INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
12–058/AWB/2012/14–3–413–418
http://www.fspublishers.org

Full Length Article

Narrow Row Spacing Ensures Higher Productivity of Low Tillering Wheat Cultivars

MUBSHAR HUSSAIN†, ZAHID MEHMOOD, MUHAMMAD BISMILLAH KHAN, SHAHID FAROOQ, DONG-JIN LEE[1]† AND MUHAMMAD FAROOQ‡
College of Agriculture, Bahauddin Zakariya University, Multan, Pakistan
†Department of Crop Science and Biotechnology, Dankook University, Chungnam, South Korea
‡Department of Agronomy, University of Agriculture, Faisalabad, Pakistan
[1]Corresponding author's e-mail: dongjlee@dankook.ac.kr

ABSTRACT

This study was conducted to appraise the performance of wheat (*Triticum aestivum* L.) cultivars, differing in tillering capacity and stature, grown under divergent row spacing. Three wheat cultivars Sahar-2006 (SH-06) (standard height & low tillering), Abdul Sattar-2002 (AS-02) (standard height & high tillering) and Triple Dwarf-1 (TD-1) (dwarf sized & low tillering) were planted under 15, 20, 25 and 30 cm spaced rows. Higher grain yield was harvested from the cultivar SH-06 due to substantial increase in number of grains per spike and grain weight; whereas higher straw and biological yield were noted in cultivar AS-02 due to sizeable increase in number of tillers. Minimum straw and biological yields were observed in TD-1 due to its dwarf stature and low tillering potential. Wheat sown under narrow row spacing, 15 cm wide rows in particular, produced higher wheat yield due to significant increase in productive tillers. Increase in number of grains per spike and 1000-grain weight, from wider row spacing (30 cm), could not compensate the drastic decrease in productive tillers resulting in severe decrease in grain yield. Wheat cultivars with low tillering ability, such as TD-1 and SH-06, planted under narrow row spacing (15 & 20 cm, respectively) produced higher grain yield, whereas high tillering cultivar AS-02 produced better grain yield in wider rows. In conclusion, planting of low tillering dwarf cultivar (TD-1) in narrow (15 cm) rows and low tillering cultivar (SH-06) in medium rows (20 cm) resulted in more productivity owing to substantial rise in fertile tillers.

Key Words: Wheat cultivars; Row spacing; Harvest index; Fertile tillers; Crop allometry

INTRODUCTION

Wheat (*Triticum aestivum* L.) is amongst the three most important cereals worldwide symbolizing over a quarter of the total world's cereal production and a chief source of calories for more than 1.5 billion people as well around the globe (Manske *et al*., 2001; Kilick, 2010). Wheat is the chief cereal crop and major staple diet in Pakistan. It contributes 14.4% to the value added in agriculture and 3.1% to GDP of the country (Government of Pakistan, 2010). Pakistan is among the top ten wheat producing countries of the world; at number nine regarding area under cultivation and ranked fifth with respect to yield provisos (Government of Pakistan, 2010).

Even though the yield potential of spring bread wheat has touched 8 t ha^{-1} in irrigated subtropics but the concrete average yield worldwide is less than 3 t ha^{-1} (CIMMYT, 1996). By the year 2030, average yield worldwide must increase to about 6 t ha^{-1} to cope with a conservative projection of a 1.6% annual rise in demand (CIMMYT, 1997). Wheat production can be enhanced through developing new high yielding varieties and by adoption of improved package of production technology (Sial *et al*., 2000; Arain *et al*., 2002). Maintenance of optimum row spacing can help to optimize tillering capacity and may better ensure wheat yield (Ayaz *et al*., 1999; Thorsted *et al*., 2006). Optimal row spacing plays crucial role to improve the crop productivity as plants growing in too wider rows may not efficiently utilize the light, water and nutrient resources; whereas growing in too narrow rows may result in severe inter-row competition (Kirkland, 1993; Ali *et al*., 1999). Competition for light penetration, water and essential nutrients availability can thus be manipulated to enhance production potential of wheat by sowing under apposite row spacing (Chen & Neill, 2006). Moreover, row spacing may modify the plant architecture, photosynthetic competence of leaves and dry matter portioning in field crops (Samani *et al*., 1999).

Increased dry matter partitioning towards grains has been observed as a fundamental response of wider row spacing in the crop plants (Salem, 2006). Thorsted *et al*. (2006) explained that improved grain yield of wheat in

To cite this paper: Hussain, M., Z. Mehmood, M.B. Khan, S. Farooq, D.J. Lee and M. Farooq, 2012. Narrow row spacing ensures higher productivity of low tillering wheat cultivars. *Int. J. Agric. Biol*., 14: 413–418

wider rows might be due to increased inter-specific interactions and decrease in intra-specific competition during the entire growing season (Marshall & Ohm, 1987; Johnson *et al*., 1988). Dwyer *et al*. (1991) observed that narrow row spacing causes higher leaf photosynthesis and suppresses weed infestation than wider row spacing. Narrow row spacing also produces high leaf area index (LAI), which results in more interception of photosynthetically active radiation (PAR) and ensures better dry matter accumulation. Cereals grown in widely spaced rows may compensate the lower number of spikes with higher grains per spike of bold size and thus yielded similar to moderate yields of cereals grown with narrow row spacing (Lafond, 1994). However, the variability in the yield response to row spacing depends to a great extent on the genotype and the environment (Marshall & Ohm, 1987).

In Pakistan, wheat is generally planted in 22.5 cm spaced rows without giving consideration to the behavior of wheat cultivars used; whereas wheat cultivars utilized available sources such as space and solar radiation etc. differently due to their different stature and tillering capacity. It is hypothesized that dwarf wheat cultivars with low tillering capacity utilizes available sources more efficiently in narrow rows, whereas wider rows favor standard height high tillering wheat cultivars. Therefore, this study was designed to evaluate the effects of divergent row spacing on growth and productivity of wheat cultivars differing in tillering ability and stature.

MATERIALS AND METHODS

Site description: This study was conducted at Agronomic Research Area, Department of Agronomy, Bahauddin Zakariya University, Multan (71.43^o E, 30.2^o N & 122 m a.s.l.), Pakistan during Rabi season 2010-2011. Climate of the region is subtropical to semi-arid. The experimental land was quite uniform and pre-sowing physico-chemical analysis was done to assess the soil fertility status (Table I).

Experimental details: The experiment was laid out in randomized complete block design (RCBD) with split plot arrangements keeping row spacing and wheat genotypes in main plots and sub plots, respectively. The experiment was replicated three times with net plot size of 5 m x 1.8 m. Three wheat genotypes Sehar-2006 (SH-06), AS-2002 (AS-02) and Triple Dwarf-1 (TD-1) were planted in 15, 20, 25 and 30 cm spaced rows. Weather data recorded during whole course of study are given in Table II.

Crop husbandry: Before crafting seedbed, pre-soaking irrigation of 10 cm was applied. When soil reached to workable moisture level, seedbed was prepared by two cultivations with tractor-mounted cultivator followed by planking. Crop was sown on November 06, 2010 on well prepared seedbed with hand drill using seed rate of 125 kg ha^{-1}. Fertilizers were applied at 200 and 150 kg ha^{-1} nitrogen and phosphorus, respectively using urea and triple super phosphate (TSP) as source. Whole phosphorus and half of nitrogen were applied as basal application and remaining nitrogen was applied with first irrigation. Overall four irrigations at crown root, booting, flowering and grain formation stages of crop were applied to avoid moisture stress. Mature crop was harvested on April 20, 2011.

Table I: Weather data during the course of study

Month	Mean monthly temperature (°C)	Mean monthly relative humidity (%)	Total monthly rainfall (mm)
November	28.20	63.00	0.00
December	23.30	67.00	0.00
January	21.60	67.00	0.00
February	21.80	67.00	0.00
March	22.30	67.50	0.00
April	25.60	62.30	4.00

Source: Agricultural Meteorology Cell, Central Cotton Research Institute, Multan, Pakistan

Table II: Physio-chemical characteristics of soil

Determination	Unit	Value	Status
Physical Analysis			
Sand	%	63.8	
Silt	%	17.5	
Clay	%	18.7	
Textural class		Sandy clay loam	
Chemical Analysis			
pH		8.70	
EC	dS m^{-1}	1.65	
Organic matter	%	0.38	Very low
Total nitrogen	%	0.02	Very low
Available phosphorus	ppm	7.00	Low
Available potassium	ppm	120.00	Medium

Observations: Total number of fertile tillers (spike bearing) was counted from a randomly selected unit area at four different locations from each plot. Plant height was measured at maturity from 10 randomly selected plants in each plot from base to top of spike with meter rod. Length of ten spikes selected at random from each plot at harvest was measured with ruler. Number of fertile spikelets were counted from ten randomly selected spikes and then averaged to record spikelets per spike. Ten randomly selected spikes from each plot were harvested, threshed manually; total number of grains were counted and then averaged to record number of grains per spike. Five random samples of thousand grains were taken at random from each seed lot, weighed on an electrical weighing balance and averaged to record 1000-grain weight. At harvest maturity, two central rows 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 on an electric balance to calculate grain yield. Grain yield was then adjusted to 10% moisture contents. After separating grains by manual threshing, the remaining straw was again tied into bundles and weighed to record straw yield. Harvest index (HI) was calculated as a 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. Thereafter, LAI was calculated using the formula given by Watson (1947). Sampling was started 45 days after sowing (DAS) and terminated at harvesting. Leaf area duration (LAD) and crop growth rate (CGR) were calculated following the procedures described by 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). Likewise graphical presentation of the data was done by using Microsoft Excel Program.

RESULTS

Varying row spacing had significant effects on allometric and yield related traits in different wheat cultivars except number of spikelets per spike (Tables III, IV; Figs. 1-3). Plant height was maximum and minimum in wheat cultivars SH-06 and TD-1, respectively whereas row spacing had no effect on plant height. Maximum fertile tillers, spike length and number of grains per spike were recorded in wheat cultivars AS-02, TD-1 and SH-06, respectively; whereas wheat cultivars didn't differ for spikelets per spike (Table III). Moreover, cultivars SH-06 and TD-1 gained higher 1000-grain weight than AS-02 (Table III). Maximum number of fertile tillers was recorded in narrow row spacing (15 cm), whereas higher number of grains per spike and 1000-grain weight was noted under wider row spacing (30 cm); however it was similar with 30 and 25 cm row spacing for number of grains per spike (Table III). There was no effect of row spacing on spike length and spikelets per spike (Table III). With respect to interactive effects, wheat cultivar AS-02 in narrow rows (15 cm), and cultivars SH-06 and TD-1 in wider rows produced maximum and minimum fertile tillers, respectively. Likewise, larger spikes were observed in TD-1 under all row spacings whereas small sized spikes were noted in cultivar AS-02 under narrow rows (Table III). Nonetheless, higher and lower grains per spike were observed in SH-06 and AS-02 planted in wider and narrow rows, respectively (Table III). Likewise, both cultivars SH-06 and TD-1 had bold sized grains with superior 1000-grain weight (Table III).

Wheat cultivar SH-06 outperformed with higher grain yield and harvest index, AS-02 produced higher biological and straw yield accompanied with smaller harvest index, whereas minimum biological and straw yields were noted in cultivar TD-I (Table IV). Wheat planted in narrow rows (15 cm) produced more grain, straw and biological yields; however this was similar to 20 cm spaced rows for grain yield (Table IV). However, harvest index was minimum in narrow rows (Table IV). Regarding interaction between cultivars and spacing, SH-06 sown in 20 and TD-1 in 15 cm spaced rows performed better with higher grain yield (Table IV). Moreover, maximum biological and straw yield was

Fig. 1: Leaf area index of (a) wheat cultivars under (b) different row spacings ± S.E

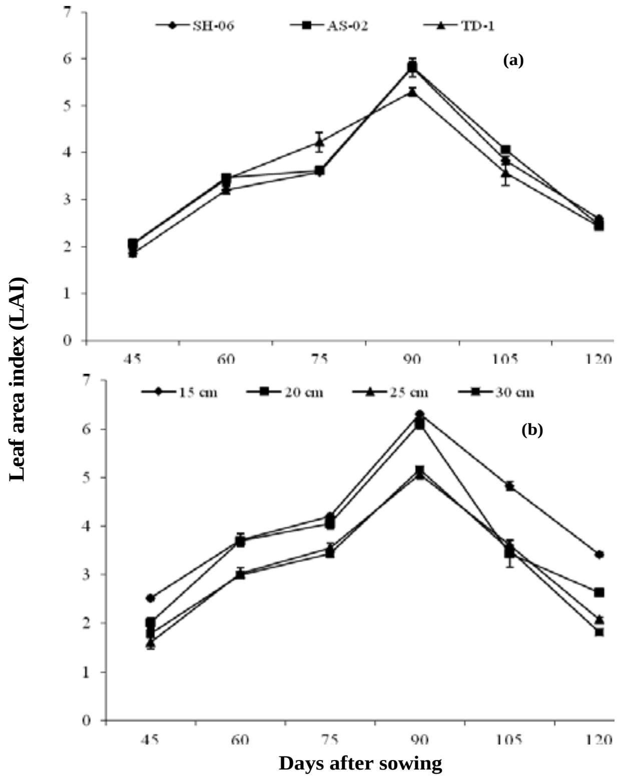


Fig. 2: Leaf area duration of (a) wheat cultivars under (b) different row spacings ± S.E

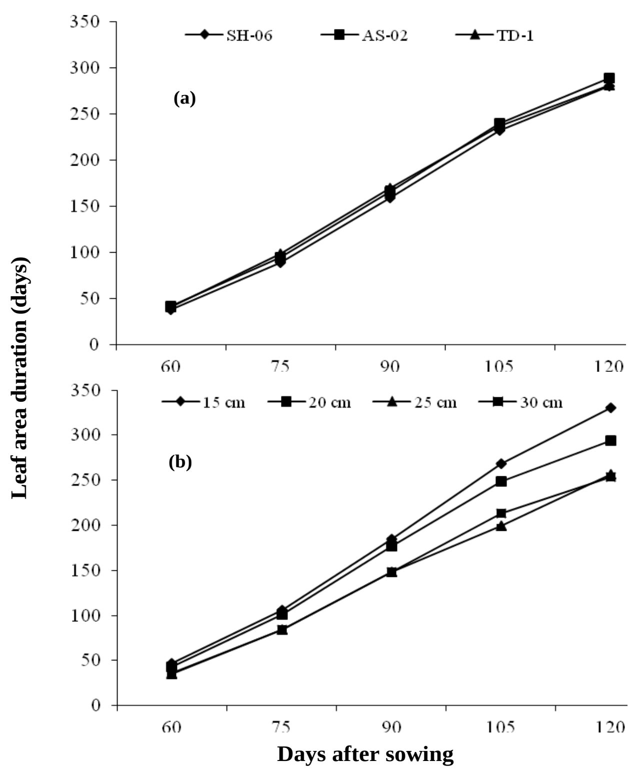


Table III: Effect of row spacing on plant height and yield related traits of wheat cultivars

Treatments	Plant height (cm)	Number of fertile tillers (m^{-2})	Spike length (cm)	Fertile spikelets per spike	Number of grains per spike	1000-grain weight (g)
Wheat cultivars (V)						
V_1 = SH-06	110.40 a	342.71 b	15.02 b	19.72	52.27 a	45.42 a
V_2 = AS-02	102.46 b	543.26 a	12.82 c	20.78	46.96 c	41.76 b
V_3 = TD-1	92.28 c	399.19 b	16.61 a	18.48	49.10 b	45.65 a
LSD at 5%	4.80	115.60	0.72	NS	1.14	0.72
Row spacing (S)						
S_1 = 15 cm	102.56	576.46 a	14.66	19.51	48.05 b	42.45 c
S_2 = 20 cm	101.54	445.00 b	14.65	19.93	48.30 b	42.79 c
S_3 = 25 cm	101.65	370.89 c	15.06	19.66	50.51 a	45.49 b
S_4 = 30 cm	101.09	321.53 c	14.89	19.54	50.93 a	46.38 a
LSD at 5%	NS	70.15	NS	NS	1.05	0.61
Interaction between V × S						
V_1S_1	110.77 ab	438.45 bcd	14.87 b	19.73	50.56 b	40.89 f
V_1S_2	109.59 ab	407.50 bcde	15.30 b	20.00	50.50 b	44.54 c
V_1S_3	109.95 ab	314.00 de	15.14 b	19.20	54.13 a	47.67 ab
V_1S_4	111.28 a	210.90 e	14.77 b	19.96	53.90 a	48.59 a
V_2S_1	105.38 bc	739.26 a	12.76 cd	20.46	45.16 e	41.68 def
V_2S_2	99.95 e	570.00 bc	12.28 d	21.60	45.70 e	40.88 f
V_2S_3	103.78 cd	424.56 bcd	13.33 c	20.60	48.53 cd	41.65 ef
V_2S_4	100.72 de	440.12 bcd	12.92 cd	20.46	48.46 d	42.65 de
V_3S_1	91.52 fg	591.67 b	16.35 a	18.33	48.43 d	44.61 c
V_3S_2	95.08 ef	357.50 cde	16.38 a	18.20	48.70 bcd	42.96 d
V_3S_3	91.22 g	374.00 cde	16.72 a	19.20	48.86 bcd	47.13 b
V_3S_4	91.29 g	313.58 de	17.00 a	18.20	50.44 bc	47.90 ab
LSD at 5%	3.65	133.63	0.83	NS	1.93	1.05

NS = Non-significant
Means not sharing the same letters within a column differ significantly for main and interactive effects at 5% of probability level

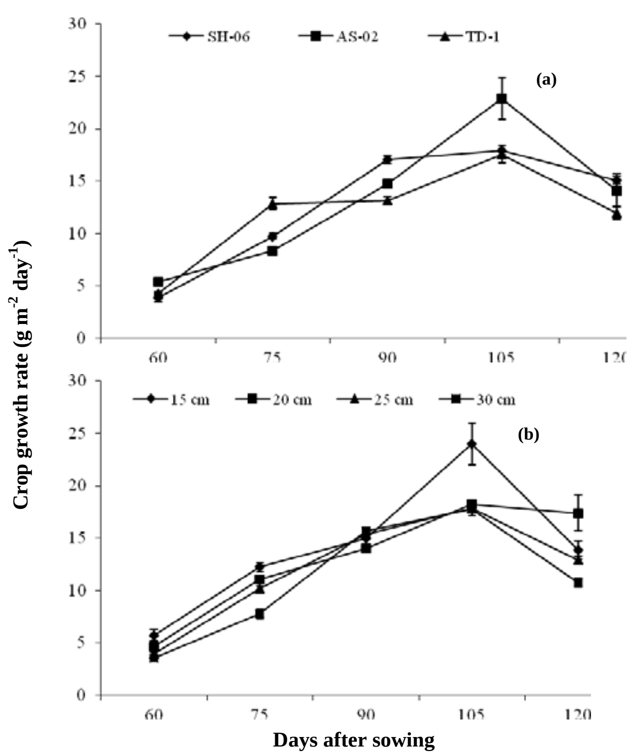
Table IV: Effect of row spacing on productivity and harvest index of wheat cultivars

Treatments	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Wheat cultivars (V)				
V_1 = SH-06	15.46 b	5.07 a	9.72 b	32.79 a
V_2 = AS-02	16.30 a	4.21 b	11.94 a	25.83 c
V_3 = TD-1	13.83 c	4.25 b	8.62 c	30.73 b
LSD at 5%	0.47	0.05	0.05	1.53
Row spacing (S)				
S_1 = 15 cm	17.64 a	4.89 a	12.29 a	27.72 c
S_2 = 20 cm	15.56 b	4.86 a	10.04 b	31.23 a
S_3 = 25 cm	14.72 c	4.54 b	9.80 b	30.84 a
S_4 = 30 cm	12.80 d	3.76 c	6.21 c	29.38 b
LSD at 5%	0.30	0.06	0.03	1.04
Interaction between V × S				
V_1S_1	17.75 b	5.39 b	12.76 b	30.37 c
V_1S_2	15.57 d	5.58 a	9.19 f	35.84 a
V_1S_3	15.21 de	5.21 c	9.51 ef	34.25 ab
V_1S_4	12.29 h	4.11 g	7.41 h	33.44 b
V_2S_1	18.74 a	3.72 i	15.64 a	19.85 f
V_2S_2	16.49 c	4.90 d	10.89 d	29.71 cd
V_2S_3	15.72 d	4.00 h	11.59 c	25.45 e
V_2S_4	14.24 f	4.24 f	9.64 ef	29.78 cd
V_3S_1	15.62 d	5.55 a	8.57 g	35.53 ab
V_3S_2	14.62 ef	4.09 gh	10.03 e	27.98 d
V_3S_3	13.21 g	4.41 e	8.30 g	33.38 b
V_3S_4	11.87 h	2.92 j	7.58 h	24.60 e
LSD at 5%	0.52	0.10	0.52	2.17

Means not sharing the same letters within a column differ significantly for main and interactive effects at 5% of probability level

noted in AS-02 planted in 15 cm spaced rows, whereas minimum straw and biological yields were observed in cultivars SH-06 and TD-1 planted in 30 cm spaced rows (Table IV). However, higher harvest index was noted in cultivars SH-06 and TD-1 sown in wider rows and minimum in cultivar AS-02 planted in narrow rows (Table IV).

Fig. 3: Crop growth rate of (a) wheat cultivars under (b) different row spacings ± S.E



Allometric data indicate that leaf area index (LAI) exhibited gradual rise up to 90 days after sowing (DAS) and then start declining (Fig. 1). Higher LAI was observed in TD-1 at 75 DAS, in both cultivars SH-06 and AS-02 at 90 DAS and in SH-06 at105 DAS (Fig. 1). Crop sown in 15 and 20 cm spaced rows maintained higher LAI than wider row spacing up to 90 DAS and after that crop sown with 15 row spacing had higher LAI up to crop maturity (Fig. 1). Wheat cultivars did not differ for LAD; however maximum LAD was noted in 15 cm spaced rows (Fig. 2). Crop growth rate (CGR) increased up till 105 DAS and then start decreasing (Fig. 3). Higher CGR was observed in narrow (15 cm) row spacing than wider rows up to 105 DAS but it was at par with 30 cm spaced rows at 90 AS and after that higher CGR was noted in 20 cm spaced rows (Fig. 3).

DISCUSSION

This study indicated that divergent row spacings had significant effect on allometric and all yield related traits in different wheat cultivars. Better grain yield was observed in wheat cultivars TD-1 and SH-06 planted in 15 and 20 cm spaced rows due to momentous improvement in fertile tillers (Table I).

Significant differences in allometric and yield related traits were noted in wheat cultivars. Cultivar SH-06 performed better than other cultivars under study with higher grain yield (Table IV). Substantial increase in number of grains per spike and 1000-grain weight may be the chief reasons of better grain yield in cultivar SH-06 (Tables III, IV). Although the higher number of fertile tillers was noted in wheat cultivar AS-2002 (Table III); but substantial decrease observed in grains per spike and 1000-grain weight in AS-02 might cause low yield than cultivar SH-06 (Tables III, IV). Grain weight and number of grains per spike are purely inherent character of wheat cultivars that are less influenced by environmental factors (Malik *et al*., 1996; Jan *et al*., 2000). Due to different genetic makeup, different wheat cultivars manifested different yield potential under same or different growing conditions (Shahzad *et al*., 2002; Alignan *et al*., 2009; Sial *et al*., 2010). Better yield in cultivar SH-06 was also attributed to higher LAI observed throughout its growth period. With better assimilatory system due to large LAI, higher accumulation of assimilates in SH-06 as evident from higher CGR (Fig. 3) resulted in more grains per spike having higher 1000-grain weight as well (Table III). Likewise, higher LAD noted in cultivar SH-2008 was also the direct result of higher LAI as LAD is derived from LAI (Fig. 2). Higher straw and biological yield noted in cultivar AS-02 was attributed to its extremely higher tillering ability and more plant height (Table III), whereas low straw and biological yields in TD-1 were due to its dwarf nature and less tillers (Tables III, IV). Harvest index is an indicator of dry matter partitioning towards the reproductive organs. Higher harvest index, noted in SH-06, indicated its superior ability of better dry matter partitioning towards grains.

Optimum row spacing can be an effective approach to optimize tillering capacity of wheat (Kakar *et al*., 2001). Higher plant population was noted in narrow row spacing (15 cm) than other rows spacing and this higher plant population accompanied with strong inter-row competition caused reduction in number of grains per spike and 1000-grain weight of crop sown in 15 cm spaced rows (Table III). More number of grains per spike and higher 1000-grain weight noted in wider rows (30 cm) (Table III) might be due to efficient utilization of water, nutrients and light due to minimal inter-rows competition and lower plant population. Wheat sown under narrow row spacing, especially 15 cm, performed better with superior grain yield primarily due to increase in productive tillers (Tables III, IV). Even significant increase in grain number and size in wider rows (Table III) could not compensate the decrease in productive tillers resulting in low grain yield (Table IV).

With more efficient utilization of all available sources, narrow row spacing attained higher LAI, while inefficient utilization of available sources in wider rows resulted in small LAI (Fig. 1). Leaves are units of assimilatory system of plants, therefore more dry matter accumulation in narrow row spacing in consequence of elevated LAI resulted in higher CGR and LAD as well (Fig. 2 & 3). Higher straw and biological yield noted in 15 cm row spacing was the direct consequence of increase in plant population, LAI and CGR (Table III; Figs. 1 & 3); as the crop in narrow row spacing more efficiently utilized solar radiation and accumulated higher dry matter. Row spacing might change the architecture, photosynthetic competence of leaves and dry matter portioning of field crops (Samani *et al*., 1999). Wider row spacing observed higher harvest index as increased dry matter portioning is a fundamental response of wider row spacing in the crops (Salem, 2006).

Interaction between row spacing and wheat varieties had significant effect on wheat productivity and presented some interesting information. Better genetic makeup of cultivars along with efficient utilization of available resources such as water nutrients, space and light; planting of wheat cultivars SH-06 and TD-1 under narrow row spacing observed superior wheat productivity (Table IV). Narrow and medium row spacing (15 & 20 cm) favored low tillering dwarf cultivar TD-1 (Table III) and standard height low tillering cultivar SH-06 (Table III) to outperform with superior productivity; whereas high tillering cultivar AS-02 performed feebly under narrow row spacing. Low tillering dwarf cultivar TD-1 (Table III) utilized available sources especially solar radiation under narrow rows more efficiently than wider row spacing. Therefore, row spacing is a prominent factor that directly influence wheat yield but different wheat cultivars behaved differently in this regard (Shahzad *et al*., 2002; Thorsted *et al*., 2006; Alignan *et al*., 2009; Sial *et al*., 2010).

In conclusion, wheat sown under different row spacing had significant effect on wheat productivity and different wheat genotypes behaved differently due to difference in stature and tillering ability. Narrowly spaced rows favored dwarf low tillering cultivars whereas cultivars with high tillering rate performed better in wider rows.

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(Received 01 February 2012; Accepted 22 February 2012)