



### Full Length Article

## Evaluating the Impact of Seed Rate and Sowing Dates on Wheat Productivity in Semi-Arid Environment

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### Abstract

Variation in temperature significantly decreased wheat productivity. Appropriate seed rate and sowing time is crucial to achieve the higher yield on a sustainable basis. To evaluate the impact of seed rates and sowing dates on agro-physiological attributes of wheat, a trial was conducted during winter 2015–2016 and 2016–2017 using randomized complete block design with split plot arrangement. Treatments were comprised of four sowing dates (10<sup>th</sup> November, 25<sup>th</sup> November, 10<sup>th</sup> December and 25<sup>th</sup> December) and four seed rates (100, 125, 150 and 175 kg ha<sup>-1</sup>). Effect of variation in temperatures were evaluated by relationship of mean temperatures with phenology and yield. Results demonstrated that more days to anthesis of 107 and maturity days of 145 were recorded at 10<sup>th</sup> November sowing date. Maximum LAI of 5.85 were recorded at 25<sup>th</sup> November sowing date with seed rate of 175 kg ha<sup>-1</sup>, which was statistically similar with 10<sup>th</sup> November sowing date with 175 kg ha<sup>-1</sup> seed rate. Higher grain yield of 4717 kg ha<sup>-1</sup> was recorded in 10<sup>th</sup> November sowing dates with 125 kg ha<sup>-1</sup> seed rate in both year. Effect of mean temperatures with phenology and yield showed a negative co-relation with R<sup>2</sup> ranged from 0.84 to 0.95. Days to anthesis decreased by 10–15 days by increase in mean temperature of 1°C. Therefore, it is concluded that higher temperature during growing season of the crop negatively affected the phenology and yield attributes of wheat. In conclusion, wheat sown from 10<sup>th</sup> to 25<sup>th</sup> November at seed rate of 125 kg ha<sup>-1</sup> harvested maximum grain yield. However, in case of late sown wheat i.e., 10<sup>th</sup> and 25<sup>th</sup> December, the seed rates of 150 and 175 kg ha<sup>-1</sup> resulted in higher wheat yield. © 2019 Friends Science Publishers

**Keywords:** Sowing dates; Seed rate; Phenology; Growth; Temporal variability

### Introduction

Wheat (*Triticum aestivum* L.) is a basic cereal crop and a staple food in many countries which is the main source of carbohydrates and protein. In Pakistan cultivated area of wheat during 2017 was 9.05 mha with the total production of 25.8 m tons (Government of Pakistan, 2017). Environmental changes could cause the uncertainty in phenology, growth and yield. The ideal sowing time and optimum seed rate is a key challenge to sustain the wheat productivity under changing environment (Hussain *et al.*, 2012a; Asseng *et al.*, 2015).

Sowing time is a fundamental factor for deciding the crop yield. The sowing of crop on ideal time is essential to achieve more yield, as sowing date is temperature dependent (Hussain *et al.*, 2012a; Shah *et al.*, 2017). Crop sowing at appropriate time provides favorable conditions for wheat growth and development (El-Gizawy, 2009). High yield could be obtained in early sowing due to extended duration at grain filling stage as delayed sowing causes the warmer conditions cause the warmer conditions which reduces the growing season

length that lead to decrease in yield (Miralles *et al.*, 2001; Hussain *et al.*, 2012b).

Relatively early planting ensures optimum emergence through sufficient tiller number per unit area. The proper sowing date for wheat in Punjab ranges from 1<sup>st</sup> to 25<sup>th</sup> November and specifically for Faisalabad it ranges from 10<sup>th</sup> November to 25<sup>th</sup> November, and proper seed rate for wheat in Faisalabad is 125 kg ha<sup>-1</sup> (Said *et al.*, 2012). Each week delay of wheat sowing reduces the crop vegetative length and reproductive stages and causes yield reduction (Akmal *et al.*, 2011). Malik *et al.* (2009) reported that high seed rate compensates the reduction in germination count and tillers. Intra and interplant competition for light, water and nutrients were influenced by the seed rates.

Seed rate strongly influences the inter and intra plant competition for nutrients, space, light and water competition for nutrients, space, light and water. Less seed rate reduces the interplant competition during vegetative growth but intraplant competition could be increased at grain formation stage due to higher number of tillers (Ozturk *et al.*, 2006). Planting time has relationship with weather parameter, increase in temperatures affected the

crop yield due to shorten the length of growing season (Olesen *et al.*, 2011; Ahmed *et al.*, 2018). Uncertain rainfall pattern also affects the growth and yield of wheat. Temperature is a key technique for the boosting the grain yield and keep away from the high temperature impact are lacking. If the relationships of temperatures at various critical stages of the crop are known, then this method will be supportive to develop response function of sowing dates and seed rates. Higher temperatures reduce the tillers, grain size and ultimately yield of crop (Pavlova *et al.*, 2014). Therefore, this two-year field study was planned to (i) find out the optimum sowing time and seed rates to harvest maximum wheat yield, (ii) and the impact of variation in temperature at different sowing dates on the growth, phenology and yield of wheat crop.

## Materials and Methods

### Study Sites

Experiment was conducted at Agronomic Research area, the University of Agriculture, Faisalabad (UAF), Pakistan (31°26' N, 73°04' E) during 2015–2016 and 2016–2017. The treatments were four sowing dates (S) (10<sup>th</sup> November, 25<sup>th</sup> November, 10<sup>th</sup> December, 25<sup>th</sup> December) and four levels of seed rates (SR) (100 kg ha<sup>-1</sup>, 125 kg ha<sup>-1</sup>, 150 kg ha<sup>-1</sup>, 175 kg ha<sup>-1</sup>). Randomized complete block design (RCBD) with split plot arrangement were used. Sowing dates were placed in main plot while seed rates were kept in subplot. The net plot size was 1.8 m × 5 m and each treatment was replicated three times. Crop was sown with hand drill with row to row distance of 22 cm. Nitrogen (N) dose of 60 kg ha<sup>-1</sup>, phosphorus (P) 85 kg ha<sup>-1</sup> and potassium (K) of 60 kg ha<sup>-1</sup> were applied at the time sowing and the second dose of nitrogen (60 kg ha<sup>-1</sup>) was applied with first irrigation. All other operations such as weed control, irrigation application and intercultural practices were performed same for all the treatments.

### Soils and Weather Data

Soil sampling was done randomly at the depth of 30 cm from the experimental site. Composite sample was made from the various collected samples for the analyses of physical and chemical characteristic. Structure of soil was determined by the methods describe by (Moodie *et al.*, 1959), while chemical properties as showing in Table 1 were estimated by Homer and Pratt (1961) methods. The soil of experimental site was sandy clay loam and proportion of sand, silt and clay were 62%, 16% and 24%, respectively. Physiochemical properties of soil are described in Table 1.

Seasonal weather data for the experiments were taken from the field observatory as shown in Fig. 1. The mean maximum temperatures of 40.5°C and minimum temperature of 26.9°C were observed during the month of June. Weather data of growing seasons during 2015–2016 and 2016–2017 are presented in Fig. 1. Results indicated

that growing season 2016–2017 was relatively warmer than 2015–2016. In case of months, March and April were warmers, then others. Less solar radiation of 30% was recorded due to foggy conditions during the months of January and February both years. Total rainfall of 1128 mm was recorded for the years 2015 to 2017.

### Sampling and Analysis

Data on phenology, growth and yield traits were taken from the experiment for both years. Five plants were tagged randomly from each plot to record the data of phenology such as days to anthesis and maturity. Half of each plot was selected to record the growth data fortnightly on leaf area index (LAI) and total dry matter (TDM). Half meter-long row from each plot was harvested at ground level. Fresh and dry weight of component fraction of plant (leaf and stem) were determined. Subsample of 5 g were taken to record the Leaf Area (LA) using LAI meter (Model CI-202, CID, Inc.), for TDM samples were oven dried at 65°C till constant weight. Similar method was used by Ahmad *et al.* (2019). LAI and TDM were calculated by the formula describe by Watson (1947). Data of yield and related traits and phenology of wheat were recorded following Hussain *et al.* (2012b, 2016).

### Statistical Analysis

Combined year analysis was performed for data analysis in SAS V9.5. Treatment differences were evaluated by using honest significant difference (HSD) test at 0.05 probability (O'Rourke *et al.*, 2013). Pearson product moment correlation analysis (Equation 1) were conducted to correlate the impact of temperatures on different phenological stages of the crop. In current study, mean temperature of both years of 2015 and 2016 were calculated at different critical stages.

$$r = \frac{n \sum xy - (\sum x)(\sum y)}{\sqrt{[n \sum x^2 - (\sum x)^2][n \sum y^2 - (\sum y)^2]}} \quad (\text{Equation 1})$$

Where “r” is the Pearson product moment correlation coefficient “n” is the number of paired “x” is the temperature and “y” is specific stage of crop.

## Results

### Crop Phenology

Phenological events such as days to anthesis and maturity were significantly affected by the sowing dates and seed rates, while the interaction between the sowing dates and seed rate and year effect was non-significant (Table 2). Crop sown on 10<sup>th</sup> of November took 107 days to flowering, while wheat sown on 25<sup>th</sup> of December took minimum 86 days to reach anthesis. Days to anthesis were gradually decreased with the delay in planting of wheat from 10<sup>th</sup>

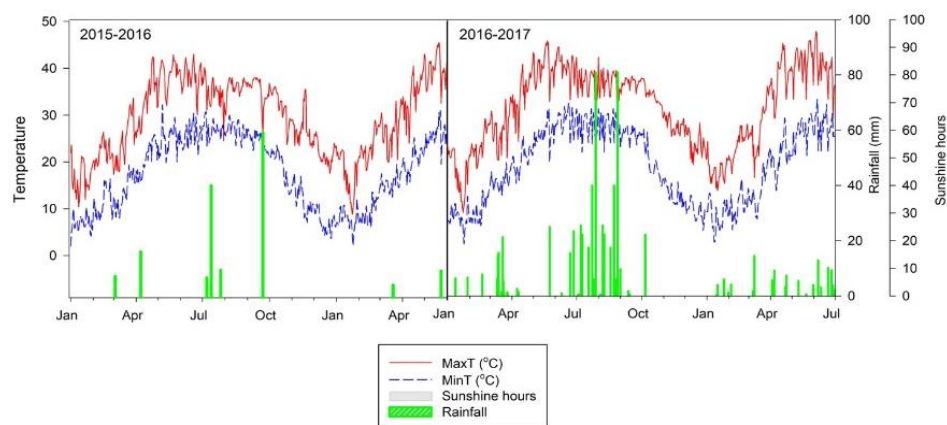
**Table 1:** Physico-chemical characteristics of experimental soil

(a) <u>Soil physical properties</u>	
Soil type	Sandy clay loam
Sand (%)	62
Silt (%)	16
Clay (%)	24
(b) <u>Soil chemical properties</u>	
Organic matter (%)	1.28
TTS (Total soluble salt) %	12.38
pH	7.52
Nitrogen (N) %	0.62
Available Phosphorus ( $P_2O_5$ ) mg kg <sup>-1</sup> )	6.92
Available Potassium (K) (mg kg <sup>-1</sup> )	19.2

**Table 2:** Analysis of variance for yield-related traits of wheat

Source of Variance	Plant height (cm)	Number of productive tillers (m <sup>-2</sup> )	Number of grains per spike	Leaf area index max.	1000-grain weight (g)	Grain yield (kg ha <sup>-1</sup> )	Biological yield (kg ha <sup>-1</sup> )	Harvest index (%)	Days to anthesis	Days to maturity
Year (Y)	0.35 <sup>NS</sup>	0.18 <sup>NS</sup>	0.23 <sup>NS</sup>	0.11 <sup>NS</sup>	0.23 <sup>NS</sup>	0.06 <sup>NS</sup>	0.11 <sup>NS</sup>	0.75 <sup>NS</sup>	0.14 <sup>NS</sup>	0.30 <sup>NS</sup>
Sowing dates (S)	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**
Y×S	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>	0.54 <sup>NS</sup>	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>	0.97 <sup>NS</sup>	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>
Seed rate (R)	0.07*	0.0001**	0.75 <sup>NS</sup>	0.001**	0.02*	0.0001**	0.0001**	0.0001**	0.21 <sup>NS</sup>	0.51 <sup>NS</sup>
S×R	1.00 <sup>NS</sup>	0.03*	0.99 <sup>NS</sup>	0.03*	0.30 <sup>NS</sup>	0.0001**	0.01**	0.0001**	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>
Y×R	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>	0.99 <sup>NS</sup>	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>
Y×S×R	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>	1.00 <sup>NS</sup>

Note: \* and \*\* are significant at 0.05 and 0.01 probability level, respectively; NS = Non-significant

**Fig. 1:** Seasonal weather data of Faisalabad during 2015-2016 and 2016-2017

November to 25<sup>th</sup> December during both years. Similarly, seed rate showed the non-significant effect on days to anthesis. More days to anthesis (107) were recorded in 10<sup>th</sup> November sowing date. However, days to anthesis of 98 were in seed rate of 175 kg ha<sup>-1</sup> were recorded.

Maturity days gradually decreased by delayed in sowing with 15 days interval. Crop sown on 10<sup>th</sup> of November, mature after 145 days, while 25<sup>th</sup> December sown crop matured after 121 days. Late sown crop showed early maturity because high temperature during mid-February increased the growth rate and shorten the length of growing period. Whereas the maximum time (134 days) was observed on 175 kg ha<sup>-1</sup> seed rate while minimum (133 days) was observed on 100 kg ha<sup>-1</sup> seed rate (Table 4).

### Yield and Related Traits

Sowing dates and seed rate affected the plant height and 1000 grain weight significantly, while the interaction and year effect of sowing date and seed rate showed non-significant result (Table 2). Maximum plant height of 103 cm was recorded on 10<sup>th</sup> November of sowing date, while minimum plant height of 87.7 cm was observed on 25<sup>th</sup> December sowing date (Table 4) and in seed rate the higher plant height 97.1 cm was recorded at 175 kg ha<sup>-1</sup> and less plant height 93.7 cm was observed at 100 kg ha<sup>-1</sup> seed rate. Higher 1000-grain weight of 38.8 g was observed with 10<sup>th</sup> November sowing date, while less 1000-grain weight of 28.3 g was found at 25<sup>th</sup> of December (Table 4). In case of

**Table 3:** Interactive effect of sowing date and seed rate on yield-related traits of wheat

Sowing dates	Seed rates (kg ha <sup>-1</sup> )	No. of productive tillers (m <sup>-2</sup> )	Leaf area index max.	Grain yield (kg ha <sup>-1</sup> )	Biological yield (kg ha <sup>-1</sup> )	Harvest index (%)
10 <sup>th</sup> November	100	277 a-d	4.86 ab	4213 b	10789 a-c	39.0 ab
	125	315 ab	5.17 a	4717 a	11486 a	41.1 a
	150	323 a	5.23 a	4061 bc	11602 a	35.1 bc
	175	307 a-c	5.22 a	3631 c	11359 ab	32.0 c
25 <sup>th</sup> November	100	267 b-d	4.32 bc	3670 c	9596 c-e	38.3 ab
	125	305 a-c	5.17 a	4325 ab	11076 a-c	39.0 ab
	150	316 ab	5.18 a	4445 ab	11473 a	39.0 ab
	175	299 a-c	5.86 a	3612 c	11481 a	31.5 dc
10 <sup>th</sup> December	100	196 f	2.73 ed	1775 e-g	7093 f	25.0 e-g
	125	234 d-f	3.14 d	2205 ed	8053 e-g	27.4 de
	150	275 a-d	3.88 c	2678 d	9809 b-d	27.3 de
	175	278 a-d	3.96 c	2647 d	9991 a-d	26.6 e
25 <sup>th</sup> December	100	185 f	2.36 e	1375 g	6569 g	21.0 g
	125	215 ef	2.82 ed	1705 fg	7718 f	22.2 fg
	150	228 d-f	2.85 ed	1870 ef	7784 gf	24.0 e-g
	175	259 c-e	3.09 d	2135 ef	8386 d-f	25.5 ef

**Table 4:** Effect of sowing date and seed rate on yield-related traits of wheat

Treatments	Plant height (cm)	No. of grains per spike	1000-grain Weight (g)	Days to anthesis	Days to maturity
10 November	102.84 a	37.49 a	38.82 a	108 a	146 a
25 November	98.67 ab	37.59 a	37.62 a	102 b	139 b
10 December	92.10 bc	31.56 b	32.64 b	93 c	129 c
25 December	87.67 c	29.11 c	28.29 c	86 d	121 d

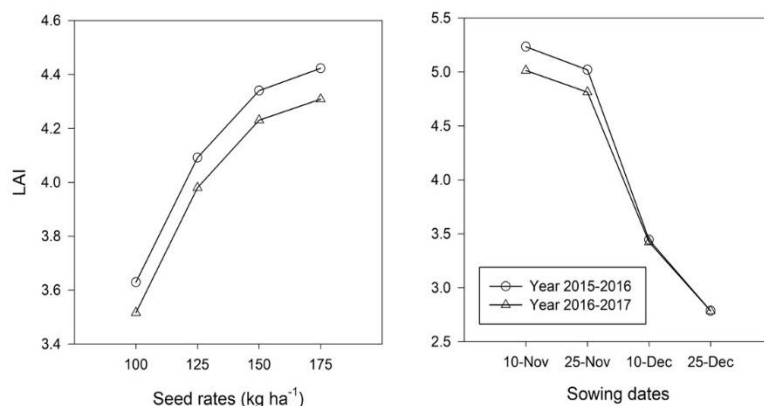
seed rate, higher grain weight of 35.0 g was found at 100 kg ha<sup>-1</sup> that was statistically similar with 125 kg ha<sup>-1</sup>. Less grain weight of 33.0 g was observed at 175 kg ha<sup>-1</sup> that is similar with 150 kg ha<sup>-1</sup> (Table 4). Thousand grain weight was also indicated a decreasing at all sowing dates after 10<sup>th</sup> November.

Interactive effect of sowing date and seed rate significantly affected the productive tillers, grain per spike, maximum LAI, harvest index, grain and biological yield. The year effect was non significant as shown in Table 2. Results indicated that higher number of tillers 323 m<sup>-2</sup> were recorded in sowing date of 10<sup>th</sup> November with 150 kg ha<sup>-1</sup> seed rate, and it is statistically at par with sowing date 25<sup>th</sup> November with 150 kg ha<sup>-1</sup> seed rate where (316) productive tillers were recorded. While a lower tillers of 185 m<sup>-2</sup> were recorded in 25<sup>th</sup> of December sowing date with 100 kg ha<sup>-1</sup> seed rate (Table 3). and it is statistically similar with the sowing date 10<sup>th</sup> December with 100 kg ha<sup>-1</sup> seed rate.

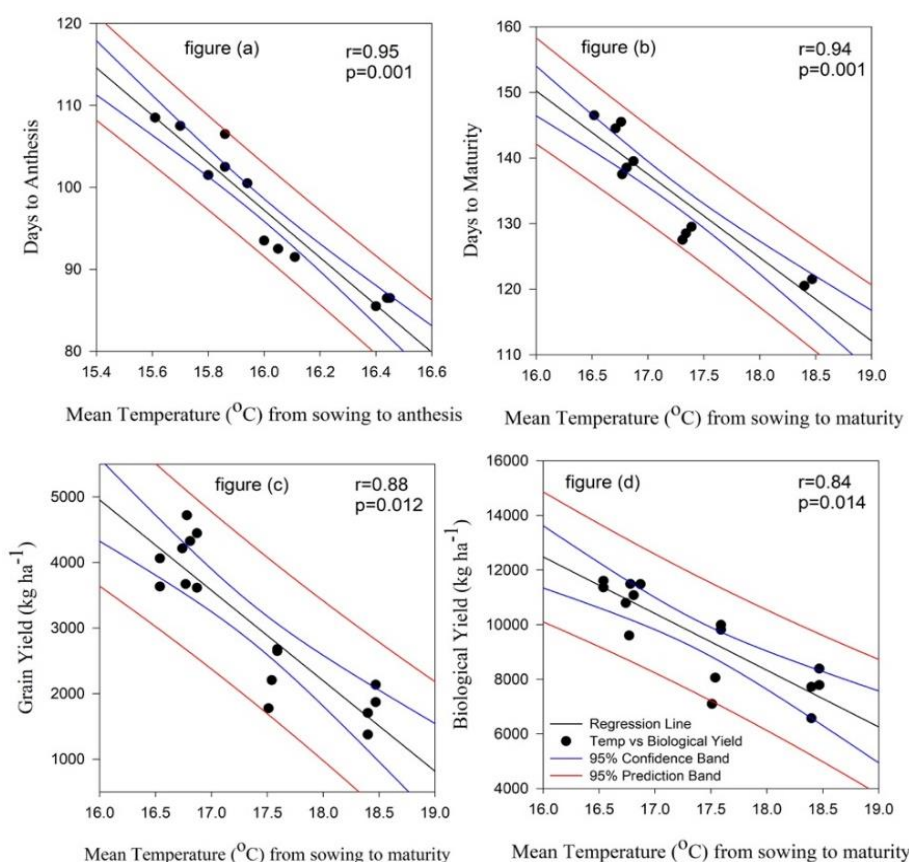
Higher grains per spike of 37.6 were observed at 25<sup>th</sup> November sowing date, which was statistically similar with 10<sup>th</sup> November sowing date. Less number of grains per spike (29.1) were found in last sowing date (i.e., 25<sup>th</sup> of December) (Table 4). The maximum grain per spike (34.3) produced by the 125 kg/ha<sup>-1</sup> seed rate whereas the minimum grain per spike were 33.5 produced by the seed rate of 175 kg ha<sup>-1</sup>. Grains per spike is significant contributor to wheat yield. Results indicated that a maximum number of grains were observed in 10<sup>th</sup> November sowing date. The number of grains per spike was lower after 10<sup>th</sup> November planting while cultivars response was different with shifting of sowing dates.

Higher LAI of 5.86 was recorded at 25<sup>th</sup> November sowing date with seed rate of 175 kg ha<sup>-1</sup>, which was statistically similar with sowing date of 10<sup>th</sup> November with 150 kg ha<sup>-1</sup> seed rate. Higher LAI was due to favorable weather condition that increases the vegetative period. Late sowing of wheat on 25<sup>th</sup> of December with 100 kg ha<sup>-1</sup> seed rate resulted in less LAI of 2.36, which could due to lower temperatures during the December (Table 3). More LAI was recorded with increased in seed rates and in case of sowing dates, LAI decreased with late planting as shown in Fig. 2. Higher grain yield of 4717 kg ha<sup>-1</sup> was recorded on 10<sup>th</sup> November with 125 kg ha<sup>-1</sup> seed rate and it is statistically at par with the 25<sup>th</sup> November sowing date where 150 kg ha<sup>-1</sup> seed rate (4445 kg ha<sup>-1</sup>) was recorded and minimum (1375 kg ha<sup>-1</sup>) was obtained from 25<sup>th</sup> of December sowing with 100 kg ha<sup>-1</sup> seed rate (Table 3). The early sowing produced maximum yield because of optimum growth duration. Wheat sown on 10<sup>th</sup> November produced higher yield as compared to remaining sowing dates. Higher biological yield of 11359 kg ha<sup>-1</sup> was found at 10<sup>th</sup> November sown with 175 kg ha<sup>-1</sup> seed rate and it was statistically similar with 25<sup>th</sup> November sowing date with 175 kg ha<sup>-1</sup> seed rate. However, less biomass of 6569 kg ha<sup>-1</sup> was recorded on late sowing date of 25<sup>th</sup> of December with 100 kg ha<sup>-1</sup> seed rate (Table 3). Biological yield was increased in early sowing as compared to late sowing due to prolonged periods.

Maximum harvest index (41.1) was observed on 10<sup>th</sup> November with 125 kg ha<sup>-1</sup> seed rate and it is statistically at par with 25<sup>th</sup> November with 125 kg ha<sup>-1</sup> where (39) was recorded. While minimum (21) was observed on 25<sup>th</sup> of December with 100 kg ha<sup>-1</sup> seed rate (Table 3).



**Fig. 2:** Maximum leaf area index of different sowing dates and seed rate during 2015-2016 and 2016-2017



**Fig. 3:** Effect of mean temperatures on phenology and yield of wheat

### Effect of Mean Temperature on Phenology and Yield of Wheat

Variation in temperature affect wheat yield. Extreme temperatures significantly decrease the wheat yield by reducing the growing period. Results showed that mean temperature affected the phenology, grain and biological yield (Fig. 3). Negative correlation ( $-0.95$ ;  $p = 0.001$ ) was

observed between mean temperature from sowing to anthesis with days to anthesis of wheat. Days to anthesis decreased by 10–15 days by increase in mean temperature of  $1^{\circ}\text{C}$  as shown in Fig. 3 (a). Mean temperature from sowing to maturity showed a strong negative correlation with days to maturity ( $-0.94$ ;  $p = 0.001$ ), grain yield ( $-0.88$ ;  $p = 0.012$ ) and biological yield ( $-0.84$ ;  $p = 0.014$ ) as shown in Fig. 3b–d.

## Discussion

Variation in temperature decrease the days to anthesis and maturity. Recent study showed that days to anthesis decreased by 20 days when sowing date is shifted from 10<sup>th</sup> November to 25<sup>th</sup> December. The reason for decreasing the anthesis days could be high temperature in late sowing which reduces the length of growing season. Asseng *et al.* (2015) and Ahmad *et al.* (2018) found that high temperature decreased the days to anthesis and maturity which lead to decrease the yield. In current study result showed that plant height, numbers of productive tillers and grains per spike were higher at 10<sup>th</sup> November and decreased by delayed in planting from 10<sup>th</sup> November to 25<sup>th</sup> December and seed rate as shown in Table 4. The reason for high yield attributes at 10<sup>th</sup> November could be extended growing and grain filling duration. However, decreased in yield attributes could be due to high temperature in late sowing which reduces the degree days, photosynthetic active radiation and efficiency of source-sink relationship. Plant height was reduced by 11 to 19% in wheat when sowing time is delayed from 25<sup>th</sup> October to 15<sup>th</sup> December (Basir *et al.*, 2015). Plant height decrease in late planting due to high temperature and photoperiod which reduce the growth cycle (Slafer and Rawson, 1994). Plant height increase with higher planting density, due to minimum space for horizontal expansion of the plant and increase the competition for light interception between plants drives upward growth Ayalew *et al.* (2017) also reported an increasing pattern in plant height with increasing seed rate ha<sup>-1</sup>. Less number of tillers is due to higher temperatures in late planting. Higher soil temperature caused the poor germination and reduced the number of tillers similar were stated by (Tahir *et al.*, 2009). Wajid *et al.* (2004) reported that lower temperatures also affected the germination and reduced the tillers. High Seed rate is required in late planting to get maximum yields. This reason could be that late planting has less degree days for development of tiller and more plant population are required to compensate the less tillers. However, in early sowing date plant received more degree days for tiller development so do not require more seed rate (Woodward, 1996; Dahlke *et al.*, 1999). Less spike length in late plating is due to higher temperature, while higher plant population also reduced the spike length due to increase in plant competition. Ahmad *et al.* (2018) found that high temperature in late sowing shorten the growing periods. Maximum LAI was recorded at 10<sup>th</sup> and 25<sup>th</sup> November sowing dates and decrease in late planting (Table 3). Higher LAI was due to favorable weather condition that increases the vegetative period. Less LAI could be due to lower temperatures during month of December and late sown crop received less solar radiation at the critical growth stages (Hussain *et al.*, 2012a). LAI increased with high seed rate (Fig. 2); the reason could be increase in plant population density per unit area increased the percentage of light

intercepted. Dry matter production was proportionally higher with more light intercepted (Ali *et al.*, 2003; Fischer *et al.*, 2019). Higher grain weight, harvest index and biological yield was recorded at 10<sup>th</sup> and 25<sup>th</sup> November and decreased in late planting as shown in table 3. The Reason for reduction in yield attribute is due to higher temperature at late sowing, reduces the degree days and efficiency of sink size (Blum *et al.*, 1994). Higher grain yield could be due to suitable temperature during season while less grain formation in wheat planted on 25<sup>th</sup> December. Wheat planted at suitable time produced higher yield, due to assimilation of more photosynthates (Spink *et al.*, 2000; Shahzad *et al.*, 2002) with more number of plants. Late-planted wheat faced late germination and low growth rate at an early stage which ultimately reduced the wheat plants per unit area and low biomass per plant as reported by (Hussain *et al.*, 2012a). High seed rate increases the plant competition in early sowing that decrease the grain weight which leads to decrease gain yield. Grain yield decreased in high plant density might be due to shriveled grain and lodging of crop. similar finding was reported by (Shahzad *et al.*, 2007; Baloch *et al.*, 2010). Crop development was strongly affected by changing sowing dates, might be due to specific genetic response at the particular date as Wollenweber *et al.* (2003) and Howarth (2005) reported three important factors which induced a specific growth stage in crops. They included aerial temperature, day length and genetic makeup of variety. Overall crop duration was gradually decreased with delay in wheat planting from 16<sup>th</sup> October to 15<sup>th</sup> march as elevation in temperature enhanced the crop processes as compared to normal temperature (Wahid *et al.*, 2007; Rahman *et al.*, 2009; Hakim *et al.*, 2012). Harvest index might be affected due to fluctuating environmental conditions and the random or sudden onset of rainfall at critical stages. Andarzian *et al.* (2014) stated that late sowing as linked to the normal sowing reduces the duration of wheat crop as well as grain weight, harvest index, grain size and number. Days to maturity decreased by 15–20 days with increase in mean temperature of 2°C (Fig. 3b). Grain and biological yields linearly decreased as temperature is increased. Ahmad *et al.* (2018) stated that increase in temperature decreases the yield due to increase in growth rate and reducing the length of growing period. Higher temperature at reproductive phase of late sown wheat reduced the grain weight due to shortening of grain filling phase that ultimately leads to reduced grain yield (Hussain *et al.*, 2012b; Ahmad *et al.*, 2018).

## Conclusion

Wheat sown on 10<sup>th</sup> November with 125 kg ha<sup>-1</sup> seed rate produced higher grain yield. Delay in sowing from 25<sup>th</sup> November to 25<sup>th</sup> December gradually decreases the growth and yield of wheat. To achieve higher yield of late sown (10<sup>th</sup> and 25<sup>th</sup> December) wheat, seed rates 150 and 175 kg ha<sup>-1</sup> could be used. Relationship of seasonal mean



temperature with phenology showed days to anthesis decreased by 10–15 days and maturity days decreased by 15–20 with increase in mean temperature of 1–2°C.

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