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EFFECT OF TIME OF PLANTING AND HEAT STRESSES ON WHEAT ADVANCED GENOTYPES

M. A. Sial, M. Umar. Dahot*, M. A. Arain, S.M. Mangrio, Mazhar H. Naqvi, and N. A. Nizamani**

Nuclear Institute of Agriculture (NIA), Tando Jam, *Institute of Biotechnology & Genetic Engineering and **Institute of Botany, University of Sindh, Jamshoro, Sindh, Pakistan
E-mail: niatjam@hyd.paknet.com.pk

ABSTRACT:

The studies were conducted to determine the effects of time of sowing and heat stresses on yield and yield associated traits of wheat genotypes. Twenty advanced wheat genotypes including a local check variety Sarsabz were screened at two sowing dates viz., normal sowing (9^{th} November) and late sowing (12^{th} December) at Experimental Farm, NIA, Tando Jam. Data on different yield and yield contributing traits were recorded and statistically analyzed. The highly significant effects of heat stresses (between 33^0C to 43^0C) were observed during grain filling periods, which affected the plant height, 1000-grain weight and grain yield, except days to heading. Delayed planting adversely affected the yield and yield components of wheat genotypes. All the genotypes produced significantly higher grain yield at normal sowing time than late sown as compared using t-statistic. Twelve genotypes produced higher grain yield (more than 4000 kg/ha) than check variety Sarsabz at normal sowing, while four genotypes viz., V-7005, SI-91195, PR-70 and 97B2210 produced higher grain yield than Sarsabz under late planting, others were either inferior or at par with Sarsabz.

INTRODUCTION:

Wheat (*Triticum aestivum,* L.), the most important food crop of Pakistan, is being grown over 8.5 million hectares with an average yield of 2.3 tons/ha and annual production of 19.5 million tones (Anonymous, 2004). It has the largest acreage of any crop, which is grown on 38% of all the cultivated area; constitutes 60 percent of the average daily diet of the common man with average per capita consumption of 125 kg (Khan, 2003). Sindh produces $\pm$ 2.23 m. tons wheat over an area of 0.8 m.ha, it shares 11.7% in the national economy with higher average yield (2746 kg/ha). It is reported that continual heat stress affects approximately 7 million hectare of wheat in developing countries, while terminal stress is a problem in 40% of the temperate environments, which cover 36 m.ha. Continual heat stress is defined a mean daily temperature of over 17.5^0C in the coolest months of the season, and over 50 counties (importing more than 20 m. tons of wheat per year) experience this type of stress throughout the entire wheat cycle (Fischer and Byerlee, 1991; Reynolds *et al,* 2001; Sial, *et al.,* 2001).

Wheat yields in Pakistan can be improved by developing new high yielding varieties and adoption of proper package of technology (Sial *et al.,* 2000; Arain *et al.,* 2002). The higher grain yields in wheat have been obtained by early sowing (Darwinkel *et al.,* 1977; Arain *et al.,* 1999; 2001; Sial, *et al.,* 2005). Genetic diversity for heat tolerance in cultivated wheat is well established (Midmore *et al.,* 1984;

Rawson, 1986; Al-khatib and Paulsen, 1990; Reynolds, 1994). Temperatures above normal alter plant functions and productivity. Short heat stresses (≥ 35°C) in the post-anthesis period can significantly reduce grain weight in wheat and barley (Wardlaw and Wrigley, 1994), decrease grain quality (Randall and Moss, 1990; Savin *et al*., 1996). The sowing dates in terms of changed temperatures are critical for determining appropriate crop yields (Stephens and Lyons 1998; Sial *et al.*, 2000).

Usually, normal planting in Sindh province has starts from first week of November to the last week of November. The first three weeks of November are supposed to optimum planting time in Sindh. The major portion of the crop is planted late in December, usually in rice- wheat, cotton-wheat and sugarcane-wheat areas of northern Sindh i.e., in Sukkur, Ghotki, Shikarpur, Dadu, Larkana and Jacobabad. Delayed planting reduces the wheat yields significantly (Arain *et al*., 1999; Sial *et al*. 2005). The delayed planting of wheat is one of a major yield limiting factors. The numbers of factors are responsible for the late planting of wheat in this province such as previous crops (rice, cotton etc.) in the field, non-availability of irrigation water and other inputs (seeds, fertilizers etc) at proper time.

The favorable temperature for wheat crop is usually 15-25^{0}C, however, its growth continues at lower temperature down to 3 to 4^{0}C or at higher temperature up to 30-32^{0}C. Maximum temperatures 35±3^{0}C in March and April are known to force maturity. The lower temperatures slow the growth while the high temperatures speed up the maturity of the crop. The wheat plants grow well at optimum temperatures for longer time, therefore, the grain filling is longer and the plant produce higher yields (Stephens and Lyons 1998). The lowest temperatures (December-January) severely affect the vegetative phase like seedling emergence, flag leaf emergence, tillering, spike length, number of grains per spike, while higher temperatures during March and April causes terminal stresses during grain filling period and shorten the reproductive phase; therefore, the late planting suffers at both the ends. Late varieties have shorter vegetative phase, flower early and, therefore, have long grain filling period, which compensate for the late growing season. This study was therefore, undertaken to determine the effects of heat shocks and time of sowing on yield and yield components of wheat-advanced genotypes.

MATERIALS AND METHODS:

Nineteen wheat (*Triticum aestivum*, L) genotypes of different origin viz. V-7014, V-97046, 97B2210, 92T009, PR-75, IBW-96405, V-89059, TD-1, V-1076, D-97603 Durum, V-5, V-8975, MAW-1, PR-74, 97B2333, V-97052, SKD-1, SI-91195, and 91BT010-84 included in National Uniform Wheat Yield Trials (NUWYT) along with Sarsabz (local check) were evaluated under two sowing dates viz. normal (9th November) and late (12th December) during wheat growing season 2001-02. The experimental trial sets were obtained with courtesy of National Co-ordinator (Wheat) NARC, Islamabad. The wheat breeders of different

Institutes of Pakistan developed the entries included in the trials. Two entries SI91195 (Khirman) and SD-1200/14 (Bhitai) included in the trials have developed by NIA Tando Jam. The trials were conducted at experimental farm of Nuclear Institute of Agriculture (NIA), Tando Jam. The experiments were laid out with four replicates in randomized complete block design (RCBD) having six rows of each genotype, 5m long and 30 cm spacing between rows. The net plot size kept in sowing was $9m^2$ (1.8m x 5m). The soil at the site was medium fertile (clay loam with a pH of 7.4) whereas, the seeding rate was 100 kg/ha at each sowing date. Meteorological data (daily minimum and maximum temperatures) were recorded throughout the entire season.

The agronomic and phenological data of each genotype recorded at each sowing date were: (i) days to heading (ii) days to maturity (iii) grain filling period (iv) plant height (v) 1000-grain weight (g) (vi) grain yield (kg/plot) and (vii) grain yield (kg/ha). Four rows (6m2 plot) out of six were harvested and threshed to record the grain yield data. Data were subjected to analysis of variance according to method suggested by Steel and Torrie 1980, and the means were compared using Duncan's Multiple Range Test (Duncan, 1955) and the student's t statistic was also performed to compare differences in both planting times.

RESULTS AND DISCUSSION:

Meteorological data summary during entire wheat growing season is given in Table 1. The high temperatures between 36-42^{0}C persisted in the month of October and also during first two weeks of November (28-36^{0}C). Temperatures then gradually decreased and it became favorable by the second week of December and remained continue (below 30^{0}C) up to 2nd week of February when the anthesis was started. The moderately high temperatures (30- 33^{0}C) were recorded during last three weeks of February. However, fluctuations in temperature were observed during the month of January –March. The increase of temperature in linear direction was continued in the month of March and by the end, it reached to 38^{0}C. In the first week of April, disastrous temperature shocks (up to 43^{0}C) were recorded, while, overall high temperatures in the range of 32^{0}C to 41^{0}C prevailed from 2nd week of April to the last week of April. However, overall high temperature shocks (between 33^{0}C to 43^{0}C) were observed during the grain filling periods of crop particularly from second week of March to first week of April. The high temperature in March and April shoots up forcing early crop maturity. All the phases of plant growth were adversely affected by the shortened growing periods. If wheat planted too early in October, it provides a longer growing period that can increase yield but the threat of frost damage always looms large (Khan, 2003).

All the measured traits except days to heading were severely affected by high temperature stress when mean values compared by using t-statistic under both normal and late planting. Moderately high temperatures (25-32^{0}C) and short periods of very high temperatures (33-40^{0}C and above) during grain filling severely affect the yield, yield components and grain quality in wheat and barley (Chowdhry and Wardlaw, 1978; Wardlaw *et al. 19*89; Stone and Nicolas, 1994; Reynolds *et al.*, 2001). The yield reduction may be more severe, when planting is still delayed as reported by Arain *et al.* (1999), where the intensity of yield depression was found to the extent of 38 kg/ha per day.

Highly significant differences were observed for all the measured agronomic traits among all the genotypes (Table-3).The morphological and physiological characters were significantly affected by changing planting time. Days required for heading in different genotypes under normal planting ranged from 52 to 91, whereas, it was reduced to 78 days (upper limit) at late sowing. Similar pattern of reduction was more prominent in the genotypes, which required more number of days to heading under normal planting time, such as SD1200/14 and V-7004 (12.5 and 14.5 days difference respectively). Sixteen genotypes did not show any significant difference for days to heading, might be tolerant to high temperatures during ear emergence (Table 2a). It is widely recognized that the time to heading shortens, in a curvilinear fashion as temperature increases (Tashiro and Wardlaw, 1999; Slafer and Whitechurch, 2001).

However, non-significant difference between normal and late planting was observed for days to heading when means were compared using t- static (Table 4). The highly significant difference for days to maturity was observed among all the genotypes ranging from 118 days (genotypes 92T009) to 137 (PR-73 and SD-1200/14) at normal planting, whereas at late planting, days for maturity ranged from 100 (92 T009) to 113 days (V-7005, DN-16, V-8964, SD-1200/14) Table 2a. Four genotypes viz., V-7004, PR-73, Inqilab-91 and SD-1200/14 were found to be more affected as regards days to maturity with the significant difference of 34.5, 27.8, 25.0 and 24.0 days respectively; however, Sarsabz (check variety) was less affected (13 days difference) due to changing planting time. Overall mean difference for days to maturity between normal and late planting was 20.6 days (highly significant difference) with t-value 18.57 and s.e 1.11 (Table 4). All the genotypes in normal sown trial took more average days to maturity (129), whereas, same genotypes ripened within less days (109). Transfer of assimilates from source to sink, determines the grain filling period. Genotypes planted in normal time took significantly more days to grain filling, the grain filling (50.5-70.5 days) as compared to late planting (31.7 to 46.2 days) Table 2a.

Overall mean for grain filling period in all the genotypes at normal planting was 60.5 days and at late sown trial 37.7 days, the mean difference was 22.8 days, indicating highly significant difference with t- value 16.41 (Table 4). Genotypes V-97112, PR-73, Inqilab-91 and 92T009 were found more sensitive during grain filling period (36.5, 29.5, 29.0 and 27.8 days respectively) due to high temperature stress (Table 2a). Photo-assimilation is more likely to be yield limiting under heat stress than in temperate environments, especially as stress typically intensifies during grain filling, where demand for assimilates is greatest (Reynolds *et al.,* 2001). Physiological evidence indicates that loss of chlorophyll during grain filling is associated with reduced yield in the field (Reynolds *et al*., 1994).

The rates of development of plant organs are generally accelerated due to increased temperatures. Plant height reduced in all the genotypes at late planting, the maximum to the extent of 22-23cm in genotypes V8964, SI-91195 and 91BT010-5 (Table 2b). The growth resources when are limited by heat stress, the size of plant organs such as leaves, tillers and spikes are reported to be reduce (Fischer, 1984).

Grain weight, an important yield associated trait is highly affected due to late planting and heat stress during grain development time. Bold grains with high mean 1000-grain weight of 46.4g was obtained from normal sown genotypes as compared to late sown (34.9g). A highly significant difference for 1000-grain weight (g) was observed among all the genotypes at both the planting dates. At normal sowing, 1000grain weight was ranged from 36.8g in PR-73 to 56.9g in 92-T009, whereas, in late planting, it was ranged from 28.1g in IBW-96405 to 44.0g in D-97603 and 92T009 genotypes. Geno type IBW-96405 and V-97046 seems to be more sensitive to high temperature stress for 1000-grain weight with 22.7g and 17.4g differences respectively (Table 2b). Six genotypes (92-T009, 91BT010-5, D97-603, V89164, IBW-96405 and SI91195) had more 1000-grain weight (50-56.9g) at normal sown trial. Overall mean 1000grain weight (g) were compared between both planting times, highly significant differences (46.4g at normal and 34.9g at late sown) were observed with 11.5g difference with t- value of 10.58 and S.E- 1.085 (Table 4).

Grain yield is a complex and polygenic character and highly influenced by genotype, environment and genotype x environment interaction (Sial *et al.,* 2003; Arain *et al.,* 2001). All the genotypes under study produced significantly higher grain yield when planted at normal sowing time (November) as compared to late sowing time (December). Twelve genotypes produced higher yield (more than 4000 kg/ha) than local check Sarsabz at normal sowing, while, four genotypes viz., V-7005, SI-91195, PR-70 and 97B2210 produced higher grain yield than Sarsabz under late planting, others were either inferior or at par with Sarsabz. Four genotypes, which produced higher yields at late sowings could be more tolerant to terminal heat stresses and might be cultivated as short duration genotypes. The higher yield obtained from early sown wheat crop have been reported by many workers (Stephan and Lyons 1998; Arain *et al*., 1999; Sial *et al.,* 2005).

Grain yield was ranged from 3584 kg/ha in genotype IBW-96405 to 5125 kg/ha in V-97052 and Inqlab-91 (national check) at normal sowing, however, in late planting, yield was ranged between 1583 kg/ha in genotype V-8964 to 2667 kg/ha in V-7005 (Table 2b). Genotypes Inqlab-91, V-97052, V-97112, V-97024, DN-16, PR-73 and SD-1200/14 showed more reduction in yield when planted late, might be more sensitive to high temperature stress as compared to other geno- types. Genotypes V-7005 and PR-70 showed comparatively less reduction in yield at heat stress as compared to other genotypes. The overall means were compared for grain yield (Kg/ ha) at both the sowing dates, the difference of 2255 kg/ha was noted (4294 kg/ha at normal and 2039 kg/ha at late planting). The t-statistic also proved that the difference in both the normal and late sowings was highly significant (Table 4) for different yield and other yield related para- meters.

These studies suggested the higher yields could be obtained by using normal to early wheat planting.

The grain yields in hot environments can be maximized significantly by adop-ting new technologies, pure, viable seeds of recommended varieties, free of weed seeds and mixtures and improving the agronomic practices, like wise proper land preparation, proper time of sowing, optimum seeding rates and plant densities, optimum use of chemical fertilizers and farm yard manures, and timely applying irrigation water during critical plant growth stages.

Table-1. Morphological data during wheat crop season 2000-01 at NIA, Tando Jam

Month	Week	Min: C°		Max: C°		Humidity %	
		Range	Mean	Range	Mean	Range	Mean
Oct. 2000	1st	21-24	22.2	40-41	40-2	55-73	62.8
	2nd	17-27	21.6	36-42	38.8	59-77	71.4
	3rd	15-22	18.0	39-40	39.33	53-84	65.83
	4th	16-21	18.0	35-42	38.83	64-84	75.66
Nov.2000	1st	15-21	18.2	32-36	33.6	65-83	73.4
	2nd	13-22	17-16	28-34	32.0	43-79	62.66
	3rd	11-16	13.57	26-31	28.85	46-81	63.0
	4th	8-17	12.83	26-31	18.16	61-91	69.16
Dec.2000	1st	9-14	11.83	26-32	29.16	56-80	72.33
	2nd	10-14	11.80	28-29	28.2	73.80	77.8
	3rd	8-10	8.6	22-28	23.6	57-76	66.4
	4th	8-15	10.0	21-28	24.6	48-77	57.8
Jan.2001	1st	6-9	8.0	21-27	24.6	62-77	68.6
	2nd	5-8	6.5	17-25	20.66	75-88	83.0
	3rd	5-9	7.66	17-25	23.0	58-86	72.66
	4th	4-8	6.6	22-27	24.8	47-77	60.4
Feb.2001	1st	5-10	6.2	19-27	23.4	52-78	64.4
	2nd	7-14	9.33	25-30	27.33	50-89	67.16
	3rd	11-21	15.0	26-33	29.2	59-83	72.2
	4th	12-22	15.25	26-33	30.0	57-83	65.25
Mar.2001	1st	9-12	10.25	27-35	30.75	61-83	76.0
	2nd	15-18	16.2	33-37	34.4	59-82	71.0
	3rd	16-20	18.8	31-36	34.2	82-84	83.0
	4th	18-25	22.4	28-38	32.2	68-84	77.6
Apr.2001	1st	16-20	18.25	37-43	40.25	68-78	74.0
	2nd	20-25	22.8	38-39	38.2	70-85	81.6
	3rd	18-20	19.0	32-39	35.2	73.85	81.6
	4th	24-25	24.6	39-41	40.0	61-85	75.8

Table-2 (a): Effect of planting time and heat stress on different yield components of wheat genotypes

Genotypes	Days to heading			Days to maturity			Grain filling Period		
	Normal (9th Nov.)	Late (12th Dec.	Difference	Normal (9th Nov.)	Late (12th Dec.)	Difference	Normal (9th Nov.)	Late (12th Dec.)	Difference
V-97024	72.0e	74.75b	-2.8	127.5g	108.8cde	18.7	55.50i	34.0i	21.5
SI-91195	70.25efg	72.25de	-2.0	131.0de	108.5de	22.5	60.75def	36.25gh	24.5
97B2236	70.75ef	72.50de	-1.8	131.3cde	111.3b	20.0	60.50def	38.75d	21.8
V-7005	79.0c	74.50bc	4.5	129.5f	113.0a	16.5	50.50j	38.50de	12.0
V-97052	67.25h	72.50de	-5.3	127.5g	108.3e	19.2	60.25defg	35.75h	24.5
DN-16	75.25d	71.75e	3.5	133.3b	113.0a	20.3	58.00gh	41.25c	16.8
PR-73	71.75e	73.50cd	-1.8	137.3a	109.5cd	27.8	65.50c	36.0gh	29.5
V-8964	57.75j	66.75h	-9.0	126.5g	113.0a	13.5	68.75ab	46.25a	22.5
D-97603	55.0k	62.75i	-7.8	122.0h	106.8f	15.2	67.0bc	44.0b	23.0
Inqalab-91	68.50gh	72.50de	-4.0	130.5ef	105.5g	25.0	62.00d	33.0ij	29.0
92T009	51.75l	61.25j	-9.5	118.5i	100.3i	18.2	66.75bc	39.0d	27.8
V-97112	58.75j	72.50de	51.3	129.3f	106.5fg	22.8	70.50a	34.0i	36.5
91BT010-5	62.50i	68.50g	-6.0	132.5bc	112.3ab	20.2	70.00a	43.75b	26.3
V-7004	84.25b	69.75f	14.5	136.0a	101.5h	34.5	51.75j	31.75j	20.0
IBW-96405	72.00e	73.75de	-1.8	131.0de	109.5cd	21.5	59.00fgh	36.75fgh	22.3
SD-1200/14	91.25a	78.75a	12.5	137.0a	113.0a	24.0	45.75k	34.25i	11.5
PR-70	70.50efg	73.50cd	-3.0	132.0bcd	112.3ab	19.7	61.50de	38.75d	22.8
V-97046	69.50fg	71.50e	-2.0	126.8g	109.8c	17.0	57.25hi	38.25def	19.0
97B2210	71.75e	72.50de	-0.8	131.0de	109.5cd	21.5	59.25efgh	37.0efg	22.3
Sarsabz (L.C)	62.00i	71.50e	-9.5	122.0h	109.0cde	13.0	60.00defg	37.50defg	22.5

Table-2 (b): Effect of planting time and heat stress on different yield components of wheat genotypes

Genotypes	Plant height (cm)			1000-Grain wt (g)			Grain Yield (Kg/ha)		
	Normal (9th Nov.)	Late (12th Dec.)	Difference	Normal (9th Nov.)	Late (12th Dec.)	Difference	Normal (9th Nov.)	Late (12th Dec.)	Difference
V-97024	90.50cde	76.50abc	14.0	45.40i	31.81hi	13.6	4708abcd	2042bcd	2666
SI-91195	97.50ab	74.50abcd	23.0	50.0e	35.63e	14.4	4625abcde	2375abc	2250
97B2236	86.75e	74.50abcd	12.3	47.21gh	34.85ef	12.4	3625gh	1979bcd	1646
V-7005	95.75abc	74.5abcd	21.3	47.90g	38.66bcd	9.24	4042bcdef	2667a	1375
V-97052	89.00de	75.75abc	13.3	49.06f	34.28f	14.8	5125a	2084abcd	3041
DN-16	89.75cde	70.0bcd	19.8	38.65l	35.03ef	3.6	4853abc	2167abcd	2686
PR-73	94.00bcd	72.0bcd	22.0	36788m	29.60j	7.2	4500abcdef	1855cd	2645
V-8964	96.25abc	73.50bcd	22.8	51.56d	39.34bc	12.2	4025bcdefg	1583d	2442
D-97603	78.25g	64.0de	14.3	53.79c	44.11a	9.7	4000cdefg	2000bcd	2000
Inqalab-91	88.25de	73.0bcd	15.3	46.96h	37.83d	9.1	5125a	1708d	3417
92T009	79.00fg	58.0e	21.0	56.95a	44.15a	12.8	3708fgh	1667d	2041
V-97112	88.75de	73.0bcd	15.8	47.03h	30.91i	16.1	4917ab	1875cd	3042
91BT010-5	101.00a	77.75abc	23.3	55.97b	39.84b	16.1	4167bcdefg	2042bcd	2125
V-7004	90.00cde	71.0bcd	19.0	41.47j	32.99gh	8.5	3792efgh	1688d	2104
IBW-96405	90.00cde	70.50bcd	19.5	50.86d	28.14k	22.7	3584h	1917bcd	1667
SD-1200/14	102.00a	84.50a	17.5	40.39k	38.31cd	2.1	4625abcde	2083abcd	2542
PR-70	85.25e	71.25bcd	14.0	37.25m	28.85jk	8.4	3833defgh	2500ab	1333
V-97046	89.75cde	69.75bcd	20.0	46.76h	29.38j	17.4	4167bcdefg	2083abcd	2084
97B2210	84.50ef	69.0cd	15.5	39.81k	32.24gh	7.6	4583abcdef	2334abc	2249
Sarsabz	96.25abc	80.0ab	16.3	44.76i	33.13g	11.6	4000cdefgh	2125abcd	1875

Table 3: Mean square and C.V. for different agronomic traits of 20 wheat genotypes under normal and late planting

Source of variation	D.F	Days to heading	Days to maturity	Grain Filling period	Plant height (cm)	1000 grain wt. (g)	Grain Yield (Kg/plot	Grain Yield (Kg/ha)
Normal planting								
Genotypes	19	363.48 ***	96.12***	170.10***	161.91 ***	141.6***	355598.69****	999460.51****
Replication	3	0.079	0.85	1.15	61.02*	0.25	585791.67**	1522127.9**
Error	57	1.93	0.85	2.11	16.09	0.36	10105.7	283238.6
Total	79							
C.V (%)		2.1	0.7	2.4	4.4	1.29	12.4	12.4
Late planting								
Genotypes	19	63.76* **	52.36***	57.65***	122.96 ***	90.53***	113373.4**	315020.6**
Replication	3	6.05**	0.43	3.65*	85.97	0.60	550114.6***	1528287.3***
Error	57	0.70	0.52	1.08	40.35	0.63	48250.6	133970.4
Total	79							
C.V (%)		1.17	0.66	2.75	8.74	2.28	17.96	17.96

Table4: Different yield and yield components of wheat genotypes as effected by different planting time (2000-01).

Agronomic traits	Mean values ± s.e			t. value+s.e **(Normal+Late)**
	Normal Planting (9^{th} Nov.)	**Late planting (12^{th} Dec.)**	**Difference**	
Days to heading	**69.09±2.132**	**71.31±0.893**	-2.2 ns	**-1.4284±1.5577**
Days to maturity	**129.61±1.097**	**109.05±0.809**	20.6***	**18.5646 ±1.1072**
Grain filling period	**60.53±1.620**	**37.74±0.849**	22.8***	**16.4131±1.4432**
Plant height (cm)	**90.63±1.423**	**72.65±1.240**	18.0***	**22.3923±0.8027**
1000 grain wt. (g)	**46.43±1.330**	**34.95±1.064**	11.5***	**10.5800±1.0847**
Grain Yield (Kg/plot)	**2579±66.671**	**1223±37.633**	1356.0***	**18.2046±74.4619**
Grain Yield (Kg/ha)	**4294±111.758**	**2039±62.752**	2255.0***	**18.0454±124.9762**

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