



Full Length Article

Delay in Planting Decreases Wheat Productivity

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ABSTRACT

This study was conducted to evaluate the growth and yield response of different wheat varieties sown on different dates. Five wheat varieties viz. Sahar-2006 (SH-06), Faisalabad-2008 (FSD-08), Lassani-2008 (LS-08), Abdul Staar-2002 (AS-02) and Triple Dwarf-1 (TD-1) were sown, at fortnightly interval, on 25th Oct, 10 and 25th Nov, and 10th and 25th Dec. Delayed wheat planting after 10th Nov decreased the grain yield by 60 kg ha⁻¹ for each day; however, varietal response was significantly variable. Although, more productive tillers were noted in 25th Oct sown wheat; however wheat productivity was maximum from wheat sown on 10th Nov owing to significant increase in spike length, spikelets per spike and grain weight. Among wheat varieties, maximum grain yield was harvested in LS-08 followed by AS-02; whereas minimum grain yield was noted in wheat variety TD-1. Regarding crop allometry, higher leaf area index (LAI) and crop growth rate (CGR) were noted from early sown crop, whereas among varieties, LS-08 and AS-02 had higher LAI and CGR than other varieties. Interaction of sowing dates and wheat varieties indicated that LS-08 and AS-02 planted on 10th Nov outperformed with maximum grain yield. In conclusion, wheat varieties LS-08 and AS-02 may be planted on 10th Nov to fetch maximum wheat productivity. © 2012 Friends Science Publishers

Key Words: Allometry; Grain yield; Sowing dates; Tillers; Varieties

INTRODUCTION

Wheat (*Triticum aestivum* L.) is a major cereal crop of Pakistan and increasing demographic pressure set a challenge to enhance its productivity. Delayed wheat planting is amongst the major yield limiting constraints in rice-wheat and cotton-wheat cropping systems of South Asia including Pakistan (Fujisaka *et al.*, 1994). In both these cropping systems, 70% wheat is sown after harvest of cotton and rice crops; and late maturing Basmati varieties of rice and delayed picking of cotton delay the sowing of wheat (Nayyar & Iqbal, 2001). Moreover, rainfall during land preparation may further delay wheat sowing by 2-3 weeks (Aslam *et al.*, 1993). Late-October to mid-November is the best time for wheat sowing in Pakistan to harvest maximum wheat yield; and any delay in wheat planting may cause yield decrease up to 50 kg ha⁻¹ per day (Aslam *et al.*, 1993).

This yield decrease is primarily due to poor and erratic germination and crown root initiation because of low temperature prevailing at that time (Phadnawis & Saini, 1992; Farooq *et al.*, 2008). Temperature plays a key role in stand establishment, leaf initiation, leaf expansion and grain development (Jame & Cutforth, 2004). Temperature regulates the wheat growth and development by two ways; firstly if temperature rises in winter, it prolonged

vegetative phase and secondly if temperature rises in spring, then it reduces its vegetative period. Moreover, late sown crop enters reproductive phase later thus experiencing terminal heat stress, which impedes the grain development resulting in yield penalty (Rahman *et al.*, 2009; Bashir *et al.*, 2010; Farooq *et al.*, 2011).

Impact of delayed planting is also reflected in the form of decrease in days to maturity and grain filling period, all resulting in reduction of yield (Farooq *et al.*, 2011). Nonetheless, being photosensitive in nature, late sown wheat has to realize its life cycle in much shorter time as starch accumulation is ended at same specific time irrespective of sowing time (Alignan *et al.*, 2009). Late planted wheat bears few small sized grains per spike than wheat planted at optimum time due to shorter growing period and low production of photosynthates due to short life cycle (Shahzad *et al.*, 2002; Alignan *et al.*, 2009).

Genetic variations among cereal crops is very common (Asseng & Milroy, 2006; Xu *et al.*, 2007) and different wheat varieties observe a great variability among their developmental responses to local climate that make them fit to grow under different climatic conditions. For instance, suboptimal temperature prevailing in late planted wheat significantly reduces the tillers per unit area; however wheat varieties behave differently in this regard (Aslam *et*

al., 2003; Shah *et al.*, 2006). Moreover, delayed planting in wheat shortened the life cycle that caused significant reduction in 1000-grain weight and fertile tillers count but different wheat genotypes differ for grain yield, shoot biomass and harvest index (Ehdaie & Waines, 2001). Short duration varieties may better fit for late sowing due to their biological efficiency (Darwinkel *et al.*, 1977; Arain *et al.*, 1999).

Although delayed planting of wheat has always negative implications on its productivity, but sometimes sowing too early also poses detrimental effects due to unfavorable temperature at sowing. High temperature such as above 13°C during night coupled with 33-35°C during day in the last fortnight of October reduced tillering capacity and produced smaller ears with fewer fertile spikelets (De *et al.*, 1983). Time to start germination, emergence rate; crown root development and stem elongation were significantly different at higher and lower temperatures in different wheat genotypes (Jame & Cutforth, 2004).

With the ongoing global climate change for the last few years, winter comes a bit late in Pakistan. Optimum temperature for wheat emergence is available even during the 1st fortnight of December. Therefore, this study was designed to optimize the sowing time of wheat in quest of best suitable planting time for harvesting higher wheat yields.

MATERIALS AND METHODS

Experimental site description: This study was carried out at Research Farm of University College of Agriculture, Bahauddin Zakariya University, Multan (71.43° E, 30.2° N & 122 meter above sea level), Pakistan, during winter 2009-2010. Climate of the region is semi-arid subtropical. Experimental field was fairly uniform and pre-sowing physico-chemical analysis was done to assess the soil fertility status (Table I).

Experimental details: The experiment was replicated thrice in randomized complete block design (RCBD) with split plot arrangements having a net plot size of 5 m × 1.8 m. Sowing dates and wheat cultivars were randomized in main plots and sub plots, respectively. Five divergent wheat varieties Sahar-2006 (SH-06) (tall & low tillering), Faisalabad-2008 (FSD-08) (tall & low tillering), Lassani-2008 (LS-08) (tall & low tillering), Abdul Staar-2002 (AS-02) (tall & high tillering) and Triple Dwarf-1 (TD-1) (dwarf & low tillering) were sown at fortnightly interval on 25th Oct, 10 and 25th Nov, and 10th and 25th Dec. Meteorological data recorded during whole course of study are given in Table II.

Crop husbandry: Prior to seedbed preparation, pre-soaking irrigation of 10 cm was applied. When field capacity was reached, seedbed was crafted by cultivating the field twice with a tractor-mounted cultivator followed by planking each time. All five wheat varieties were sown in well prepared seedbed on aforementioned sowing dates.

Table I: Pre-sowing physico-chemical analysis of soil

Determination	Unit	Value	Status
Physical Analysis			
Sand	%	67.70	
Silt	%	16.20	
Clay	%	16.10	
Textural class		Sandy clay loam	
Chemical Analysis			
pH		7.80	
EC	dS m ⁻¹	1.27	
Organic matter	%	0.58	Low
Total nitrogen	%	0.04	Very low
Available phosphorus	ppm	10.00	Low
Available potassium	ppm	127.00	Medium

Table II: Meteorological data during the course of study

Month	Mean monthly Temperature (°C)	Mean monthly RH (%)	Total rainfall (mm)
Oct 2009	25.30	59.60	0.50
Nov 2009	19.20	75.10	0.00
Dec 2009	15.50	76.80	0.00
Jan 2010	12.20	79.00	2.10
Feb 2010	15.80	63.00	2.40
Mar 2010	23.50	62.00	45.10
Apr 2010	30.40	34.00	6.50

Source: Agro-climatic cell, Central Cotton Research Institute, Multan, Pakistan

Sowing was done by a single row hand drill in 22.5 cm spaced rows using seed rate of 125 kg ha⁻¹. Fertilizers were applied at 200 and 150 kg ha⁻¹ nitrogen and phosphorus, respectively in the form of urea and triple super phosphate. Whole phosphorus and half nitrogen were applied at the time of sowing, while remaining nitrogen was applied at first irrigation (25 days after sowing). Besides soaking irrigation, four irrigations i.e., at crown root, booting, flowering and grain formation stages of wheat were applied to evade the crop from the detrimental effects of water stress. Mature crop was harvested during April 10-20, 2010.

Observations: Total number of fertile (spike bearing) tillers was counted from a randomly selected unit area (1 m × 1 m) at four different locations in each plot. Length of ten randomly selected spikes was measured with ruler. Number of fertile spikelets were counted from ten randomly selected spikes and then averaged to record spikelets per spike. Total florets from five randomly selected spikes were counted and averaged to record number of florets per spikelet. Ten randomly selected spikes from each plot were harvested, threshed manually; total number of grains was counted. Five random samples of thousand grains were taken at random from each seed lot, weighed and averaged to record 1000-grain weight. At harvest maturity, two central rows (5 m long) were harvested, sun dried for three days, tied into bundles and weighed to record biological yield. After that it was threshed manually, grains were separated and weighed. Grain yield was then adjusted to 10% moisture contents. Harvest index (HI) was calculated as ratio between grain yield and biological yield expressed in percentage.

Leaf area was measured with leaf area meter (DT Area Meter, model MK2, Delta, T Devices, Cambridge, UK) at 15 days interval. Sampling was started after 45 days of sowing and terminated just before maturity. Thereafter, leaf area index (LAI) was calculated as ratio of leaf area to land area (Watson, 1947). Crop growth rate (CGR) was calculated following the Hunt (1978).

Statistical analysis: The collected data were statistically analyzed by using Fisher's analysis of variance technique and LSD test at 5% probability was used to compare the differences among treatments' means (Steel *et al.*, 1997). Graphical presentation of the data was done using Microsoft Excel.

RESULTS

Delayed planting (25th Dec) caused significant reduction in fertile tillers (m⁻²) than early sown wheat; whereas among wheat varieties, higher fertile tillers were observed in AS-02 than other wheat varieties under study (Table III). Regarding interactive effect, maximum fertile tillers were noted in early sown (25th Oct) AS-02 and SH-06; while SH-06, FSD-08, LS-08 and TD-1 planted on 25th Dec produced minimum fertile tillers (Table IV). Large sized spikes were found in wheat sown on 10th and 25th Nov against late sown wheat (25th Dec); whereas large sized spikes were observed in wheat variety

Table III: Influence of sowing dates on yield and yield related traits of different wheat varieties

Treatments	Fertile tillers (m ⁻²)	Spike length (cm)	Spikelets per spike	Florets per spikelet	Number of grains per spike	1000-grain weight (g)	Grain yield (t ha ⁻¹)	Biological yield (t ha ⁻¹)	Harvest index (%)
Sowing dates (D)									
D ₁ = 25 Oct	440.40 a	10.94 b	19.25 bc	4.26 b	54.09 cd	41.12 b	6.12 b	18.87 a	32.44 ab
D ₂ = 10 Nov	376.40 b	12.54 a	20.11 ab	4.45 ab	59.10 b	44.18 a	6.48 a	19.23 a	33.94 a
D ₃ = 25 Nov	306.70 c	12.12 a	20.34 a	4.65 a	64.26 a	38.07 c	4.89 c	16.41 b	31.01 b
D ₄ = 10 Dec	146.70 d	11.14 b	20.27 a	4.72 a	54.56 c	37.01 d	4.76 c	14.86 c	31.71 b
D ₅ = 25 Dec	120.70 f	10.03 c	19.12 c	4.60 a	52.70 d	35.77 e	3.78 d	13.45 d	27.91 c
LSD at 5%	20.98	0.60	0.98	0.28	1.51	0.83	0.15	0.92	2.07
Wheat varieties (V)									
V ₁ = SH-06	266.90 b	10.94 bc	19.29 c	4.87 a	57.94 b	42.67 a	5.55 c	17.29 b	32.25 a
V ₂ = FSD-08	280.30 b	10.47 c	18.48 d	4.53 bc	53.60 b	36.47 d	4.72 d	16.63 c	28.17 b
V ₃ = LS-08	268.80 b	13.16 a	21.01 b	4.67 ab	59.84 a	40.96 b	5.93 a	18.17 a	32.74 a
V ₄ = AS-02	307.90 a	10.91 bc	21.64 a	4.35 cd	59.91 a	37.91 c	5.77 b	17.79 ab	32.31 a
V ₅ = TD-1	287.10 b	11.29 b	18.68 d	4.27 d	53.42 b	38.13 c	4.08 e	12.95 d	31.54 a
LSD at 5%	19.50	0.47	0.57	0.25	1.96	0.66	0.13	0.62	1.33

Means sharing a letter in common within a column did not differ significantly at 5% level of probability by LSD test

Table IV: Interaction of sowing dates and wheat varieties for yield and yield related traits of wheat

Treatments	Fertile tillers (m ⁻²)	Spike length (cm)	Spikelets per spike	Florets per spikelet	Number of grains per spike	1000-grain weight (g)	Grain yield (t ha ⁻¹)	Biological yield (t ha ⁻¹)	Harvest index (%)
D ₁ V ₁	513.30 a	10.11 hij	18.67 ghijk	4.67	53.93 fghi	43.50 c	6.86 b	21.41 a	32.06 fg
D ₁ V ₂	376.00 b	10.93 efgh	19.07 efghi	4.60	56.78 efg	40.21 fg	5.76 d	18.96 bc	30.37 ghi
D ₁ V ₃	396.30 b	12.68 b	19.93 cdef	4.37	51.60 hi	42.72 cde	5.94 cd	18.96 bc	31.31 fgh
D ₁ V ₄	547.30 a	10.31 ghij	20.73 bcd	3.80	56.80 efg	40.00 fg	7.12 ab	19.63 b	36.32 bcd
D ₁ V ₅	369.00 b	10.65 fghi	17.87 ijk	3.87	51.32 i	39.17 gh	4.95 e	15.41 def	32.12 fg
D ₂ V ₁	292.30 ef	12.02 bcd	18.17 ijk	4.73	52.87 ghi	48.38 a	6.07 c	17.85 c	34.03 def
D ₂ V ₂	465.30 b	12.21 bcd	19.00 efghi	4.67	63.44 bc	42.01 de	5.80 cd	19.19 bc	30.29 ghi
D ₂ V ₃	394.00 c	14.13 a	21.40 b	4.40	55.87 fgh	45.87 b	7.27 a	21.41 a	34.02 def
D ₂ V ₄	378.00 c	12.11 bcd	23.20 a	4.07	63.00 bc	43.16 cd	7.26 a	22.00 a	33.03 efg
D ₂ V ₅	352.30 cd	12.23 bcd	18.80 fghij	4.40	60.33 cde	41.47 ef	6.01 cd	15.70 def	38.34 b
D ₃ V ₁	267.70 f	11.65 bcdef	20.07 cde	4.93	65.97 b	42.69 cde	5.15 e	1807 c	28.66 hij
D ₃ V ₂	312.00 de	10.64 fghi	18.57 ghijk	4.40	57.40 ef	35.23 k	4.22 fg	15.85 de	26.67 jk
D ₃ V ₃	300.30 ef	14.17 a	21.87 b	4.93	73.67 a	38.97 gh	6.00 cd	1966 b	30.86 gh
D ₃ V ₄	322.70 de	11.36 cdef	21.67 b	4.53	66.53 b	36.45 jk	5.15 e	1899 bc	27.14 jk
D ₃ V ₅	330.70 de	12.24 bcd	19.53 defg	4.47	57.73 def	37.00 ij	3.95 g	9.48 k	41.71 a
D ₄ V ₁	147.00 gh	11.22 defg	20.07 cde	5.07	62.40 bc	40.37 fg	5.18 e	14.74 efg	35.19 cde
D ₄ V ₂	129.30 gh	9.94 hij	18.23 hijk	4.60	45.87 j	33.12 l	4.22 fg	1536 def	27.48 ij
D ₄ V ₃	145.00 gh	11.89 bcde	21.87 b	4.80	55.93 efgh	38.35 hi	5.94 cd	16.30 d	36.48 bcd
D ₄ V ₄	163.00 g	11.43 cdef	21.67 b	4.80	56.53 efg	37.10 ij	5.76 d	15.14 defg	38.11 bc
D ₄ V ₅	149.30 gh	11.22 defg	19.53 defg	4.33	52.07 hi	36.13 jk	2.71 i	12.74 ij	21.28 l
D ₅ V ₁	114.00 h	9.68 ij	19.47 efgh	4.93	54.53 fghi	38.43 hi	4.49 f	14.37 fgh	31.31 fgh
D ₅ V ₂	118.70 h	8.64 k	17.53 k	4.40	44.53 j	31.80 l	3.58 h	13.78 ghi	26.02 jk
D ₅ V ₃	108.30 h	12.37 bc	20.00 cdef	4.87	62.13 bcd	38.90 gh	4.50 f	14.50 efgh	31.05 gh
D ₅ V ₄	128.30 gh	9.36 jk	20.93 bc	4.53	56.67 efg	32.83 l	3.55 h	13.19 hi	26.93 jk
D ₅ V ₅	134.30 gh	10.11 hij	17.67 jk	4.27	45.63 j	36.88 j	2.77 i	11.41 j	24.25 k
LSD at 5%	43.60	1.04	1.27	NS	4.41	1.40	0.29	1.40	2.96

Means not sharing same letter with in a column differ significantly from each other at 5% level of probability by LSD test

Here D₁, D₂, D₃, D₄ and D₅ represents 25 Oct, 10 Nov, 25 Nov, 10 Dec and 25 Dec, respectively; whereas V₁, V₂, V₃, V₄ and V₅ represents SH-06, FSD-08, LS-06, AS-02 and TD-1, respectively; NS = Non-significant

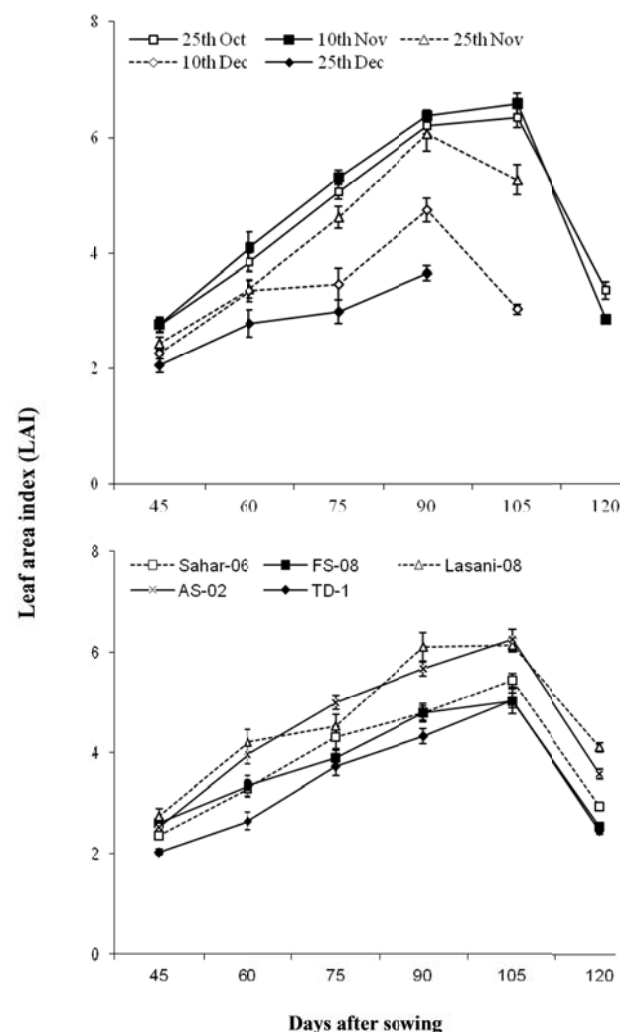
LS-08 than other varieties (Table III). With respect to interactive effect, large sized spikes were observed in LS-08 planted on 10th and 25th Nov while FSD-08 and AS-02 had small sized spikes in case of late planting i.e., 25th Dec (Table IV). Wheat sown on 10th and 25th Nov and 10th Dec exhibited more spikelet per spike compared with both too early and late planted (25th Oct & 25th Dec) crop. Likewise, early planted wheat (25th Oct) had fewer florets per spikelet, while more and less florets per spikelet were recorded in wheat varieties SH-06 and TD-1, respectively (Table III). However, interactive effect was non-significant regarding number of florets per spikelet (Table IV).

More grains per spike were noted in 25th Nov sown wheat, while both too early (25th Oct) and too late (25th Dec) planted crop had fewer grains per spike; whereas more grains per spike were observed in wheat varieties SH-06, LS-08 and AS-02 than FSD-08 and TD-1 (Table III). With respect to interactive effect, more grains per spike were observed in wheat variety LS-08 sown on 25th Nov while small number of grains per spike was noted in both FSD-08 and TD-1 planted on 25th Dec (Table IV). Maximum and minimum 1000-grain weight was recorded in 10th Nov and 25th Dec sown crop, and wheat varieties SH-06 and FSD-08, respectively (Table III). Regarding interactive effect, higher 1000-grain weight was observed in wheat variety SH-06 sown on 10th Nov while less grain weight was recorded in late planted FSD-08 and AS-02 (Table IV).

Wheat sown on 10th Nov produced higher grain yield than late sown crop (25th Dec), which had minimum grain yield; whereas among wheat varieties, maximum grain yield was harvested for LS-08 (Table IV). Regarding interaction amid sowing dates and wheat varieties; maximum grain yield was harvested by sowing LS-08 and AS-02 on 10th Nov and minimum grain yield was recorded in TD-1 sown on 25th Dec (Table IV). Early and late planted wheat had more and less biological yield, respectively while wheat varieties FSD-08, LS-08 and AS-02 recorded higher biological yield that was significantly lower for TD-1 (Table III). With respect to interactive effect, higher biological yield was noted in LS-08 and AS-02 sown on 10th Nov and SH-06 sown on 25th Oct whereas lower biological yield was noted in TD-1 sown on 25th Nov (Table IV). Wheat planted on 25th Oct and 10th Nov observed higher harvest index than late planted (25th Dec) crop. Regarding interactive effect, higher and lesser harvest index was recorded in TD-1 planted on 25th Nov and 10th Dec, respectively (Table IV).

Allometric data show that LAI and CGR progressively increased up to 105 DAS and then declined (Figs. 1 & 2). At 90 DAS, notably higher LAI was observed in wheat sown on 25th Oct, 10th Nov and 25th Nov than wheat sown on 25th Dec. At 105 DAS, 25th Oct and 10th Nov sown wheat had more LAI than late sown crop (25th Dec). At 120 DAS, wheat planted on 10th Nov observed higher while 25th Oct sown crop recorded lower LAI (Fig. 1). Likewise, higher LAI was observed in wheat varieties LS-08 and AS-02 up to 105 DAS and after that LS-08 observed higher LAI;

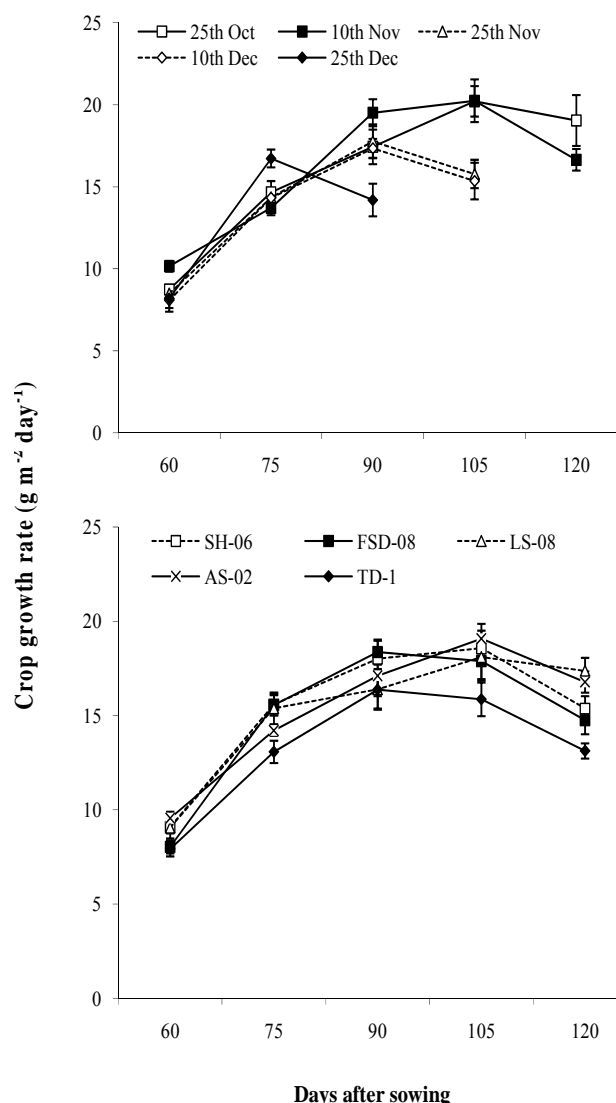
Fig. 1: Influence of sowing dates on leaf area index (LAI) in different wheat varieties \pm S.E.



while lesser LAI was recorded in wheat varieties TD-1 and FSD-08 through entire growing season (Fig. 1). Wheat sown on 10th Nov recorded higher CGR up to 90 DAS, at 105 DAS, wheat sown on 25th Oct and 10th Nov recorded higher CGR, and at 120 DAS, wheat sown on 25th Oct observed higher CGR; while wheat sown on 25th Dec had minimum CGR (Fig. 2). Similarly, more CGR was noted in SH-06 and FSD-08 up to 90 DAS, in AS-02 and SH-06 at 105 DAS, and in LS-08 and AS-02 at 120 DAS; whereas CGR was minimum in TD-1 during the entire growing period (Fig. 2).

DISCUSSION

Delayed wheat planting imposed severe yield penalty by 60 kg ha⁻¹ day⁻¹ for each day delay after 10th Nov due to drastic decrease in all yield related traits yet different wheat varieties behaved differently in this regard (Tables III & IV). Impaired seed emergence and crown root initiation due

Fig. 2: Influence of sowing dates on crop growth rate (CGR) in different wheat varieties \pm S.E.

to prevailing low temperature (Table II) in delayed planted wheat caused gradual reduction in number of fertile tillers (Shah *et al.*, 2006; Qasim *et al.*, 2008). Early planted crop enjoyed more time with suitable temperature for tillering and ultimately recorded more fertile tillers (Donaldson *et al.*, 2001; Shehzad *et al.*, 2002). Longer spikes observed in early sown crop might be due to prolonged leaf area duration enjoyed by crop resulting in more dry matter accumulation due to sizeable increase in LAI and CGR (Figs. 1 & 2). These large sized spikes coupled with more dry matter accumulation due to higher CGR might be responsible for more spikelets per spike in early sown crop (Table II; Fig. 2). Miralles *et al.* (2001) also reported higher spikelets per spike in early sown wheat. Short growing season accompanied with lesser CGR (Fig. 2), small spikes and lower production of photosynthates due to smaller LAI (Fig. 1) might be the possible reasons of fewer grains per

spike observed in late sowing than Nov sown crop (Table III). There are many reports available that warrant the role of delayed planting of wheat in reducing grains per spike (Shahzad *et al.*, 2002; Asseng and Milroy, 2006; Spiertz *et al.*, 2006; Alignan *et al.*, 2009; Tahir *et al.*, 2009). Too early planted wheat (25th Oct) also had fewer grains per spike than Nov sown wheat might be due to production of fewer florets per spikelet (Table III); as florets per spikelet play a key role in determining number of grains per spike.

Impaired grain filling rate and duration due to suboptimal prevailing temperature in late sown wheat and reduced dry matter accumulation were the chief reasons of lower 1000-grain weight; as late planted crop matures a bit late and prevailing temperature at that time is high enough to impede grain filling rate (Xu *et al.*, 2007; Rahman *et al.*, 2009). Earlier, Qasim *et al.* (2008) and Tahir *et al.* (2009) also reported decreased 1000-grain in delayed planted wheat. Higher grain yield noted in 10th Nov planted wheat might be attributed to higher number of grains per spike and 1000-grain weight (Table III). Although, higher fertile tillers were noted in 25th Oct sowing but wheat sown on 10th Nov was found more productive due to notable improvement in spike length, spikelets per spike, florets per spike, grain number and grain size than Oct sown crop (Table III). Wheat productivity reduced by 60 kg ha⁻¹ day⁻¹ when sowing was done after 10th Nov and wheat planted on 25th Dec faced 58% yield reduction (Table III). Less productive tillers (Table IV), smaller spikes with fewer small sized grains (Table III) due to short growing season coupled with lower dry matter accumulation due to smaller LAI and CGR (Figs. 1 & 2) were the chief reasons of yield decrease in late planted wheat. Earlier many researchers quoted similar findings (Shahzad *et al.*, 2002; Aslam *et al.*, 2003; Alignan *et al.*, 2009; Tahir *et al.*, 2009). Higher biological yield as observed in early sown crop was mainly due to higher numbers of tillers and more dry matter accumulation due to elevated LAI and CGR (Figs. 1 & 2). As leaves are the units of assimilatory system of plants and therefore due to higher LAI, early sown crop may capture more solar radiation, which increase the biomass as evident from higher values of CGR (Fig. 2). Donaldson *et al.* (2001) reported that early sowing resulted in higher biological yield due to more number of tillers and dry matter production. Higher harvest index in early planted wheat indicated better assimilate partitioning towards developing grains. Late planted wheat matures a bit late and prevailing temperature at that time is high enough to impede its grain filling rate and duration leading to poor harvest index coupled with yield penalty (Xu *et al.*, 2007; Rahman *et al.*, 2009).

Likewise, higher grain yield recorded in wheat variety LS-08 was attributed to sizeable elevation in yield related traits like spike length, florets per spikelet, number of grains per spike and 1000-grain weight (Table III). Although higher fertile tillers were noted in wheat variety AS-02 but due to remarkable reduction in 1000-grain weight (Table

III) had grain yield next to LS-08 (Table III). Considerable reductions in all yield related traits accounted for lower grain yield in TD-1 (Table III). Variable grain yield levels harvested for different wheat genotypes might be due to their genetic diversity (Arain *et al.*, 1999; Ma *et al.*, 2007; Alignan *et al.*, 2009; Sial *et al.*, 2010) and morpho-physiological variations (Farooq *et al.*, 2011). Differences in number of grains per spike and 1000-grain weight among wheat varieties might be attributed to these variabilities (Shahzad *et al.*, 2002; Alignan *et al.*, 2009; Tahir *et al.*, 2009; Sial *et al.*, 2010). Similarly, higher biological yield recorded in wheat variety AS-2002 was due to higher number of tillers (Table III); whereas minimum biological yield as recorded in TD-1 can be attributed to lesser number of tillers (Table III). Wheat genotypes had positive interaction for biological yield due to their genetic makeup (Maqsood *et al.*, 1999).

Interaction between wheat varieties and sowing dates had significant effect on wheat productivity along with all yield related traits. Wheat varieties LS-08 and AS-02 planted on 10th Nov appeared superior with higher grain yield due to larger spikes having more grains of bold size; although higher fertile tillers of both varieties were noted in 25th Oct sown wheat (Table IV). Substantial decrease in all yield related traits observed in TD-1 planted on 10th and 25th Dec resulted in minimum grain yield. The different wheat genotypes had significantly different LAI (Fig. 1) and it might be due to their genetic makeup. Higher CGR in early sown crop and wheat genotype LS-08 might be due to higher LAI (Fig. 1). Both wheat varieties LS-08 and AS-02 observed higher LAI and consequently higher CGR (Figs. 1 & 2); and ultimately produced more grains per spike of bold size. Genetic variations among cereal crops is very common and different wheat varieties depicted immense variability for their developmental responses and produce various grain yields, shoot biomass and harvest index under same or different environmental conditions (Ehdaie & Waines, 2001; Aslam *et al.*, 2003; Asseng & Milroy, 2006; Xu *et al.*, 2007). For example, suboptimal prevailing temperature in late planted wheat reduces significantly number of tillers per unit area but divergent wheat varieties behave differently in this regard (Aslam *et al.*, 2003; Shah *et al.*, 2006). Likewise, low temperature results in less germination count of late planted wheat but different wheat genotypes differ in germination count owing to their genetic diversity in late sown crop (Aslam *et al.*, 2003).

In crux, delayed planted wheat experienced yield penalty of 60 kg ha⁻¹ day⁻¹ for each day delay after 10th Nov due to drastic reduction in all yield related traits; and 58% grain yield reduction was observed in late planted wheat (25th Dec) than 10th Nov and different wheat varieties behaved differently in this regard. Wheat varieties LS-08 and AS-02 sown on 10th Nov were more productive.

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