GENETIC ANALYSIS FOR SOME PHENOLOGICAL AND MORPHOLOGICAL TRAITS IN WHEAT (*TRITICUM AESTIVUM* L.) UNDER TWO DIFFERENT SOWING WINDOWS

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Abstract. Major effect of climate change can be seen in developing countries like Pakistan that make them food insecure. Grain yield of wheat (*Triticum aestivum* L.) is low as it is affected by erratic weather conditions. Latest development of wheat genotypes applicable for late planting is one of the prime objectives of wheat breeders. Keeping in view the climatic conditions of Pakistan, current investigations were conducted to figure out the inheritance pattern and extent of variations using generation mean analysis. For the aforementioned study the two genotypes Miraj 2008 and Punjab 2011 were evaluated along with following generations i.e. F_1, F_2, BC_1 and BC_2 in normal and late sowing trial in Faisalabad, Pakistan. The highest reduction percentage was observed in grain weight per spike (-33.6%). The inheritance of all traits revealed complex inheritance due to the involvement of non-allelic interactions. The traits like days to heading and days to maturity had both additive, additive × additive i.e. fixable and additive × dominant non fixable genetic effects. So, selection in later generation would be fruitful for these traits when combinations are fixed. Heritability estimates for narrow sense was also determined. Low to moderate heritability was depicted under late sowing conditions.
Keywords: *late planting, generation mean, reduction percentage, grain weight, heritability*

Introduction

Crop yield is reducing due to adverse weather conditions whereas, supplies are becoming scarce, and the price is rising ultimately leads to food insecurity. Global mean temperature has risen at a rate of 0.3°C per decade during the twentieth-century (IFPRI, 2009) and is expected to reach 1 and 3°C above the current value by 2025 and 2100 respectively, resulting in more severe global climatic changes in near future. Heat stress (late sowing) at grain filling stage of wheat causes physiological and biochemical processes abort (Gupta et al., 2013). Therefore, selection of genotypes tolerant to high temperature with proper sowing time is a priority to manage the adverse effects of environments (Alghabari et al., 2014). Time of planting is one of the most important non-monetary input for optimizing the growth according to prevailing agro-climatic conditions and genotypes (Jena et al., 2017). It is an ultimate truth that crop yield is the inter-play of crop genetics, environment and management practices (Mirshekarnezhad et al., 2018). It is impossible to control the environment, but we can develop genotypes that can cope with changing environment. Among many other factors, late sowing is one of the major causes of lower wheat yield in Pakistan. Many cropping patterns prevailing in Pakistan have rotation like wheat; cotton, rice, maize, vegetables, fodders and sugarcane. This inertia in crop rotation cannot allow wheat to have an optimum

time of plantation resulting in a large spectrum of sowing dates. About 80% of the wheat crop is grown after cotton, sugarcane and rice which exposes the crop to high temperature during the gain filling time that is the terminal heat stress which leads to drastic loss in grain yield and ultimately shortage of food (Prasad et al., 2011). High temperature is found to be accompanied with drought stress because of the rise in evapotranspiration. Terminal heat stress has drastic impacts on reproductive development such as flower initiation, ovary and pollen development, fertilization leading to reduction in sink potential which further results in yield loss (Barnabas et al., 2008). Selection of appropriate variety with respect to date of sowing is important to cope with the expected temperature rise at reproductive stage without compromising yield. Thus improvement in the crop genetic is the only inexpensive, effective and targeted approach available for wheat breeders in developing countries like Pakistan (Saxena and Toole, 2002). It is really important to know about genetic components as well as their interactions to achieve a workable breeding program. Generation mean analysis is a unique biometrical technique based on phenotypic performance of traits under study (Mather and Jinks, 1982). Generation mean analysis is most trusted biometric technique to investigate the genetic and epistatic effects. The present study was designed to achieve the information regarding the extent of variation and inheritance patterns in wheat genotypes under two different sowing windows.

Materials and Methods

Plant material

The current study was carried out in the research area of Department of Pant Breeding and Genetics University of Agriculture Faisalabad, Pakistan. The investigational material comprised of two bread wheat cultivars Miraj-2008 and Punjab-2011 (*Table 1*) as parents and their generation's i.e. F_1, F_2, BC_1, and BC_2 were established from two contrasting cultivars selected based on their planting time and commercial importance.

Table 1. *Name and pedigree of parental bread wheat cultivars (spring type)*

Parent	Name	Pedigree
1	Miraj-2008	SPARROW/INIA//V7394/WL711/13/BAUS
2	Punjab-2011	AMSEL/ATTILA//INQ-91/PEW'S'

All six generations of cross were sown on November 15, 2015 under normal (optimum) sowing conditions. The research trial was conducted in randomized complete block design (RCBD) with three replicates (P×P=15 cm; R×R= 30 cm). Dibbler method was used for sowing. To attain a single vigorous seedling per hole thinning was done after germination. To abate the border effect lines of non-experimental material was sown at the border of the experiment. Total four irrigations were applied. First irrigation was applied at tillering stage, second at booting stage, third at anthesis stage, fourth at milking stage. Fertilizer were applied at the rate of 46 kg nitrogen, 34 kg phosphorus and 25 kg potash per acre. Twenty well-guarded plants from P_1, P_2 and F_1 was tagged. Fifty plants from each back cross (BC_1 and BC_2) and two hundred plants from F_2 generation per replication were tagged prior to flowering. Similar activities were

performed for the late sowing experiment on December 20, 2015. Harvesting was done 8-15 April, 2016. Data were recorded for the following traits: Plant height, tillers number per plant, Days taken to heading, days taken to maturity, grain filling duration (*Eq. 1*), grain filling rate (*Eq. 2*), harvest index (*Eq. 3*) and grain weight per spike.

$$\text{Grain filling duration} = \text{Days to maturity - days to heading} \qquad \text{(Eq.1)}$$

Grain filling rate was estimated using following formulae (*Eq. 2*):

$$\text{Grain filling rate} = \frac{\text{Grain yield}}{\text{Grain filling period}} \times 100 \qquad \text{(Eq.2)}$$

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100 \qquad \text{(Eq.3)}$$

Statistical analysis

Analysis of variance was done following Steel et al. (1997) and generation mean analysis (*Eq. 4*) was performed according to the method given by Mather and Jinks (1982). A computer program provided by Dr. H.S. Pooni, School of Biological Sciences, University of Birmingham UK was used for generation mean analysis by the method of Mather and Jinks (1982). The narrow sense heritability (h^2ns) was estimated by the method shown by Mather and Jinks (1982) and Saleem et al. (2016).

$$Y = m + \alpha[d] + \beta[h] + \alpha^2[i] + 2\alpha\beta[j] + \beta^2[l] \qquad \text{(Eq.4)}$$

where Y = mean of one generation, m = mean of all the generations, d = sum of additive effects, h = sum of dominance effects, i = sum of additive × additive gene interaction i.e. complementary, j = sum of additive × dominance α^2, $2\alpha\beta$ and β^2 were the coefficient of genetic parameters, l = sum of dominance × dominance interaction i.e. duplicate.

Results and discussion

Understanding the genetic makeup of any crop plants is dire to batten the crop performance in the current scenario of climate change. Analysis of variance revealed significant genotypic difference for each generation (P_1, P_2, F_1, F_2, BC_1 and BC_2) for all traits under study. Under both sowing conditions parents and generations exhibited significant differences (*Table 2*). The presence of genetic diversity in breeding material is basic criterion for success in any breeding program. Under different sowing conditions changed behavior of breeding material is an indication of significant environment into genotypes interaction (Akram, 2011; Saleem et al., 2016).

Comparison of two treatment means of six generations of cross Miraj 2008 × Punjab 2011 under normal and late sowing conditions

Expression of genes in any stress become restricted. Under late sowing trial the overall performance of all the traits decreased. The magnitude of sensitivity was different for the different traits. Most sensitive traits grains weight per spike with a reduction of 33.6% succeeded by tillers number per plant 28.3% and harvest index

27.1%. In contrast the lowest reduction was shown by days to heading 12.3% followed by grain filing rate 13.4% and grain filling duration 17.0% (*Table 3*). Scientists have also exhibited that under stressed environment, traits do not fully express themselves (Tahir et al., 2009; Sohail et al., 2014).

Table 2. *Analysis of variance of different traits under studied of cross Miraj-2008 × Punjab-2011 under normal and late sowing conditions*

Traits	Normal sowing	Late sowing
Plant height	61.1819**	57.4181**
Tillers numbers per plant	0.72056**	1.29956*
Days to heading	25.5520*	12.6195**
Days to maturity	20.1437**	15.3067**
Grain filling duration	16.2646**	18.8524**
Harvest Index	13.1339*	8.12861**
Grain filling Rate	2.15689**	8.01126*
Grain weight per spike	0.03896**	0.12190*

*, ** Significant at 5% and 1%, probability levels, respectively

Table 3. *Growth and yield parameters of six generations means of Cross Miraj 2008 × Punjab 2011 under normal and late sowing conditions with % reduction under late sowing conditions*

Traits	Normal sowing	Late sowing	% change
Plant height	101.81	76.747	-24.4
Tillers numbers per plant	12.372	8.8756	-28.3
Days to heading	96.200	84.393	-12.3
Days to maturity	133.92	114.55	-14.5
Grain filling duration	37.772	31.336	-17.0
Harvest Index	42.377	30.878	-27.1
Grain Filling Rate	94.535	81.857	-13.4
Grain weight per plant	2.2550	1.4978	-33.6

Phenological traits

Days to heading

Heading time is phenological stage as it determines the pattern of yield potential and stability. When overall reduction percentage was exhibited from pooled means (*Table 3*) of both parents (P_1 and P_2) and their generations (F_1, F_2, BC_1 and BC_2) the results depicted that growth span reduction percentage maximum in BC_2 (15.81%) and minimum in F_2 (10.28%), and when individual performance of parents and generation was investigated for mean values the response was different in both normal and late sowing conditions (*Figure 1*). In late sowing condition F_2 depicted maximum mean value for days to heading (117.35) which revealed more variation in the segregating generation. Those observation were in line with the finding of Kilic and Yagbasanlar (2010). The study of controlling days to flowering is really pivotal as per genetic needs because genetic potentials would show negative indicators with the onset of erratic weather conditions. The genotypes with more days to heading in delayed planting

conditions produce more grain yield because these genotypes assimilate nutrient from stem to kernels very precisely and grains enjoyed large size ultimately increased grain weight.
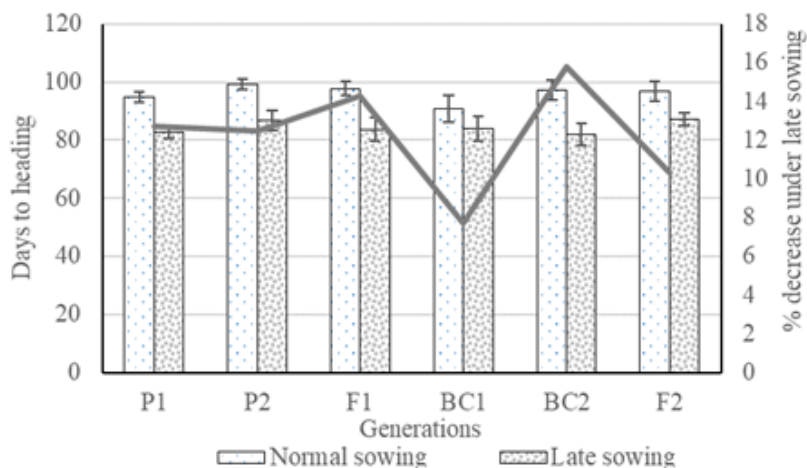

Figure 1. *Days to heading of six generations of cross Miraj 2008 × Punjab 2011 under normal and late sowing conditions along with % increase or decrease. Error bar represents standard errors and overlapping bars are statistically at par with each other*

Days to maturity

The stress environment forced early maturity and abridged the life cycle of the genotypes and their generation. P_1 exhibited uppermost reduction percentage (16.5%) for maturity days and lowermost (11.52%) was revealed by F_2 (*Table 3*). It means P_1 was more sensitive to environmental stress. While in late sowing date F_2 depicted highest days to maturity (117.3) and lowest magnitude (112.2) were documented for BC_1 (*Figure 2*). Those statement were also analogous with the finding of Kilic and Yagbasanlar (2010).
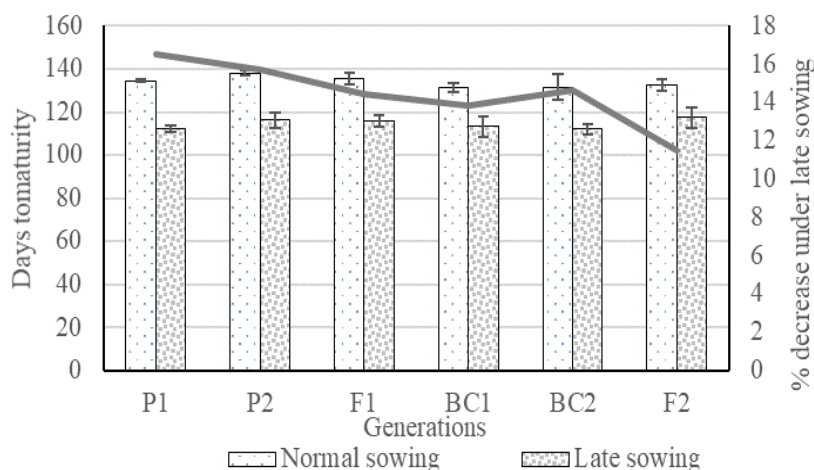

Figure 2. *Days to maturity of six generations of cross Miraj 2008 × Punjab 2011 under normal and late sowing conditions along with % increase or decrease. Error bar represents standard errors and overlapping bars are statistically at par with each other*

Grain filling duration

When genotypes were sown in normal dates more grain filling days were produced comparative to late sowing (*Table 3*). For grain filling duration in pooled mean values of both parents and generations back cross 1 attained highest reduction (27.9%) percentage while lowest value (13.59%) was noted in F_2 depicted in *Figure 3*. The losses percentage was out of parents range. In late planting conditions P_2 (33.86) illustrated maximum grain filling days and P_1 (28.60) showed lowest value when separate performance of parents and generations was observed. Delayed sowing shortens the duration of each development phase which ultimately reduces grain filling period resulting in lower grain weight (Kaur, 2017). It additionally shows that the optimum planted genotype relished a prolonged development stage and favorable pre-heading environments, which have had a persist impact on grain weight via stem reserves mobilization (Baloch et al., 2012).
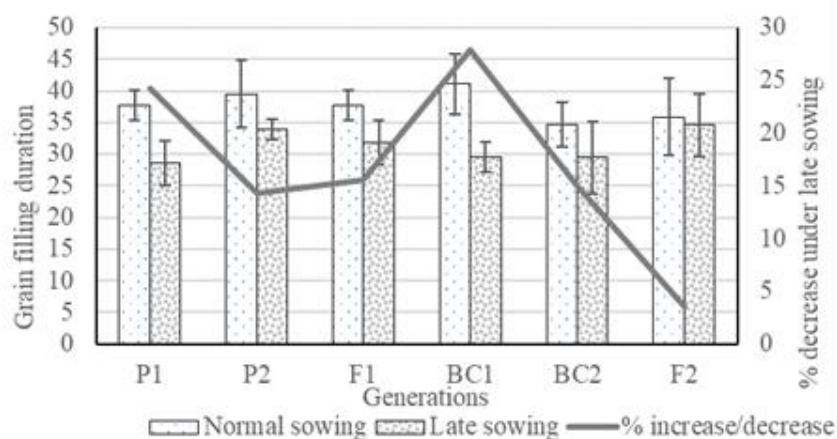

Figure 3. Grain filling duration of six generations of cross Miraj 2008 × Punjab 2011 under normal and late sowing conditions along with % increase or decrease. Error bar represents standard errors and overlapping bars are statistically at par with each other

Grain filling rate

It is also an important penolohgiacal trait. In pooled mean values for both parents and their generations P_1 showed maximum reduction percentage magnitude (14.96%) and minimum value showed by F_2 that was (11.52%). For observing individual performance in all generation and parents under both normal and late sowing trial the uppermost mean magnitude revealed by F_2, while the lowermost value was perceived by BC_1 (93.41) in normal and P_1 (80.05) scored minimum in late planting experiment (*Figure 4*). Similar results were presented by Tahir et al. (2009), Laghari et al. (2012) and Golparvar (2012). Grain filling rate is critical growth phase where hostile environmental circumstances leads to harmful effect on grain yield and quality. Delay planting face high temperature at the time of maturity and reduced grain filling duration. It has been noted in the recent studies high temperature stress increase rate of stem reservoir mobilization towards grain filling but not reimburse for short grain filling days (Farooq et al., 2011). Due to this reason grain could not reach maximum size ultimately decline in grain yield occured.

Harvest index

It may be explained as translocation of nutrients from vegetative part to reproductive part. In pooled mean value of both parents and generations, highest reduction percentage was noted in F_2 segregating generation (32.89%) while the lowest percentage was revealed by F_1 (23.62%) of cross Miraj 2008 × Punjab 2011. while in detecting individual performance of parents and generations under normal planting trial F_2 represented (44.10%) highest mean value and BC_2 showed (38.59%) the lowest value, whereas in late planting trial P_2 obtained (32.23%) highest mean value (*Figure 5*). Harvest index deliver fruitful information regarding selection of genotypes in late sowing conditions. It has been noted in literature the genotypes with more harvest index attained more biomass and performed well in delay sowing conditions (Akram, 2011; Mushtaq et al., 2011).
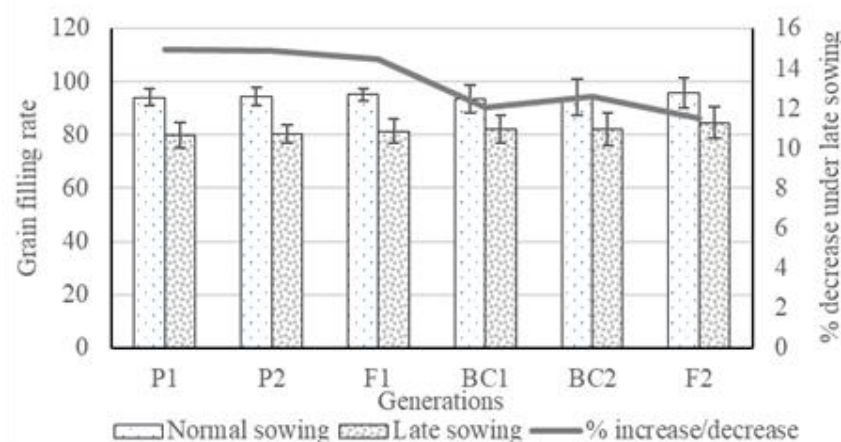

Figure 4. *Grain filling rate of six generations of cross Miraj 2008 × Punjab 2011 under normal and late sowing conditions along with % increase or decrease. Error bar represents standard errors and overlapping bars are statistically at par with each other*

Figure 5. *Harvest index of six generations of cross Miraj 2008 × Punjab 2011 under normal and late sowing conditions along with % increase or decrease. Error bar represents standard errors and overlapping bars are statistically at par with each other*
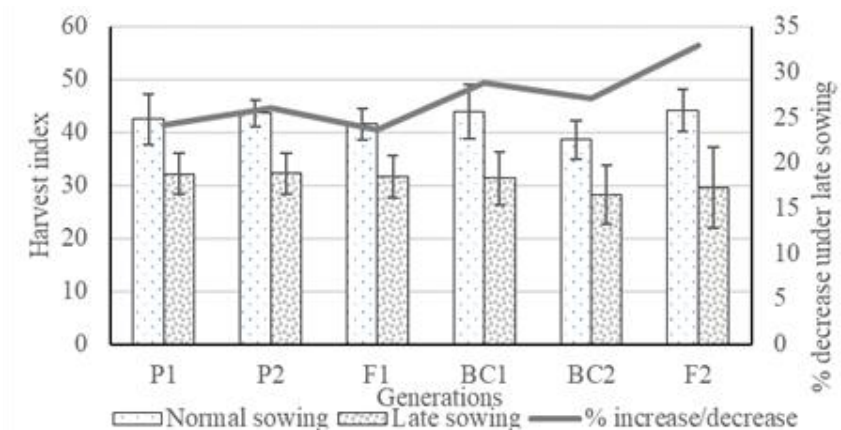
Morphological and yield related traits

The yield associated traits like Plant height (*Figure 6*), tillers number per plant (*Figure 7*) and grain weight per spike (*Figure 8*) were advisedly affected under late sowing conditions. Grain weight per spike revealed maximum decline, as all other yield related traits add up to decrease grain yield in delay planting condition. To select genotypes with optimum plant height with vigorous vegetative growth is painstaking criteria. Tillering in wheat crop help to compensate the yield even though plant population is not met adequately. Number of tillers per plant is reportedly decreased with the onset of late planting due to less growing degree days. Grain weight per spike is more sensitive trait under late sowing conditions.
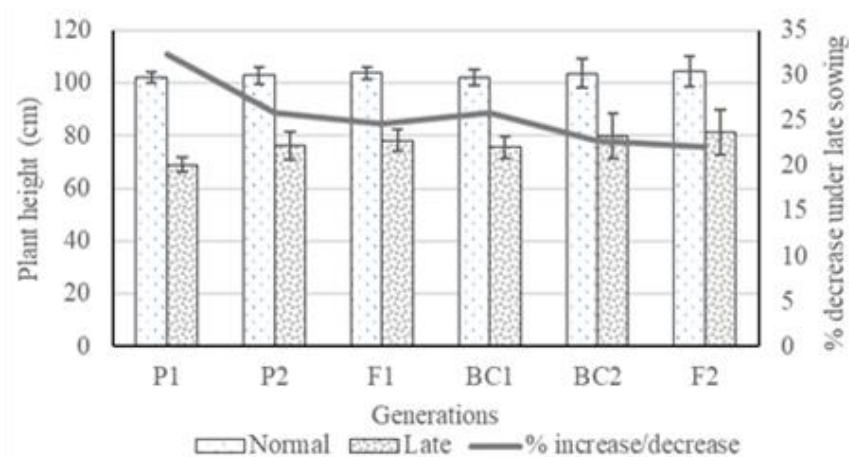

Figure 6. *Plant height of six generations of cross Miraj 2008 × Punjab 2011 under normal and late sowing conditions along with % increase or decrease. Error bar represents standard errors and overlapping bars are statistically at par with each other*

Figure 7. *Tillers number per plant of six generations of cross Miraj 2008 × Punjab 2011 under normal and late sowing conditions along with % increase or decrease. Error bar represents standard errors and overlapping bars are statistically at par with each other*

Figure 8. Grain weight per spike of six generations of cross Miraj 2008 × Punjab 2011 under normal and late sowing conditions along with % increase or decrease. Error bar represents standard errors and overlapping bars are statistically at par with each other
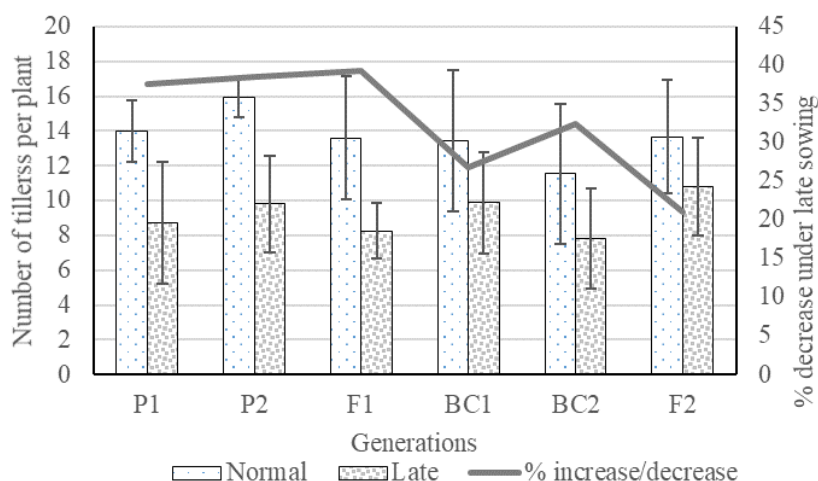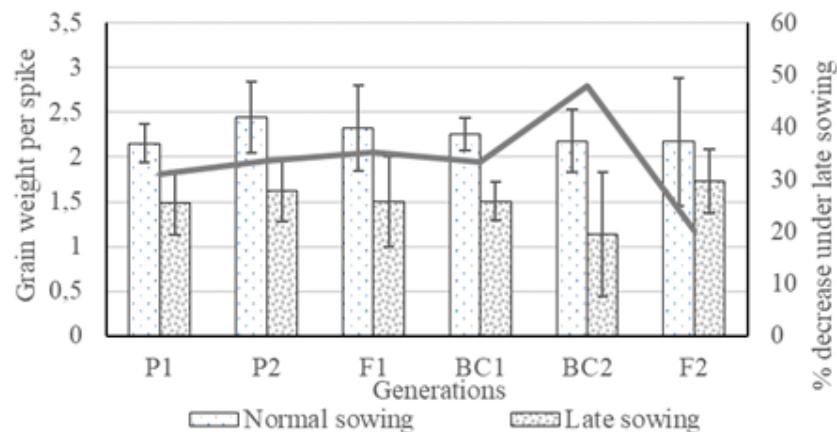
Gene action

Generation mean analysis was employed to assess the mean [m], additive [d], dominance [h], additive × additive [i], additive × dominance [j] and dominance × dominance [l] gene actions and magnitudes. The best efficacy of model was selected using two things i.e. lowest standard error and non-significant value of chi square χ^2 test for all traits under observation. For the detection of inheritance array in normal conditions for plant height five parameter model was best and vastly presence of additive [d] genetic effect than dominance [h], while the adequacy of three parameter model in late sowing conditions observed best fitted. Additive × additive [i] gene effects were significant. This suggests that selection should be carried out in later generations and the interaction should be fixed by selection under selfing conditions. These results are agreed with the observation of Farshadfar et al. (2001). Ojaghi and Akhundova (2010) noted additive, while conflicting results were depicted by Saleem et al. (2016). For tillers number per plant significant additive genetic effects with epistatic effects were also recorded. Additive × additive [i] interaction is more valuable for genetic improvement of characters through selection. In normal planting condition five [mdhij] and four [mdhi] parameter models in late planting conditions were observed best tailored to explain the genetic variation existed in breeding material for number of tiller per plant. Such type of findings were documented via Badran and Moustafa (2014) and conflicting conclusion were publicized by Ullah et al. (2010) and Rashid et al. (2012). Generation mean analysis revealed that days to heading was governed by polygenes i.e., complex genetic inheritance. The negative magnitude of [i] additive × additive epistatic effect showed in late sowing conditions gene expression not fully expressed in stressed condition and nature of epistasis was duplicate as main additive effect [d] were also reported. Five parameters [mdhij] in late and four [mdhi] parameter models obtained best fit to examine the variation in inheritance pattern (*Table 4*). Zara-Kohan and Heidari (2012) witnessed similar results. They revealed both fixable and non-fixable gene action. According to the nature of treatments in cross for days taken to maturity five parameter model [mdhij] was investigated fit for detection of gene action under both planting conditions. Hybrid breeding is fruitful for selection of trait because

prominent dominant [h] effect was paving. In normal planting non fixable gene action somewhat more percentage than fixable gene action.

Additive type of gene action was prominent in grain filling period in normal planting conditions with [i] and [j] epistatic effects but under late planting conditions change in gene action was witnessed (*Table 4*). It viewed under the effect of environment and duplicate type of epistasis was found because of main dominance effect [h] and epistatic dominance × dominant [l] effect had opposite sign under late planting time. The similar situation was examined by Nazeer et al. (2004). Zara-Kohan and Heidari (2012) reported selection in stable generation would be fruitful due to governing of non-fixable type of gene action for this parameter. For the inheritance of grain filing rate under late planting conditions four parameter model [mdhl] was found best fit (*Table 4*).

Table 4. *Estimates of the best fit model for generation means parameters (±, standard error) by weighted least squares analysis in cross Miraj 2008 × Punjab 2011 under normal and late sowing conditions*

Traits	Cross	Genetic Effects						χ2 (df)
		m ± S.E	[d] ± S.E	[h] ± S.E	[i] ± S.E	[j] ± S.E	[l] ± S.E	
Plant height	N	124.21±3.06	4.48±0.231	49.54±8.07	25.61±3.05	-	31.84±5.13	0.2864(1)
	L	84.40±1.05	3.61±0.23		11.79±1.08	-		0.8651(3)
Tiller number per plant	N	11.53±0.53	0.19±0.20	1.05±0.79	1.22±0.57	7.10±1.45	-	1.7860(1)
	L	7.18±0.42	0.41±0.14	1.04±0.40	1.97±0.45	-		4.455(2)
Days to heading	N	97.03±0.16	2.47±0.15	5.45±0.88	6.21±0.90	-	-	1.7548(2)
	L	88.96±0.65	1.95±0.22	-5.42±0.80	4.35±0.70	-7.55±1.58	-	1.1269(1)
Days to maturity	N	136.87±0.43	1.73±0.12	1.99±0.62	0.80±0.45	1.42±0.32	-	1.9142(1)
	L	133.24±1.90	1.77±0.20	46.30±4.99	-18.92±1.89	28.97±3.20	-	1.5337(1)
Grain filling duration	N	34.27±0.52	0.88±0.22	-3.60±0.72	4.44±0.57	-14.58±1.30	-	1.9844(1)
	L	31.23±0.24	2.63±0.24	6.19±1.02	-	-	-5.47±1.34	1.2870(2)
Harvest index	N	38.79±0.51	0.567±0.21	2.76±0.68	4.236±0.56	11.81±1.17	-	0.0158(1)
	L	26.84±0.74	1.01±0.27	4.43±1.23	-5.24±0.81		6.58±1.37	2.2183(1)
Grain filling rate	N	94.48±0.27	0.44±0.17	3.79±1.48	4.78±2.19	-	2.99±1.22	0.1496(1)
	L	80.70±1.28	5.19±1.12	8.50±5.04	-	-	7.72±2.22	1.1150(2)
Grain weight per spike	N	2.01±0.06	0.14±0.02	-	-	-0.44±0.20		4.5642(3)
	L	1.55±0.01	0.06±0.01	0.80±0.10	-	-0.88±0.12	0.74±0.10	1.2521(1)

N = normal sowing, L= late sowing conditions

Due to presence of non-allelic interaction this attribute was governed by multiple genes. Hybrid breeding is done for the improvement of grain filling rate due to presence of dominance component [*h*]. To obtain maximum grain filing rate selection could be done in succeeded generations. These results are lined with Nazeer et al. (2010) and clashing conclusions obtained by Ullah et al. (2010). For harvest index five parameters models i.e. [mdhij] and [mdhil] were found best fit under both normal and late planting environments. In late sowing condition [i] epistatic gene action showed negative sign which exhibited that gene interacting with one another (*Table 4*). Due to presence of main dominance effect [h] and dominant × dominant [l] selection can also performed in later generation and also hybrid breeding for harvest index would be fruitful. Farshadfar

et al. (2001) displayed same type of conclusion while. Grain weight per spike five parameter model [mdhjl] was adequate to elucidate the gene inheritance in late planting environment (*Table 4*). In order to attain higher grain weight per spike selection in succeeded generation could be helpful. Parallel results are confirmation with Amin (2006) and El-Rahman (2013).

Heritability studies

Estimation of heritability is another important estimate in order to understand the potential of characters to be improved through selection and also tells about the possibility of accumulation of favorable gene in the successive generation after selection. It also indicates the amount of genetic variability relative to environmental affects and is considered a good index of transmission of characters from parents to their offspring. Under normal sowing conditions range of narrow sense heritability was from 0.35 to 0.90 (*Table 5*). Most of the examined traits revealed moderate to high heritability except grain filling rate and grain weight per spike. The range (0.23 to 0.71) was observed under late sowing conditions (*Table 5*). Low to medium narrow-sense heritability can be attributed to the reduction of genetic variability in the late sowing environment. The higher heritability value will make the selection process effective, which will result in higher response. Selection of traits with high heritability in early generation is more fruitful. Abinasa et al. (2011) and Saleem et al. (2016) found high heritability for plant height, days to heading and days to maturity. While moderate type of heritability was observed by Nazeer et al. (2010). Zara-Kohan and Heidari (2012) and Khan and Naqvi (2011) have also noted high heritability for grain filling period. The reduction in heritability value under late sowing conditions indicated that gene responsible for the heritability of trait do not expressed themselves strongly in late sowing. Usually late sowing produce early senescence hence decrease in grain filling period causing reduction in yield. Therefore the genotypes which have longer grain filling period under stress conditions would be better yielder.

Table 5. Estimation of narrow sense heritability of different traits under studied

Traits	Normal sowing	Late sowing
Plant height	0.90	0.67
Tiller number per plant	0.76	0.23
Days to heading	0.89	0.71
Days to maturity	0.78	0.55
Grain filling duration	0.64	0.26
Harvest index	0.62	0.65
Grain filling rate	0.35	0.33
Grain weight per spike	0.47	0.41

Conclusion

Optimum sowing date for any cultivar is very crucial to accumulate ample dry matter and grain weight per spike yet to elude potential yield losses form high temperature stress during critical time mainly flowering initiation to grain filling stage. Genetic analysis showed that all traits under study were under the control of complex inheritance due to presence of epistasis. So, selection for these traits would be done in

later generations when combinations fixed. The phenological traits grain filling rate, grain filling duration and harvest index considered pivotal for the development of genotypes in late sowing conditions. So, for efficient breeding utilization of these phenological traits like grain filling rate, grain filling duration and harvest index are necessary to improve crop yield for late sowing wheat areas.

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