Pak. J. Phytopathol., Vol. 28 (01) 2016. 61-69

Official publication of Pakistan Phytopathological Society
Pakistan Journal of Phytopathology
ISSN: 1019-763X (Print), 2305-0284 (Online)
http://www.pakps.com

RESISTANCE TO LEAF RUST IN COMMERCIAL WHEAT VARIETIES OF SINDH AND THEIR AGRONOMIC PERFORMANCE UNDER DIFFERENT SOWING REGIMES

[a]Abdul W. Channa*, [b]Mahboob A. Sial, [a]Hadi Bux,[c]Jam G.M. Sahito
[a] *Institute of Plant Sciences, University of Sindh, Jamshoro 76080, Pakistan.*
[b] *Plant Genetics Division, Nuclear Institute of Agriculture (NIA), Tandojam 70060, Pakistan.*
[c] *Faculty of Agricultural Social Sciences, Sindh Agriculture University, Tandojam, Pakistan.*

A B S T R A C T

To evaluate the response of ten commercial wheat varieties of Sindh province under different sowing dates for grain yield, its associated traits and leaf rust disease resistance, an experiment was carried out at research field of Nuclear Institute of Agriculture Tandojam, Pakistan during 2013-14. Results revealed that the late planting decreased 1000-grain weight, grain yield per plant, grain yield per plot, biological yield per plot, harvest index, ten grains length and ten grains width among wheat varieties along severe leaf rust disease infection. Mean comparison demonstrated that early planted varieties produced highest 1000-grain weight (50.25 g), grain yield per plant(21.5 g) and grain yield per plot (405.3 g) escaping thermal stress and disease infestation. Three varieties planted at normal sowing; NIA-Amber, Sassui and Sarsabz performed better with 1000-grain weight (40-43g). On the other hand, the varieties Khirman and NIA-Saarang had the highest 1000-grain weight (37.6-39.7g) under late sowing indicating their tolerance to heat stress. Results suggest that there is strong influence of weather over genotypic performance and it is advisable for farmers to cultivate wheat crop at optimum time to get maximum harvest and minimize the leaf rust disease infestation.

Keywords: Commercial wheat varieties, thermal stress, brown rust, yield components.

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is major food crop and occupies important position for supplying food in 94 developing countries to more than 4.5 billion people (Braun *et al*., 2010). To ensure the global food security for such a huge population through sustainable wheat production is a major challenge due to enhancing worse impact of climate change. Lack of awareness among farmers regarding the utilization of proper agronomic management viz. seed rate, variety, fertilizers dose, planting date and important production practices is basic reason of low yield. Despite all these efforts, planting time is an essential to get promising yields (Palm *et al*., 2010; Rymuza *et al*., 2012).

All stages of crop like maturity, anthesis, ear emergence, booting, tillering and germination are affected by the temperature which behaves as modifying factor that causes reduction in water supply and other growth regulating substrates. High temperatures also influence reproductive phases which lead to crop yield reduction (Wanjura and Buxtor, 1972; Wahid *et al*., 2007). There is variation in plant response to high temperature based on type of species, variety and phenological stages. Different studies reported that productivity and phenology of wheat is significantly influenced by planting times. Weak plants are produced along with poor root system when planting occurs too early (Haq and Khan, 2002; Hussain *et al*., 2012).

Unlike early planted wheat, delayed sown wheat often matures late and get exposed to high temperature stress which affects grain formation along with penalty of yield (Rahman *et al*., 2009). For wheat crop normally (68 to 90) days are required for grain filling but late planted wheat exhibits significant reduction in grain formation time (up-to 56 and 45 days) sown in December (Hussain *et al*., 2007)due to increased temperature at reproductive phase and its short life cycle (Slafer and Whitechurch, 2001; Sial*et al*., 2005; Khan *et al*., 2010; Riaz-ud-Din *et al*., 2010). Yield and yield associated traits such as heading, anthesis,

* Corresponding Author:
Email: awabdulwajid440@gmail.com

maturity, plant height, grain formation time are severely affected by delayed sowing (Miralles *et al*., 2001; Rahman *et al*., 2009; Nahar *et al.,* 2010). Late sowing may not allow the crop to attain the required level of vegetative growth, causing low productivity and forced maturity due to high temperature during late season (Farooq *et al*., 2011). In Pakistan after 20th November onwards each day late in planting of wheat crop results in reduction of grain yield at the rate of 36 kg ha^{-1} (Hussain *et al*., 1998).

Besides abiotic environmental stresses, wheat is affected by three rust diseases (*Puccinia* spp.) and leaf rust disease is most frequent of them (Huerta-Espino *et al.,* 2011). Leaf rust is caused by *Puccinia triticina* (Stuthman *et al.,* 2007; Huerta-Espino *et al*., 2011) mostly attacks on leaf blades while glumes and leaf sheath can be infected in highly susceptible cultivars (Huerta-Espino *et al*., 2011). Infected wheat crop possesses lower kernel weights, reduced numbers of kernels per head, reduction in harvest index, test weight, seeds/spike and biomass. Yield losses due to leaf rust accounts from 30-70% (Singh and Huerta-Espino, 1994; Kolmer *et al*., 2005). Present study was undertaken to evaluate the agronomic performance and leaf rust disease response of 10 wheat varieties grown at different sowing dates under natural field conditions.

MATERIAL AND METHODS

The experiments were conducted at experimental farm of Nuclear Institute of Agriculture (NIA) Tandojam, during 2013-14. It is one of the suitable areas in the country for wheat cultivation and also most conducive for leaf rust occurrence. A set of ten different commercial wheat varieties (Table 2) were planted under three different planting dates viz., early November 08, 2013, normal planting on November 25, 2013 and late planting was conducted on December 10, 2013. Experiment was laid in randomized complete block design (RCBD) with three replications of two rows each 2m long and spaced 30 cm apart. The susceptible check "morocco" was planted around the plots as a check and spreader. Seeding rate was 50 kg/ha on each sowing date.

The agronomic traits measured on plot basis at each sowing date were peduncle length (cm), ten grains length (cm), ten grains width (cm), 1000- grains weight (g), grain yield per plant(g), grain yield per plot (g), biological yield per plot (g) and harvest index (%). Leaf rust occurrence was recorded in severity as reported by Peterson *et al*., (1948) and response was noted (Roelf *et al*., 1992). Maximum and minimum temperatures (meteorological data) and humidity were recorded (Table 6).

At maturity rows in each plot were harvested, dried to constant weight, weighed and biological yield per plot was determined using the formula, Biological yield (g) = biological yield per plot/ plot area harvested × 1000 (Zafar *et al*., 2011). Harvest index was calculated as the ratio of harvested product to total above-ground biological yield, which is an economic HI, and is usually calculated from unit area yield and dry matter data (machine-harvested yield/ total plant dry weight at maturity).Harvest index was calculated using the following formula, Harvest index (%) = Grain yield/ Biological yield ×100 (Reddy *et al.,* 2004).

Data were analyzed statistically for analysis of variances (ANOVA) using (Statistix 8.1) version and means were compared through LSD at 5 % level of probability using (DMRT) Duncan's Multiple Range Test (Duncan, 1955).

RESULT AND DISCUSSION

The pooled ANOVA for all the characters has been summarized (Table 1a & b). The genotypes, sowing dates and genotype x sowing date interaction were highly significantly (P ≤0.001) different with each other for most of the characters noted. Mean squares (MS) for the traits peduncle length, ten grains length, ten grains width, 1000-grain weight, grain yield per plant, biological yield per plant and harvest index, showed significant differences, whereas grain yield per plot showed non-significant differences.

Table 1(a). Pooled analysis of variance (ANOVA) for different traits of wheat genotypes evaluated at different planting dates.

Source of variation	D.F	Mean square (MS)			
		Grain Yield per plant	TG length	TG Width	Harvest index
Rep	2	45.7	0.12	0.07	19.56
Geno	9	26	0.09***	0.15	46.13**
Rep x Geno	18	42.8	0.0	0.13	11.58
SD	2	80.5***	5.65***	1.36***	1945.49***
Geno x SD	18	4.1	0.06	0.23	22.45*
Rep x Geno x SD	40	4.8	0.02***	0.15	9.55
Total	89	-	-	-	-

****= Significant at P≤0.05. ** = Significant at P≤ 0.01. *** = Significant at P≤ 0.001.***

Table 1(b). Pooled analysis of variance (ANOVA) for different traits of wheat genotypes evaluated at different planting dates.

Source of variation	D.F	Mean square (MS)			
		Peduncle Length	Ten Grain Length	Ten Grain Width	1000-grain weight
Rep	2	14.518	620	574778	95.5
Geno	9	33.848***	14785***	418630*	45.2*
Rep x Geno	18	1.81	1953	175889	16.4
SD	2	888.65***	393898	1234778***	678.7***
Geno x SD	18	8.08***	2446***	52556	8.7
Rep x Geno x SD	40	1.97	1427*	51611	10.1
Total	89				

= Significant at P≤0.05. ** = Significant at P≤0.01. * = Significant at P≤ 0.001. Rep= Replication, Geno= Genotypes, SD= Sowing dates.*

Table 2. Mean comparison of yield and its associated traits as affected by different planting time.

Genotypes	Peduncle length (cm)			Ten grains length (cm)			Ten grains width (cm)		
	Early	Normal	Late	Early	Normal	Late	Early	Normal	Late
Sarsabz	20.6A	20.0A	17A	7.6CD	7BCD	6.8BCD	3.5BC	3.1C	2.6B
Kiran	17.3A	18.6A	16A	7.6BCD	7.1ABCD	6.8BCD	3.4C	3.1BC	2.7B
Khirman	20.6A	18.6A	16A	7.5D	7.0DE	7.0A	3.5BC	3.1BC	3.1AB
SKD-1	13.6A	14.6A	12A	7.5CD	7.2AB	6.7CD	3.1E	3.2AB	2.9B
NIA-Sarang	19.0A	16.6A	13A	7.6CD	6.8E	6.7DE	3.6A	3.2A	3AB
TD-1	15.3A	16.0A	14A	7.5D	7.0DE	6.8BCD	3.5AB	2.9D	2.9B
TJ-83	16.0A	20.0A	16A	7.7BCD	7.2A	6.5E	3.1E	3.1C	4.1A
Sassui	19.0A	21.0A	16A	8.0A	7.2ABC	6.9ABC	3.6A	3.3A	3AB
NIA-Amber	18.0A	18.0A	14A	7.9AB	7.1ABCD	6.9AB	3.3D	2.9D	2.9B
Bakhtawar	18.0A	18.0A	16A	7.8ABC	7.0CDE	7.0A	3.3D	2.9D	2.9B
Mean	18.3A	17.8A	15.2B	7.6A	7B	6.8C	3.4A	3.1B	3B
LSD (0.05)	8.28	7.41	5.43	0.26	0.19	0.18	0.08	0.1	1.12

Means denoted by the same letters in a column are not significantly different from each other.

Peduncle length (cm): The mean values comparison of the peduncle length for varieties revealed that the highest length 18.3cm was recorded at early planting which decreased significantly 17.8cm at normal and 15.2cm at late sowing date (Table 2). Highest peduncle length 20.6cm was recorded in Sarsabz and Khirman at early planting, 21cm in Sassui at normal planting, while 17cm in Sarsabz at late planting time. Minimum 15.3cm was observed in TD-1 at early, 14.6cm in SKD-1 at normal and 12cm in SKD-1 at late planting. Hassan panah *et al*., (1995) results showed that peduncle length is positively correlated with grain yield, plant height and biological yield. Other researchers (Blum, 1986; Ehdaie and Waines 1996) stated that peduncle length is an organ which accumulates the photosynthetic material and involves in transferring to grains at formation.Khan *et al*., (2010) recorded positive direct effect of peduncle length on grain yield.

Ten grains length (cm): Significant (P≤0.001) differences were observed for ten grains length at three different sowing dates (Table 2). The mean differences for ten grains length showed significantly highest length was 7.6cm at early planting which decreased significantly 7cm at normal and 6.8cm at delayed planting. Maximum 8cm ten grains length was recorded in Sassui at early, 7.2cm in SKD-1, TJ-83 &Sassui at normal while 7cm in Khirman & Bakhtawar at late planting. While minimum 7.5cm was observed in Khirman, SKD-1 & TD-1 at early, 6.8cm in NIA-Sarang at normal and 6.5cm in TD-1at late planting date (Table 2). After fertilization, the morphology of grain alters rapidly and its length, width, volume and height increase sharply. The grain length is first dimension to grow in maximum value followed by other traits (Hasan *et al.*, 2011). Wheat grain size (width and length) along with its shape significantly influence flour quality, grain weight and grain yield also (Xiao *et al*., 2011; Williams *et al*., 2013).

Ten grains width (cm): Average values for ten grains width was 3.4cm at early planting, 3.1cm at normal and 3cm at late planting (Table 2). Ten grains width at early planting ranged from 3.1cm in SKD-1 & to 3.3cm in TJ-83 at normal while it ranged from 2.6cm in Sarsabz to 4.1cm in TJ-83 at late planting. Maximum 3.6cm ten grain width was recorded in NIA-Sarang&Sassui at early, 3.3cm in TJ-83 at normal while 4.1cm in TJ-83 at late planting time. While minimum 3.1cm was observed in SKD-1 & TJ-83 at early, 2.9cm in TD-1, NIA-Amber &Bakhtawar at normal and 2.6cm in Sarsabz at late planting (Table 2).The wheat grain size (width) and weight has been reported a significant factor affecting grain characteristics, baking quality and yield (Williams *et al*., 2013; Evers, 2000).

Table 3. Mean comparison of yield and its associated traits as affected by different planting time.

Genotypes	1000-grain weight (g)			Grain yield per plant (g)			Grain yield per plot (g)		
	Early	Normal	Late	Early	Normal	Late	Early	Normal	Late
Sarsabz	47.7C	43.0A	33.0CD	18.9D	15.4AB	8.5E	460.6A	277ABC	206A
Kiran	53.3B	38.0A	34.6BCD	24.1BC	16.5A	12.2AB	424.3ABC	272ABC	212A
Khirman	48.5C	38.6A	39.7A	25.6AB	16.5A	11.8AB	411.3BC	227BCD	188A
SKD-1	47.6C	38.0A	34.6BCD	16.9DE	12.5C	8.9DE	439.0AB	309A	195A
NIA-Sarang	56.3A	37.3A	37.6AB	23.0C	15.7AB	11.0BC	424.3ABC	207CD	144A
TD-1	47.6C	37.0A	33.0CD	16.2E	12.9C	10.9BC	234.0D	173D	148A
TJ-83	45.6C	36.3A	31.33 D	22.6C	14.8ABC	10.3C	407.3BC	261ABC	184A
Sassui	55.6AB	40.3A	36.0BC	19.2D	14.0BC	10.2CD	420.3ABC	221CD	156A
NIA-Amber	54.3AB	43.6A	34.0CD	26.9A	15.7AB	12.5A	419.3ABC	249ABCD	171A
Bakhtawar	45.6C	39.0A	32.0D	21.9C	13.4BC	11.4ABC	446.6AB	305AB	207A
Mean	50.25 A	39.13 B	34.6 C	21.5A	14.7B	10.8C	405.3A	250.5B	181.6C
LSD (0.05)	2.847	7.9854	3.474	2.39	2.44	1.32	48.03	82.15	67.79

Means denoted by the same letters in a column are not significantly different from each other.

1000-grain weight (g): Significant differences (P<0.001) were observed for 1000-grain weight. However mean comparison showed that 1000-grain weight reduced to 34.6g at late sowing as compared to normal 39.13g and early sowing 50.2g (Table 3). Highest 56.3g thousand grain weight was recorded in NIA-Sarang at early planting, in NIA-Amber 43.6g at normal planting, while 39.7g in Khirman at late planting. While lowest 1000-grain weight 45.6g was observed in TJ-83 and Bakhtawar at early while 36.3g in TJ-83 at normal and 31.3g in TJ-83 at late planting (Table 3). Previous studies indicate that 1000-kernel weight along with flour yield and test weight decreases gradually with delay in planting because grain size may not get enough time to increase due to delay in planting and higher temperature (Slafer and White church., 2001; Abdullah *et al*., 2007; Hozayan and Monem, 2010).

Grain yield per plant (g): Significant ($P\leq 0.001$) differences were recorded for grain yield per plant (Table 3). Mean comparison showed significantly highest grain yield per plant (21.5 g) at early planting which significantly decreased 14.7g at normal planting and 10.8g in late planting. Grain yield per plant at early planting ranged from 16.2g in TD-1 to 26.9g in NIA-Amber and 12.5g in SKD-1 to 16.5g in Kiran &Khirman at normal while it ranged from Sarsabz 8.5g to 12.5g NIA-Amber at late planting. Highest grain yield per plant 26.9g was recorded in NIA-Amber at early sowing, 16.5g in Kiran &Khirman at normal sowing, while 12.5g NIA-Amber at late sowing time. While lowest grain yield per plant 16.2 g was observed in TD-1 at early, 12.5 g in SKD-1 at normal and 8.5g in Sarsabz at late planting (Table 3). Qamar *et al*., (2004) recorded the higher grain yield at early planting times whereas Rafay (2011) recorded 7.9% yield reduction at late in planting time. Similarly, Ram *et al*., (2012) reported that the timely sowing of wheat provides higher grain yield due to maximum growing days, photo thermal units and yield associated trait.

Grain yield per plot (g): Non-significant differences were observed for grain yield per plot(Table 3). Comparison of average values showed highest number of grain yield per plot 405.3g at early planted varieties, whereas it was significantly decreased 250.5g at normal and 181.6g at late planting. At early planting grain yield per plot ranged from 234g in TD-1 to 460g in Sarsabz and 173g in TD-1 to 309g in SKD-1 at normal while it ranged from 144g in NIA-Sarang to 212g in Kiran at late planting. Highest grain yield per plot 460g was recorded in Sarasbz at early, 309g in SKD-1 at normal while 212g in Kiran at late planting. While lowest yield 234g was observed in TD-1 at early, 173g in TD-1 at normal and 144g in NIA- Sarang at late planting. Hameed *et al*., (2003) reported that late planting crop suffered higher yield losses than timely planted which results in greater yield gains. Ali *et al*., (2004) observed that wheat grain yield is affected by sowing times and timely planting crop has maximum growth along with yield. In another study, Madarresi*et al*., (2010) recorded about 46.63% yield reduction due to higher temperature at delayed sowing time.

Table 4. Mean comparison of yield and its associated traits as affected by different planting time.

Genotypes	Biological yield per plot (g)			Harvest index (%)		
	Early	Normal	Late	Early	Normal	Late
Sarsabz	1933ABCD	1666ABC	1533AB	24.6AB	18.1A	13.9A
Kiran	2233AB	1866AB	1633AB	19.3BC	15.4AB	13.1AB
Khirman	2000ABCD	2066 A	1533AB	20.6ABC	10.9B	12.4ABC
SKD-1	1833BCD	1733ABC	1466B	24.2AB	17.8AB	14.9A
NIA Sarang	2000ABCD	1900 AB	1566AB	19.5BC	10.9B	9.3BC
TD-1	1433D	1200C	1433B	18.1BC	14.4AB	9.03C
TJ-83	2466A	1933AB	1900A	16.6C	13.5AB	9.9BC
Sassui	1600CD	1500BC	1433B	26.8A	15.1AB	12.2ABC
NIA Amber	2066ABC	1600ABC	1600AB	20.0BC	13.5AB	11.3ABC
Bakhtawar	2033ABC	1733ABC	1633AB	21.8ABC	17.5	12.7ABC
Mean	1960 A	1720B	1556 C	21.18A	14.73B	11.9C
LSD (0.05)	584.3	551	413	6.62	6.84	3.95

Means denoted by the same letters in a column are not significantly different from each other.

Biological yield per plot(g): Significant increase was recorded for biological yield per plot 1960g at early sowing, which reduced to 1720g at normal and 1556.7g at late sowing (Table 4). Biological yield per plot ranged from 1433.3g in TD-1 to 2466g in TJ-83 at early planting and 1200g in TD-1 to 2066g in Khirman at normal while at late planting it ranged from 1433.3g in TD-1 and Sassui to 1900g in TJ-83. Highest 2466g biological yield per plot was recorded in TJ-83 at early, 2066g in Khirman at normal while 1900g in TJ-83 at late planting. Minimum 1433.3g yield was observed in TD-1 at early, 1200g in TD-1 at normal and 1433.3g in TD-1 and Sassui at late planting (Table 4). Irfaq *et al*., (2005) also recorded the decrease in biological yield in his experiment in all wheat genotypes tested at various locations as delay in planting time.

Harvest index (%): The percentage grain inthe total plant biomass is called as harvest index. Harvest index at three different sowing dates revealed significant (P≤0.001) differences (Table 4). The overall mean difference showed highest 21.1% value at early planting which significantly reduced to 14.7% at normal and at late planting 11.9%. The range of harvest index at early planting remained from 16.6% in TJ-83% to 26.8% in Sassui and 10.9% in Khirman& NIA-Sarang to 18.1% in Sarsabz at normal while it ranged from 9.03% in TD-1 to 14.9% in SKD-1 at late planting. Maximum harvest index 26.8 % was recorded in Sassui at early, 18.1% in Sarsabz at normal while 14.9% in SKD-1 at late planting date. While minimum 16.6% was observed in TJ-83 at early, 10.9% in Khirman& NIA-Sarang at normal and 9.03% in TD-1 at late planting. Rahman *et al*., (2009) and Mazid *et al*., (2013) reported that delayed sown wheat matures quite late and results in poor harvest index along with yield penalty.

Leaf rust observations: Different patterns of leaf rust appearance and distribution were observed at three different sowing times under natural field conditions (Table 5). Late planted varieties suffered highest disease infestation due to disease epidemic as compared to early. Leaf rust observations at early sowing dates indicated that TD-1 showed susceptibility while most of varieties were found as moderately susceptible. Due to susceptibility to leaf rust infection, yield and its contributing traits such as grain yield per plant, grain yield per plot, biological yield per plot were reduced in TD-1 variety at most of the planting times. Among ten varieties, Bakhtawar and Sassui were resistant. Based on resistance, Bakhtawar showed better performance for grain yield per plot, biological yield per plot and ten grains length. Likewise, Sassui produced promising 1000-grain weight, harvest index, ten grains length and ten grains width. Similar response was recorded in normal and late plantings. The varieties SKD-1 and TJ-83 showed moderately susceptible to susceptible response along decreased yield. Significant impact of leaf rust on yield and yield contributing traits have been reported (Abebe *et al*., 2013; Kolmer et al., 2005).

Table 5. Leaf rust disease observations.

Genotypes	Early	Normal	Late
Sarsabz	30MS	60MS	70MS
Kiran	20MS	50MS	70MS
Khirman	30MS	50MS	60MS
SKD-1	30MS	50MSS	60MSS
NIA-Sarang	20MS	40MS	60MS
TD-1	50S	80S	80S
TJ-83	40MS	50MSS	70MSS
Sassui	10R	10R	20R
NIA-Amber	10MS	30MS	40MS
Bakhtawar	5R	10R	20R
Morroco	80S	100S	100S

*Leaf rust data has two parts, first is severity percentage according to modifies Cobb's scale and second is response to infection; R = resistant, MR = moderately resistant, MS = moderately susceptible, MSS= moderately susceptible to susceptible and S = susceptible.

Thermal stress: The meteorological data of entire season is given in Table 6. The early trial experienced the minimum temperature from 18.6 C° to 22.6 C° while maximum temperature ranged from 31.2 C° to 35.2 C°. In the month of March when grain filling was in progress the minimum mean temperature was 14.17 and maximum temperature was 35C°. The early trial escaped the heat stress and avoided significant damage to various yield associated traits due to early maturity.

At the normal trial, sown in the month of November the mean temperature ranged from minimum 10.17 C° to maximum 31.4 C°. Below the 30 C° temperatures is thought to be favorable for wheat crop. At the time of grain filling the mean temperature reached up-to the 35C° which was injurious to formation of grain and might have caused grain shrinkage. In the month of April when the wheat crop maturity occurs the mean temperature exceeded from optimum ranges and reached up-to 40.80 C°.

The late sown trial was planted in the month of December, meanwhile the mean temperature ranged from 3.25 C° to 22 C°. In the critical month of March when the grain filling was in progress, the mean temperature increased from optimal temperature to exceeded temperature 35 C°. The grain filling process might have been badly affected by the harsh environmental conditions and grains could not have been filled. Where as in the month of April, the harsh temperature (40.80 C°) continued and might affected the maturity of wheat crop. Based on temperature observations, the terminal heat and water stresses may have severely affected the final grain weight in late sown trial which produced very low 1000 grain weight as compared to early and normal.

Table 6. Meteorological data for wheat cropping season 2013-14 at NIA Tandojam.

			Minimum Temperature °C		Maximum Temperature °C		Humidity	
S.No	Month	Week	Range	Mean	Range	Mean	Range	Mean
1.	Oct 2013	1	25-30	28.4	36-39	38.0	67-85	77.4
		2	27-30	28.6	36-40	38.2	67-86	75.0
		3	24-28	25.2	34.39	36.4	61-84	69.4
		4	26-29	27.75	35-38	36.5	75-92	80.0
2.	Nov 2013	1	20-25	22.6	32-37	35.2	66-93	70.6
		2	18-20	18.6	30-32	31.2	57-71	65.0
		3	18-23	21.0	32-35	33.2	57-82	73.0
		4	19-23	20.25	29-33	31.5	64-81	74.0
3	Dec 2013	1	18-20	19.4	28-34	31.0	61-91	73.8
		2	18-19	18.4	30-32	31.4	71-89	79.4
		3	14-21	18.4	25-30	27.8	69-89	78.0
		4	6-14	10.17	15-25	23.0	41-87	67.5
4	Jan 2014	1	0-5	3.25	14-20	17.5	58-80	69.88
		2	2-6	4.25	15-21	17.5	55-80	69.88
		3	5-10	8.13	18-22	19.75	69-76	73.75
		4	7-10	9.0	21-23	22.0	67-78	74.43
5	Feb 2014	1	7-12	10.51	21-27	24.29	64-79	74.86
		2	6-9	7.29	19-23	20.86	56-76	67.57
		3	4-9	6.57	18-23	21.0	65-80	75.43
		4	8-10	8.57	19-25	22.71	71-78	73.43

Continue…

6	Mar 2014	1	6-20	14.17	26-30	27.33	66-80	74.83
		2	18-21	22.67	29-35	31.5	40-73	59.83
		3	18-22	20.0	30-35	34.0	49-76	67.0
		4	22-25	21.17	33-37	35.0	52-73	63.5
7	April 2014	1	20-28	25.7	37-39	38.0	55-89	69.17
		2	19-25	22.2	40-42	40.80	53-70	60.2
		3	25-28	26.83	39-42	39.42	70-84	74.33
		4	26-30	28.60	39-43	39.43	55-62	60.20

CONCLUSION

Significant differences were observed among ten commercial varieties of Sindh for 1000 grain weight, grain yield per plot, grain yield per plant, biological yield per plot and harvest index at three different sowing dates. Similarly, severity of leaf rust response varied under different sowing regimes. The varieties Sarsabz, Kiran, Khirman, SKD-1, NIA-Sarang, TD-1, TJ-83, Sassui, NIA-Amber and Bakhtawar showed significant increase in yield at early sowing date escaping thermal stress and disease infestation. Results suggested that there is strong influence of weather on genotypic performance. It will be advisable for farmers to cultivate wheat at optimum time to get maximum harvest and avoid leaf rust epidemic.

REFERENCES

Abdullah, M., Aziz-Ur-Rehman, N. Ahmad and I. Rasul (2007).Planting time effect on grain and quality characteristics of wheat.*Pak. J. Agri. Sci.,* Vol. 44 (2): 200-202.

Abdullah, M., Aziz-Ur-Rehman, N. Ahmad and I. Rasul 2007. Planting time effect on grain and quality characteristics of wheat. Pak. J. Agri. Sci., 44 (2): 200-202.

Ali, M. A., Ali, M. and Din, Q. M. 2004. Determination of grain yield of different wheat varieties as influenced by planting dates in agro-ecological conditions of Vehari. Pakistan Journal Life Societa Sciences, 2(1):5-8.

Blum, A., 1986. The effect of heat stress on wheat leaf and ear photosynthesis. J. Exp Bot 37 (174): 111-118.

Braun HJ, Atlin G, Payne T. 2010. Multi-location testing as a tool to identify plant response to global climate change. In Climate change and crop production. Wallingford, UK: CABI Publishers; 115–138.

Duncan, D.B. 1955. 'Multiple Range and Multiple F tests.'Biometrics. 11: 1-42.

Ehdaie, B.; Waines, J.G. Genetic variation for contribution of preanthesis assimilates to grain yield in spring wheat. J Genet & Breed, v.50, n.1, p.47-55, 1996.

Evers, A.D. (2000). Grain size and morphology: Implications for quality. In Wheat Structure, Biochemistry and Functionality, D. Schofield, ed (London: Royal Society of Chemistry), pp. 19–24.

Farooq, M., H. Bramley, J.A. Palta and K.H.M. Siddique. 2011. Heat stress in wheat during reproductive and grain filling phases. Crit. Rev. Plant Sci. 30:491-507.

Hameed, E., Shah, W. A. Shad, A. A. Bakht, J. and Muhammad. T. 2003. Effect of different planting dates, seed rates and nitrogen levels on wheat. Asian Journal Plant Sciences, 2 (6):464- 474.

Hassan panah D., M. Moghaddam, M. Valizadeh, S. Mahfoozi, R. Shahriyari, Abstract of Articles of the 4 the Iranian Congress of Agronomy and Plant Breeding Science, August 26-29. 1995, College of Agriculture, Isfahan University of Technologyu, Isfahan, Iran, p 242 (with English abstract).

Hassanpanah D., M. Moghaddam, M. Valizadeh, S. Mahfoozi, R. Shahriyari, 1995. Abstract of Articles of the 4 the Iranian Congress of Agronomy and Plant Breeding Science, August 26-29. College of Agriculture, Isfahan University of Technologyu, Isfahan, Iran, p 242 (with English abstract).

Hozayan, M and A.A.A. Monem (2010). Alleviation of potential impact of climate change of wheat productivity using arginine under irrigated Egyptian agriculture, *Options mediterrraneennes,* A. No. 95, 2010. Economic of drought and drought preparedness in climate change context. p. 95-100.

Huerta-Espino J., R.P. Singh, S. German, B.D. McCallum, R.F. Park, W.Q. Chen, S.C. Bhardwaj, H. Goyeau 2011. Global status of wheat leaf rust caused by Puccinia triticina Euphytica, 179, pp. 143–160.

Hussain, A., M. Maqsood, A. Ahmad, S. Aftab and Z. Ahmad, 1998.Effect of irrigation during various development stages on yield, component of yield and harvest index of different wheat cultivars. Pakistan J. Agric. Sci ., 34: 104–107.

Hussain, M., M. Farooq, G. Shabir, M.B. Khan, A.B. Zia and

D.J. Lee. 2012. Delay in planting decreases wheat productivity. Int. J. Agric. Biol. 14:533-539.

Hasan AK, Herrera J, Lizana C, Calderini DF. 2011. Carpel weight, grain length and stabilized grain water content are physiological drivers of grain weight determination of wheat. *Field Crops Research* 123, 241–247.

Irfaq, M., T. Muhammad, M. Amin and A.Jabbar. 2005. Performance of yield and other agronomic characters of four wheat genotypes under heat stress. International Journal of Botany,1(2): 124 -127

Khan, M.B., M. Ghurchani, M. Hussain and K. Mahmood, 2010.Wheat seed invigoration by pre-sowing chilling treatments.*Pak. J. Bot.,* 42: 1561–1566.

Khan A. J. , F. Azam and A. Ali 2010. Relationship of morphological traits and grain yield in recombinant inbred wheat lines grown under drought conditions Pak. J. Bot ., 42(1): 259-267, 2010.

Kolmer J.A., D.L. Long, M.E. Hughes Physiological specialization of *Pucciniatriticina* on wheat in the United States in 2003 Plant Dis., 89 (2005), pp. 1201–1206.

Mazid, M.S., Rafii, M.Y., Hanafi, M.M., Rahim, H.A. , Latif, M.A. (2013). Genetic variation, heritability, divergence and biomass accumulation of rice genotypes resistant to bacterial blight revealed by quantitative traits and ISSR markers.PhysiologiaPlantarum 149(3), 432–447.

Miralles, D.J., B.C. Ferro and G.A. Slafer. 2001. Developmental responses to sowing date in wheat, barley and rapeseed. Field Crop Res. 71:211-223.

Nahar, K., K.U. Ahamed and M. Fujita. 2010. Phenological variation and its relation with yield in several wheat (*Triticumaestivum*L.) cultivars at normal and late sowing mediated heat stress condition. Not. Sci. Biol. 2:51-56.

Palm CA, Smukler SM, Sullivan CC, Mutuo PK, Nyadzi GI, Walsh MG 2010: Identifying potential synergies and trade-offs for meeting food security and climate change objectives in sub-Saharan Africa. Proc Natl AcadSci U S A 2010, 107:19661–19666.

Peterson, R. F., A. B. Campbell and A. E. Hannah. 1948. A diagrammatic scale for estimating rust
intensity of leaves and stem of cereals. Can J. Res. Sect. C, 26:496-500

Qamar, M., Shafiullah and S. Makeen. 2004. Genetic variability among wheat cultivars and effect of planting date on grain and Straw yield under double cropping zone of Northern areas Of Pakistan. Sarh. J. Agric. 20:99-102

Rahman, M.M., A. Hossain, M.A. Hakim, M.R. Kabir and M.M.R. Shah, 2009.Performance of wheat genotypes under optimum and late sowing condition.*Int. J. Sustain. Crop Prod*., 4: 34–39.

Ram H, Singh G, Mavi GS and Sohu VS (2012).Accumulated heat unit requirement and yield of irrigated wheat (*Triticumaestivum*L.) varieties under different crop growing environment in central Punjab.*Journal of Agrometeorology*14(2):147-153.

Riaz-ud-Din, M.S. Ghulam, A. Naeem, H. Makhdoom and Aziz Ur Rehman, 2010.Effect of temperature on development and grain formation in spring wheat.*Pak. J. Bot.,* 42: 899–906

Reddy ,S.R. 2004 Principals of crop production 2nd edition kalyani publisher New Dehli India 46p.

Roelfs, A. P., R. P. Singh and E. E. Saari. 1992. Rust Diseases of Wheat: Concepts and Methods ofDisease Management. Mexico, D.F.: CIMMYT. 81.

Sial, M.A., M.A. Arain, S. Khanzada, M.H. Naqvi, M.U. Dahot and N.A. Nizamani. 2005. Yield and quality parameters of wheat genotypes as affected by sowing dares and high temperature stress. Pak. J. Bot. 37:575-584.

Slafer, G.A. and E.M. Whitechurch, 2001.Manipulating wheat development to improve adaptation.*In* Application of Physiology in Wheat Breeding.Reynolds, M.P., Ortiz-Monasterio, J.I. and A. Mcnab. (Eds.). Mexico, D.F.: CIMMYT.

Stuthman, D.D., K.J. Leonard, and J.M. Garvin (2007).Breeding Crops for Durable Resistance to Disease. Adv. Agron. 95: 319-367.

Wahid, A., Gelani, S., Ashraf, M., and Foolad, M. R. 2007. Heat tolerance in plants: an overview.
Environ. Exp. Bot. 61 : 199–223.

Wanjura, D. F. and D.R.Buxtor.1972. Hypocotyl and radicle elongation of cotton as affected by soil environment.Agron.J.64:431-435

Williams K, Munkvold J, Sorrells M: Comparison of digital image analysis using elliptic Fourier descriptors and major dimensions to phenotype seed shape in Hexaploid wheat (Triticumaestivum L.). *Euphytica*2013, 190:99–116

Xiao Y, He S, Yan J, Zhang Y, Zhang Y, Wu Y, Xia XC, Tian J, Ji W, He ZH: Molecular mapping of quantitative trait loci for kernel morphology traits in a non-1BL.1RS × 1BL.1RS wheat cross. Crop Pasture Sci 2011, 62:625–638.

Zafar Mohsin, M. KaleemAbbasi, Abdul Khaliq and Zahid-ur-Rehman 2011.Effect of combining organic materials with inorganic phosphorus sources on growth, yield, energy content and phosphorus uptake in maize at Rawalakot Azad Jammu and Kashmir, Pakistan. Archives of Applied Science Research, 2011, 3 (2):199-212.