing date for grain yield (Table 18), the lowest values of SSI (stress sensitivity index similar to HSI in calculation method) lower than one was recorded for lines 20, 31, Misr2, line 24 and 13, indicating, these genotypes could be tolerant to both nitrogen and heat stress. Three genotypes from them line 20, Misr2 and line 13 recorded the lowest heat sensitivity index HSI (Table 17). Confirming, these three genotypes are tolerant to both nitrogen and heat stress. The heat stress-tolerant of line 20 may be attributed to escape from heat stress where, HSI was low (0.89) for days to heading. While heat stress tolerance of Misr2 may be attributed to low flag leaf area which recorded low HSI (0.77) (Table 17). Similar findings were revealed by Mondal *et al.* (2013).

The ranking method according to (Farshadfar and Elyasi, 2012) for the genotypes based on all N stress tolerance parameters under three sowing dates is shown in Table 19.

Table 18. Nitrogen stress tolerance parameters under early, normal and late sowing dates averaged over two seasons

G\Trait	GY s	GY p	SSI	STI	MP	GMP	TOL	YSI	HM	SNI	NI	RNI
Early sowing date												
L2	12.33	17.31	1.72	1.11	14.82	14.61	4.98	0.71	14.40	0.29	0.76	0.59
L4	12.50	11.68	-0.42	0.76	12.09	12.08	-0.83	1.07	12.08	-0.07	1.16	0.89
L8	7.59	10.86	1.80	0.43	9.22	9.08	3.28	0.70	8.93	0.30	0.46	0.58
L13	12.66	17.00	1.52	1.11	14.83	14.67	4.34	0.74	14.51	0.26	0.81	0.62
L14	14.11	14.57	0.19	1.06	14.34	14.34	0.46	0.97	14.34	0.03	1.18	0.81
L15	14.54	16.81	0.81	1.27	15.68	15.63	2.28	0.86	15.59	0.14	1.09	0.72
L17	12.26	15.21	1.16	0.97	13.73	13.65	2.95	0.81	13.57	0.19	0.85	0.67
L20	10.19	12.20	0.99	0.64	11.19	11.15	2.02	0.83	11.10	0.17	0.74	0.69
L23	8.63	11.00	1.28	0.49	9.81	9.74	2.37	0.78	9.67	0.22	0.59	0.65
L24	11.50	13.41	0.85	0.80	12.46	12.42	1.91	0.86	12.38	0.14	0.85	0.71
L31	11.26	13.46	0.97	0.78	12.36	12.31	2.20	0.84	12.26	0.16	0.81	0.70
L34	12.83	15.83	1.13	1.05	14.33	14.25	3.00	0.81	14.17	0.19	0.90	0.67
Misr2	10.63	10.65	0.01	0.59	10.64	10.64	0.02	1.00	10.64	0.00	0.92	0.83
Giza 168	11.24	16.73	1.96	0.97	13.98	13.71	5.49	0.67	13.44	0.33	0.65	0.56
Gemmeiza12	11.23	11.73	0.26	0.68	11.48	11.48	0.50	0.96	11.48	0.04	0.93	0.80
Recommended sowing date												
L2	17.26	24.52	1.51	0.87	20.89	20.57	7.26	0.70	20.26	0.30	0.68	0.57
L4	14.77	18.01	0.92	0.55	16.39	16.31	3.24	0.82	16.23	0.18	0.68	0.66
L8	10.22	15.08	1.65	0.32	12.65	12.42	4.86	0.68	12.19	0.32	0.39	0.55
L13	19.37	22.52	0.72	0.90	20.94	20.88	3.15	0.86	20.83	0.14	0.94	0.69
L14	17.54	22.54	1.14	0.81	20.04	19.89	5.00	0.78	19.73	0.22	0.77	0.63
L15	21.00	29.12	1.43	1.26	25.06	24.73	8.13	0.72	24.40	0.28	0.85	0.58
L17	23.40	24.23	0.18	1.16	23.81	23.81	0.83	0.97	23.81	0.03	1.27	0.78
L20	16.29	19.09	0.75	0.64	17.69	17.63	2.80	0.85	17.58	0.15	0.78	0.69
L23	14.01	20.93	1.69	0.60	17.47	17.12	6.92	0.67	16.78	0.33	0.53	0.54
L24	20.93	20.40	-0.13	0.88	20.67	20.66	-0.53	1.03	20.66	-0.03	1.21	0.83
L31	19.67	18.22	-0.41	0.74	18.94	18.93	-1.44	1.08	18.92	-0.08	1.20	0.87
L34	21.99	27.93	1.09	1.26	24.96	24.78	5.95	0.79	24.61	0.21	0.97	0.63
Misr2	15.08	22.45	1.68	0.70	18.77	18.40	7.38	0.67	18.04	0.33	0.57	0.54
Giza 168	16.81	22.99	1.38	0.79	19.90	19.65	6.18	0.73	19.42	0.27	0.69	0.59
Gemmeiza12	18.00	22.94	1.10	0.85	20.47	20.32	4.94	0.78	20.17	0.22	0.80	0.63
Late sowing date												
L2	7.28	14.03	1.46	0.56	10.65	10.10	6.75	0.52	9.58	0.48	0.41	0.35
L4	8.34	13.03	1.10	0.59	10.68	10.42	4.70	0.64	10.17	0.36	0.59	0.43
L8	6.28	10.94	1.30	0.37	8.61	8.29	4.66	0.57	7.98	0.43	0.40	0.39
L13	10.83	13.93	0.68	0.82	12.38	12.28	3.10	0.78	12.18	0.22	0.93	0.52
L14	8.68	14.25	1.19	0.67	11.47	11.12	5.58	0.61	10.79	0.39	0.58	0.41
L15	10.63	21.11	1.51	1.22	15.87	14.98	10.48	0.50	14.14	0.50	0.59	0.34
L17	8.95	13.03	0.95	0.63	10.99	10.80	4.08	0.69	10.61	0.31	0.68	0.46
L20	9.85	9.31	-0.18	0.50	9.58	9.58	-0.54	1.06	9.58	-0.06	1.15	0.71
L23	7.05	9.91	0.88	0.38	8.48	8.36	2.86	0.71	8.24	0.29	0.55	0.48
L24	10.61	12.40	0.44	0.72	11.51	11.47	1.78	0.86	11.44	0.14	1.00	0.57
L31	9.91	10.02	0.03	0.54	9.96	9.96	0.11	0.99	9.96	0.01	1.08	0.66
L34	10.94	18.42	1.23	1.10	14.68	14.20	7.47	0.59	13.73	0.41	0.72	0.40
Misr2	11.07	11.82	0.19	0.71	11.45	11.44	0.74	0.94	11.43	0.06	1.14	0.63
Giza168	7.99	15.60	1.48	0.68	11.80	11.17	7.61	0.51	10.57	0.49	0.45	0.34
Gemmeiza12	8.02	15.48	1.47	0.68	11.75	11.14	7.46	0.52	10.56	0.48	0.46	0.35

The four lines L14, L15, L24 and L34 in the early sowing date, L13, L17, L24, and L34 in recommended sowing date, L13, L17, L24 and Misr2 in the late sowing date were gavine the lower ranking sum, hence they were the most N stress tolerant genotypes. L13, L17 and L24 were tolerant to N stress under recommended and late sowing dates in addition to L24 in early sowing

date. L34 was N stress-tolerant in both early and recommended sowing dates (Table 19). Abd El-Mohsen *et al.* (2015) and Fouad (2018) indicated that the ranking method according to Farshadfar and Elyasi, 2012 identified the most drought-tolerant wheat genotypes based on all drought stress tolerance indices.

Table 19. Ranks (R), ranks mean ($\overline{R}$) standard deviation of ranks (SDR) and rank sum (RS) for the genotypes of nitrogen stress tolerance parameters under early, recommended and late sowing dates averaged over two seasons

G\Trait	GY_s	GY_p	SSI	STI	MP	GMP	TOL	YSI	HM	SNI	NI	RNI	$\overline{R}$	SDR	RS
Early sowing date															
L2	6	1	13	3	3	3	14	13	3	13	11	13	8	5.2	13.2
L4	5	12	1	10	10	10	1	1	10	1	2	1	5	4.64	9.97
L8	15	14	14	15	15	15	12	14	15	14	15	14	14	0.89	15.22
L13	4	2	12	2	2	2	13	12	2	12	9	12	7	4.99	11.99
L14	2	7	3	4	4	4	3	3	4	3	1	3	3	1.44	4.86
L15	1	3	5	1	1	1	8	5	1	5	3	5	3	2.34	5.59
L17	7	6	10	7	7	7	10	10	6	10	7	10	8	1.73	9.81
L20	13	10	8	12	12	12	6	8	12	8	12	8	10	2.35	12.44
L23	14	13	11	14	14	14	9	11	14	11	14	11	13	1.78	14.28
L24	8	9	6	8	8	8	5	6	8	6	8	6	7	1.27	8.43
L31	9	8	7	9	9	9	7	7	9	7	10	7	8	1.11	9.28
L34	3	5	9	5	5	5	11	9	5	9	6	9	7	2.49	9.24
Misr2	12	15	2	13	13	13	2	2	13	2	5	2	8	5.67	13.5
Giza168	10	4	15	6	6	6	15	15	7	15	13	15	11	4.5	15.09
Gemmeiza2	11	11	4	11	11	11	4	4	11	4	4	4	8	3.66	11.16
Recommended sowing date															
L2	9	3	12	6	5	6	13	12	6	12	11	12	9	3.50	12.42
L4	13	14	6	14	14	14	6	6	14	6	12	6	10	3.94	14.36
L8	15	15	13	15	15	15	7	13	15	13	15	13	14	2.31	15.98
L13	6	8	4	4	4	4	5	4	4	4	5	4	5	1.23	5.90
L14	8	7	9	8	8	8	9	9	8	9	9	9	8	0.67	9.09
L15	3	1	11	2	1	2	15	11	2	11	6	11	6	5.10	11.44
L17	1	4	3	3	3	3	3	3	3	3	1	3	3	0.87	3.62
L20	11	12	5	12	12	12	4	5	12	5	8	5	9	3.53	12.11
L23	14	10	15	13	13	13	12	15	13	15	14	15	14	1.51	15.01
L24	4	11	2	5	6	5	2	2	5	2	2	2	4	2.70	6.70
L31	5	13	1	10	10	10	1	1	10	1	3	1	6	4.72	10.22
L34	2	2	7	1	2	1	10	7	1	7	4	7	4	3.17	7.42
Misr2	12	9	14	11	11	11	14	14	11	14	13	14	12	1.72	14.06
Giza168	10	5	10	9	9	9	11	10	9	10	10	10	9	1.50	10.83
Gemmeiza12	7	6	8	7	7	7	8	8	7	8	7	8	7	0.65	7.98
Late sowing date															
L2	13	6	12	11	11	11	11	12	12	12	14	12	11	1.93	13.35
L4	10	8	8	10	10	10	9	8	10	8	9	8	9	0.95	9.95
L8	15	12	11	15	14	15	8	11	15	11	15	11	13	2.38	15.13
L13	3	7	5	3	3	3	6	5	3	5	5	5	4	1.38	5.80
L14	9	5	9	8	7	8	10	9	6	9	10	9	8	1.54	9.79
L15	4	1	15	1	1	1	15	15	1	15	8	15	8	6.77	14.44
L17	8	9	7	9	9	9	7	7	7	7	7	7	8	0.97	8.72
L20	7	15	1	13	13	13	1	1	13	1	1	1	7	6.20	12.87
L23	14	14	6	14	15	14	5	6	14	6	11	6	10	4.19	14.60
L24	5	10	4	4	6	4	4	4	4	4	4	4	5	1.76	6.51
L31	6	13	2	12	12	12	2	2	11	2	3	2	7	4.93	11.51
L34	2	2	10	2	2	2	13	10	2	10	6	10	6	4.36	10.27
Misr2	1	11	3	5	8	5	3	3	5	3	2	3	4	2.77	7.11
Giza168	12	3	14	6	4	6	14	14	8	14	13	14	10	4.41	14.57
Gemmeiza12	11	4	13	7	5	7	12	13	9	13	12	13	10	3.37	13.29

3.4. Phenotypic and genotypic correlation

Grain yield showed negative or weak positive phenotypic and genotypic correlation with days to heading, plant height, flag leaf area, number of grains per spike and 1000 grain weight for the most environments (Table 20).

Grain yield showed median phenotypic correlation with PH in 2nd season on the early sowing date under the recommended N, with SL in the early sowing date under low N and (SL and TGW) in the recommended sowing date under low N in 2nd season. While, correlation converted to negative correlation with each of FLA and NG S^{-1} on the late sowing date under recommended N in 2nd season (Table 20). Grain yield showed median or strong positive phenotypic and genotypic correlation coefficients with each of BY and HI in the most environments except with BY on early and recommended sowing dates under low N in the two seasons. Fouad (2019) found a positive genotypic correlation coefficient between biological yield and grain yield by (0.52) on a favorable sowing date and (0.69) on a late sowing date. Negative genotypic correlation (-0.27) between grain yield and heading date in the late planting date. Mecha *et al.* (2017) revealed positive phenotypic and genotypic correlation for grain yield with BY and HI.

Table 20. Phenotypic (rp) and genotypic (rg) correlation between grain yield/fed with the other traits in the sowing dates and two N levels in first and second seasons

S	D	N	r	HD	PH	FLA	SL	NG	TGW	NS/plot	BY/fed	HI
First season (2021/2022)	ED	LN	rp	0.21	0.01	0.05	0	-0.38	0.23	0.44	0.35	0.67
			rg	0.2	0.02	0.04	0.09	-0.46	0.42	0.56	0.38	0.67
		RN	rp	-0.01	0.42	-0.06	0.13	-0.04	-0.17	0.76	0.66	0.49
			rg	0.01	0.28	0	0.11	-0.04	-0.06	0.55	0.49	0.67
	RD	LN	rp	-0.27	0.05	-0.08	0.46	-0.12	0.24	0.75	0.23	0.69
			rg	-0.28	0.08	0.02	0.35	-0.07	0.2	0.53	0.19	0.77
		RN	rp	-0.18	0.02	-0.29	-0.13	-0.13	-0.36	0.71	0.5	0.46
			rg	-0.06	-0.01	-0.16	-0.06	-0.09	-0.24	0.28	0.54	0.49
	LD	LN	rp	-0.24	0.34	-0.08	-0.09	-0.26	-0.31	0.75	0.84	0.57
			rg	-0.2	0.21	-0.07	-0.03	-0.09	-0.2	0.66	0.77	0.58
		RN	rp	-0.28	0.39	-0.41	0.14	-0.06	0.27	0.54	0.6	0.67
			rg	-0.18	0.25	-0.33	0.17	0.01	0.2	0.46	0.5	0.72
Second season (2022/2023)	ED	LN	rp	-0.07	-0.14	-0.02	0.7	-0.1	-0.11	0.43	-0.21	0.88
			rg	-0.07	-0.05	0.05	0.53	-0.04	-0.05	0.34	-0.02	0.78
		RN	rp	0.09	0.61	-0.17	0	0.02	0.15	0.81	0.73	0.61
			rg	0.1	0.38	-0.14	-0.04	-0.02	0.12	0.67	0.67	0.65
	RD	LN	rp	-0.17	-0.06	-0.22	0.54	-0.35	0.52	0.9	0.13	0.66
			rg	-0.13	-0.09	-0.23	0.39	-0.29	0.33	0.67	0.12	0.74
		RN	rp	0.29	0.22	-0.25	0.25	0.26	-0.07	0.58	0.81	0.07
			rg	0.16	0.2	-0.12	0.15	0.26	0	0.43	0.63	0.42
	LD	LN	rp	0.39	0.41	-0.23	0.11	-0.35	0.58	0.54	0.77	0.32
			rg	0.24	0.24	-0.23	0.07	-0.27	0.3	0.53	0.66	0.52
		RN	rp	0.02	0.34	-0.65	-0.04	-0.19	-0.51	0.78	0.65	0.57
			rg	0.03	0.37	-0.28	-0.01	-0.1	-0.47	0.56	0.52	0.69

4. Conclusion

Lines 15, 34, Giza 168 and Gemmieza12 could achieve high grain yield with sowing in a late date in case of adding recommended N fertilization to compensate for the late of sowing date. Moreover, lines 15 and L34 achieved the highest grain yield on the recommended and late dates.

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All authors are contributed in this research

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Not applicable

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Conflicts of Interest

The authors disclosed no conflict of interest.

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