*Journal of Agriculture and Ecology Research International*
*11(1): 1-16, 2017; Article no.JAERI.31744*
*ISSN: 2394-1073*

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# Canopy Characters and Light-Use Efficiency of Some Modern Wheat Varieties in Bangladesh

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Author MAA designed the study, wrote the protocol and first draft of the manuscript. Author MRA managed the field work. Author M. Saidur Rhaman performed the statistical analysis. Authors IJS and M. Shahidur Rahman managed the literature searches. All authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/JAERI/2017/31744
Editor(s):
(1) George Tsiamis, Department of Environmental and Natural Resources Management, University of Patras, Greece.
Reviewers:
(1) Mehmet Oz, Uludag University, Turkey.
(2) Leyla Idikut, Sutcu Imam University, Turkey.
Complete Peer review History: http://www.sciencedomain.org/review-history/18018

***Original Research Article***

***Received 23rd January 2017***
***Accepted 18th February 2017***
***Published 2nd March 2017***

## ABSTRACT

**Aim:** An experiment was conducted to analyze the canopy characters and light-use efficiency along with yield of five modern wheat varieties viz. BARI wheat-23, BARI wheat-24, BARI wheat-25, BARI wheat-26, and BARI wheat-27.

**Study Design:** The experiment was laid-out following a Randomized Complete Block Design (RCBD) with 3 replicates.

**Place and Duration of Study:** The experiment was conducted at the Crop Botany Field Laboratory, Bangladesh Agricultural University, Mymensingh during the period extended from December 2013 to April 2014.

**Methodology:** Measurements included phenophase development, plant height, tiller production, leaf area development, light interception, dry matter accumulation, yield components, yield and harvest index.

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**Results:** The wheat varieties exhibit significant difference in phenological development, plant height, tiller production, leaf area index, dry matter accumulation, light interception and use, yield and yield components like spike number/plant, spike length, grain number and weight per spike and thousand grain weight. The BARI wheat-24 and BARI wheat-25 varieties matured earlier than BARI wheat-27 or BARI wheat-26 by about a week while the remaining one matured in between. The BARI wheat-23 and BARI wheat-25 showed better performance and the BARI wheat-27 showed poor performance in all affairs of growth studied while the remaining others ranked intermediate.

**Conclusion:** Higher light-use efficiency leads to greater accumulation of dry matter and higher grain yield is directly linked to their greater partitioning of biomass into the grains i.e. higher harvest index.

*Keywords: Canopy characters; light-use efficiency; PAR; phenophase development; wheat.*

## 1. INTRODUCTION

Wheat (*Triticum aestivum* L.), an important cereal crop, occupies about 17% of the world's cropped land that contributes 33% of the staple food for human [1]. Its grain has higher protein content than rice or maize, the other major cereals. For example, wheat contains 12.1% protein as compared to 8.29% in rice. It additionally contains 2.1% fat, 78.1% starch and 2.1% mineral matter. Its grain is also rich in vitamins [2]. In developing countries, wheat meets 21% of the total calories intake and 12.1% protein [3]. Therefore wheat is the leading source of cereal protein in human diet. Its demand may increase by 60% of the present up to year 2050 [4] due to rapid expansion in world human population which may touch 8.3 billion up to 2025 [5].

In Bangladesh, wheat cultivation covers about 1029 thousand acres of land that produced 1255 thousand metric tons with an average yield of 3 ton per hectare during the year of 2012-2013 [6]. The current production of wheat in Bangladesh is deficit for fulfilling the demand of country's need. Thus, every year a huge amount of foreign currency is curtailed for the importing of wheat grain. As of February 2013, Bangladesh wheat imports reached 1.14 million tons mainly to meet the demands of the public food distribution system. Bangladesh is a small country with a large population and its population has an increasing trend, so cereal crop production like wheat production should be increased to meet the demand of the escalating population where per capita requirement of cereal food is more than 454 g [7]. Yield improvement through management practices almost reaches to its maximum level. Therefore variety selection that captures more sunlight may expand extra margin on yield.

Under non-stressed environmental conditions, the amount of dry matter produced by a crop is linearly related to the amount of solar radiation or light, specifically photosynthetically active radiation (PAR) intercepted by the crop canopy. Monteith [8] demonstrated that biomass production for many crops grown with adequate soil water supply was closely related to cumulative seasonal light interception. He formulized and fully established the experimental and theoretical grounds for the relationship between accumulated crop dry-matter and solar radiation or light energy, arguing that this approach is robust and theoretically appropriate to describe crop growth.

The arrangement, shape and number of leaves in plant canopy affect the penetration, interception, distribution and reflection of light [9]. Larger interception of light in crop canopy with smaller mutual shading produces higher harvest index [8,10]. Absorption of light by different row crops depends on row width, width of inter-row, row height and sun and row's geometry [11]. Variation in economic yield of a healthy, well watered and fertilized crop can be related to the interception of photosynthetically active radiation (PAR), the radiation-use efficiency (conversion of that PAR energy to dry matter), and the partitioning of that dry matter to economic part that constitutes the yield [12-14].

There is a great scope to increase the utilization of solar energy by the wheat crops as a plenty of solar radiation is available in cloudless wheat growing season of Bangladesh. However, there is no research conducted yet on the underlying concept. In order to increase production per unit of land, attention may be given in our country for maximizing the utilization of solar radiation by the suitable wheat variety. Therefore, the present study was undertaken to evaluate the canopy characters, and light interception and use as well as yield performance of some modern wheat varieties developed by the Bangladesh Agricultural Research Institute (BARI).

## 2. MATERIALS AND METHODS

### 2.1 Geographical Location, Crop Husbandry and Experimentation

The experiment was conducted in the Crop Botany Field Laboratory, Bangladesh Agricultural University, Mymensingh during the winter season extended from December 2013 to April 2014. Geographically, the experimental field is located at 24°25" N latitude and 90°50" E longitude and 18 m above the sea level. The experimental field was medium high land belonging non-calcareous, dark-grey flood plain soil under the Sonatola series of Old Brahmaputra Flood Plain. It is located at Agro-Ecological Zone 9 (AEZ-9). The soil is silt loam with imperfectly to poorly drained permeability. There was a moderate cold air during the month from December to early February and somewhat warm air during the rest of the months of the year. The average air temperature during the experimental period was 18.6°C to 27.8°C. The average relative humidity was 64% to 83% and the average sunshine varies from 98 to 230 hours/month during experimental period. Daily climatic parameters like air temperature, relative humidity, solar radiation, rainfall and wind speed are shown in Figs. 1-2.

The experiment comprised of five treatments or varieties viz. i) BARI wheat-23; ii) BARI wheat-24; iii) BARI wheat-25; iv) BARI wheat-26 and v) BARI wheat-27. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The size of unit plot was 5m × 4m. Distance between plots to plot was 1 m. The row to row distance was 20 cm and plant to plant distance within a row was 5 cm. Seeds were sown by hand at 2-3 cm depth of soil in the row. After sowing, the seeds were covered with the loose soil by hand. At least three seeds were shown in each sowing point and one healthy seedling was kept after emergence. Different sorts of intercultural operations were done in daily basis.

### 2.2 Light Measurements

Light interception of the growing wheat canopies was recorded with a Radiometer (model LI-189, Li-Cor, Lincoln, NE, USA) connected to a 1m long Line Quantum Sensor (Sr. no. LQA 1401, Li-Cor, Lincoln, NE, USA). The measurements were done only under blue-sky conditions with no cloud cover. Therefore, data were recorded at intervals of 9–12 days, depending on the sky conditions, starting from complete seedling emergence until maturity of crops. Percentage of light interception was calculated as

$$\%I = (I_o - I_t)/I_o \times 100$$

where,

$I_o$ = Intensity of light incident above the canopy and
$I_t$ = Intensity of light transmission through canopy

Use of solar radiation was calculated using the Monteith [8] model:

$$e_i = \mathrm{DM} \Big/ \int_{t_1}^{t_2} \alpha\, f_1(\beta R_S)\,\mathrm{dt}$$

where $e_i$ is the light-use efficiency (LUE) or radiation-use efficiency (RUE; the subscript $i$ denotes the experimental treatments), DM is the crop dry matter, the variable $t$, including the integration limits ($t_1$ and $t_2$), represents time of the growing season, $f_1$ is a function of canopy development and stand duration indicating the fraction of radiation intercepted by the stand canopy, $\alpha$ the absorptivity for PAR, and *Rs* is the short-wave solar radiation (0.3- 3.0 µm) and $\beta$ the ratio of PAR to global solar radiation.

### 2.3 Crops Sampling and Data Collection

The data on crop growth parameters were recorded on the same dates as light measurement. From each experimental plot 5 plants were uprooted with maximum roots. The plant heights were measured from ground level to the tip of plant. Number of tiller per plant was recorded from the selected plants. Leaf area was measured by an electronic Leaf Area Meter (model LI-3100, Li-Cor, Lincoln, NE, USA) and then leaf area index was recorded as the leaf area/ground area ($m^2$ $m^{-2}$). The harvested material was dried to a constant weight in an oven at 80±2°C. The total crop dry weight was then recorded as the sum of the weights of the root, stem, leaves, and spike.

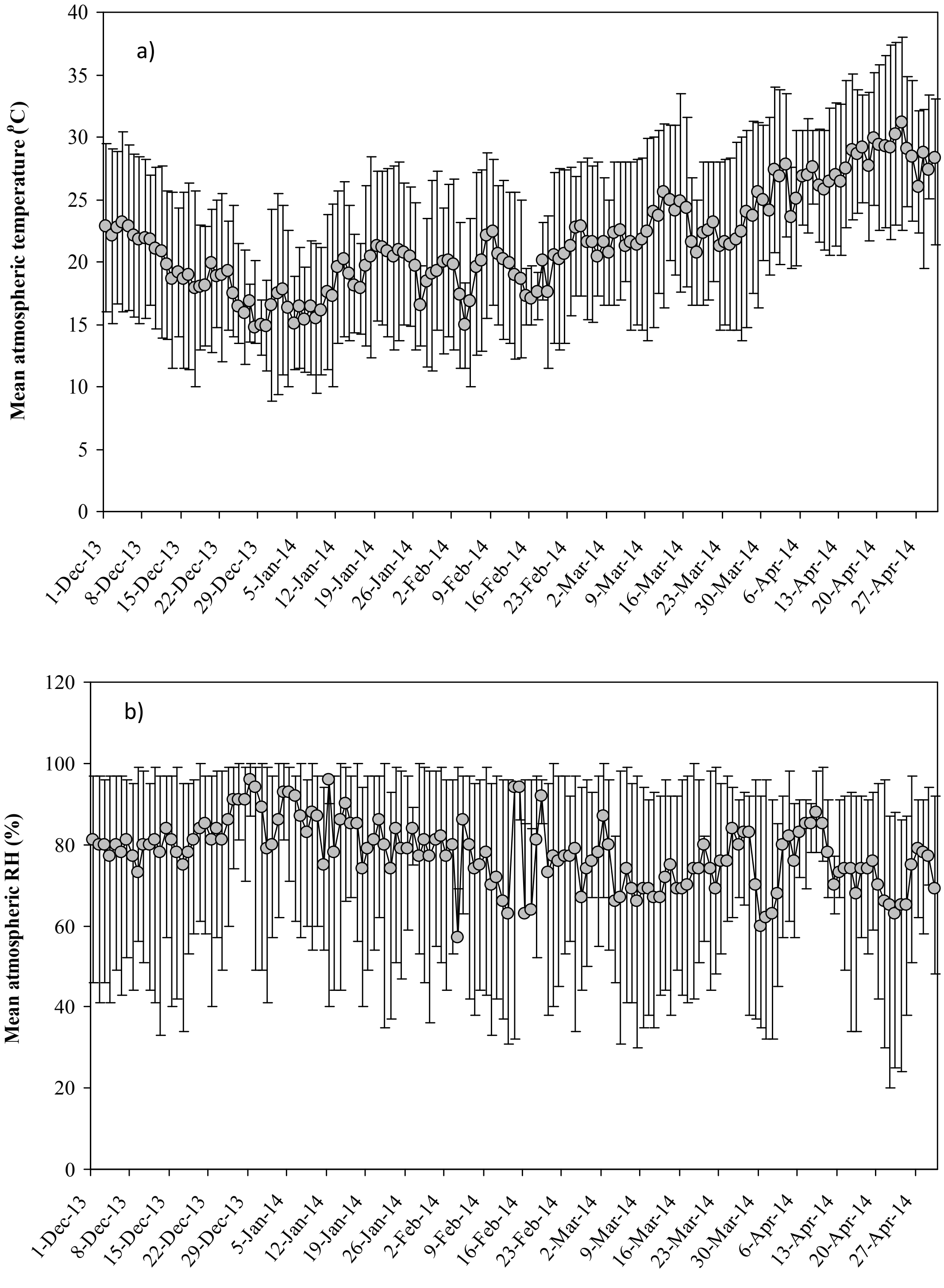


**Fig. 1. Mean atmospheric temperature (a) and relative humidity (b) during the study period from December 2013 to April 2014 [15]. Upper vertical bars indicate maximum while lower vertical bars indicate minimum deviation from the mean values**

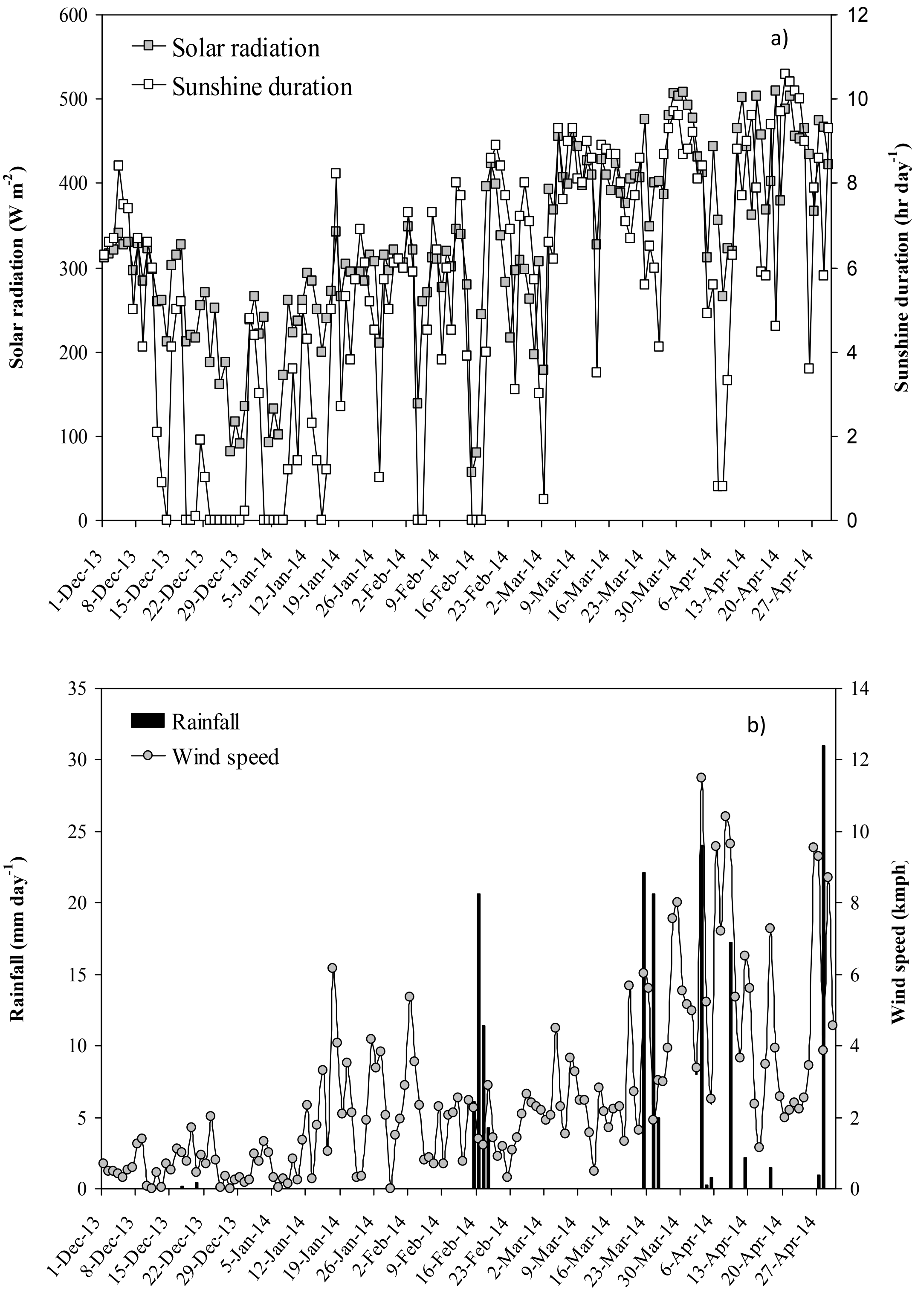


**Fig. 2. Daily incident short-wave solar radiation along with sun duration (a), and rainfall and prevailing wind speed (b) during the study period from December 2013 to April 2014 [15]**

Yield components and yield were recorded during physiological maturity of crops. Crop plants were harvested when most of the grains become mature. Fifty randomly selected plants from each plot were carefully uprooted to find out the yield components and yield of the crop. Harvest index was recorded as grain yield/total dry matter.

## 3. RESULTS

### 3.1 Crop Phenophase Development

Most of phenophase development events except days to seedling emergence was significantly differed among the wheat varieties (Table 1). All the wheat varieties took about a week for emergence their seedling from the soil level. The variety BARI wheat-24 took the shortest time of about 60 days and BARI wheat-27 took the longest time of about 64 days to emerge the spike from the flag leaf while the other varieties ranked intermediate. The variety BARI wheat-27 took the maximum time of about 83 days to leaf yellowing completion while BARI wheat-24 took the minimum time of about 75 days. Similarly, BARI wheat-24 took the comparatively less number of days of about 115 days to crop harvest and BARI wheat-27 took the longest time of about 123 days while the other varieties ranked intermediate.

### 3.2 Plant Height

Plant height was recorded from 42 DAS (days after sowing) till final harvest of crops at 9-12 days interval depending on the available sunny days. Plant height increased gradually with the progress of growth stages (Fig. 3). The results relating to the plant height indicated that there was a significant variation among the five varieties of wheat at different growth stages (*P<0.01*; except *P<0.05* at 52 DAS). The tallest plant was produced by BARI wheat-23 whereas the shortest plant by BARI wheat-27 during entire stages of growth. The other varieties ranked intermediate.

### 3.3 Production of Tiller

Initial lower tiller number per plant gradually increased with time with significant (*P<0.01*; except *P<0.05* at 62 DAS) variation among the varieties (Fig. 4 above). The maximum number of tillers per plant was recorded in BARI wheat-23. In contrast, the minimum tiller per plant was recorded in BARI wheat-24 while the other varieties ranked in between.

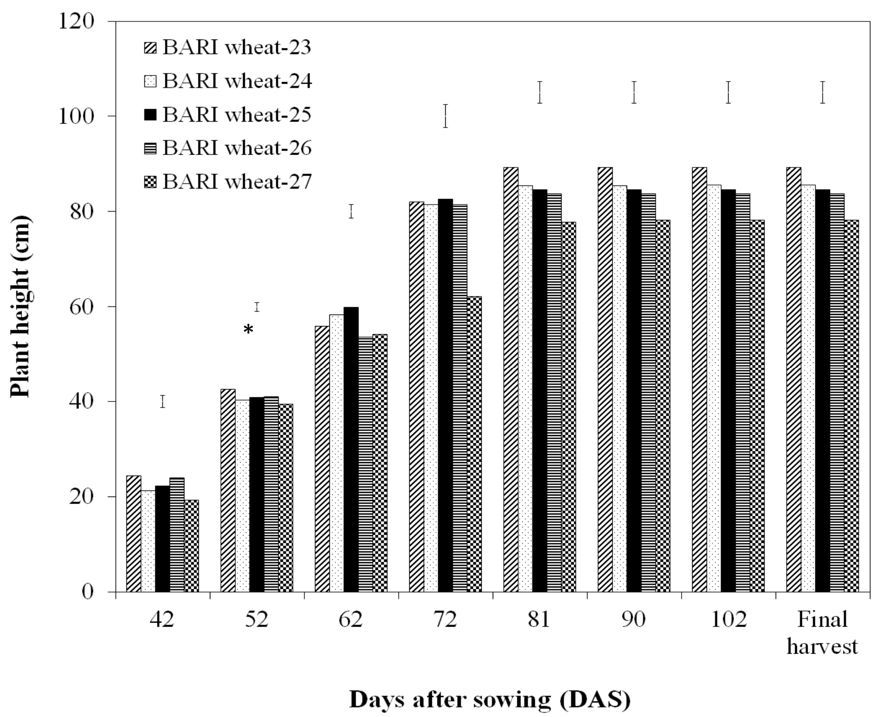


**Fig. 3. Plant height of five BARI wheat varieties at different days after sowing (DAS). Vertical bars indicate the LSD at *P*<0.01 (**P*<0.05)**

**Table 1. Phenological development events of five wheat varieties**

| Variety | Days to seedling emergence | Days to spike emergence | Days to leaf yellowing completion | Days to final harvest |
|---|---|---|---|---|
| BARI wheat-23 | 7 | 62 b | 78 b | 118 abc |
| BARI wheat-24 | 7 | 60 c | 75 b | 115 c |
| BARI wheat-25 | 7 | 62 b | 76 b | 116 bc |
| BARI wheat-26 | 7 | 61 bc | 81 a | 121 ab |
| BARI wheat-27 | 7 | 64 a | 83 a | 123 a |
| LSD | ns | 1.78** | 2.93** | 5.45* |

*Similar lower case letters within a column do not differ significantly at 1% (**) or 5% (*) level of probability. ns = not significant*

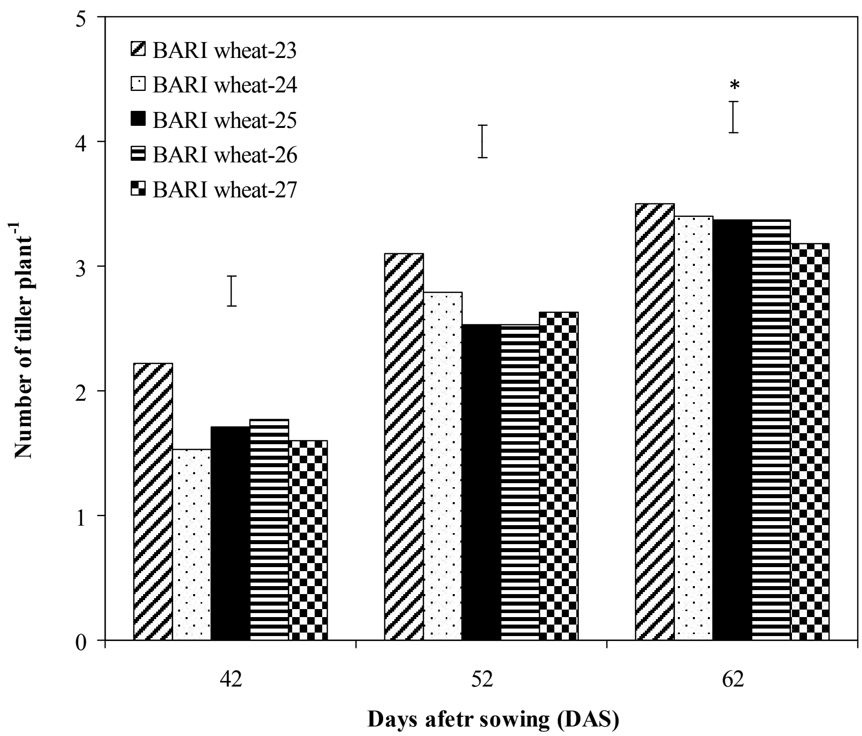


**Fig. 4. Number of tiller per plant of five BARI wheat varieties at different days after sowing (DAS). Vertical bars indicate the LSD at *P*<0.01 (**P*<0.05)**

## 3.4 Leaf Area Index (LAI)

The LAI was ranged from 0.5-1.0 during the initial stage of crop growth (i.e. 42 DAS) (Fig. 5). Subsequently the LAI gently rose up to 81 DAS followed by a sharp decrease towards maturity of crops. The LAI difference between five tested varieties of wheat was found significant ($P<0.05$). The maximum LAI was recorded in BARI wheat-23 while minimum LAI was recorded from variety BARI wheat-27 throughout the crop growth. The remaining wheat varieties showed intermediate performance. Irrespective of the varieties, lower LAI is mainly due to smaller plant population.

## 3.5 Light Interception by the Crop Canopy

Light interception was recorded from 42 to 102 DAS at 9-12 days interval depending on the sunny-day (Fig. 6). About 15-20% of total incident light was intercepted by the crop canopy following the seedling emergence. Thereafter PAR interception slowly increased up to 81 DAS followed by a slow decline towards maturity of crops. The difference between 5 varieties of wheat in PAR interception was found significant ($P<0.01$; except $P<0.05$ at 102 DAS). The maximum light interception was recorded in BARI wheat-26 as well as BARI wheat-23 while minimum light interception was recorded from variety BARI wheat-25 as well as BARI wheat-27 throughout the growth period. The BARI wheat-24 variety ranked in middle.

### 3.6 Accumulation of Dry Matter

Total dry matter (TDM) was the sum of dry weight of roots, stem, leaves and spike. The TDM accumulation was lower at initial growth stage (Fig. 7). Thereafter the TDM almost linearly and steadily increased to attain its peak or maximum value at 102 days after sowing (DAS). Then the TDM slowly declined at the approach of maturity of crops. The TDM accumulation among the varieties was significantly differed (*P<0.01*). The BARI wheat-23 accumulated comparatively greater amount of TDM than BARI wheat-25 and lower TDM was noticed in BARI wheat-27 while the other varieties ranked intermediate.

### 3.7 Seasonal Changes in Light-Use Efficiency (LUE)

Initially the LUE increased with time. Thereafter, the seasonal change in LUE showed much irregular pattern in all the varieties (Fig. 8). The varieties BARI wheat-24 and BARI wheat-27 maintained somewhat lower while BARI wheat-23 and BARI wheat-25 maintained higher LUE during different stages of growth especially during 62 to 90 DAS. The LUE declined to approach maturity of crop except the varieties BARI wheat-24 and BARI wheat-27.

### 3.8 Seasonal Mean LUE

The accumulation of TDM has been regressed against cumulative amount of PAR intercepted (Fig. 9) where the slope from linear function considered as seasonal mean LUE. The mean LUEs for the different varieties were found within the ranges from 0.68 to 0.91 g $MJ^{-1}$ PAR and the data are shown in (Fig. 10). The varieties BARI wheat-23 and BARI wheat-25 had comparatively higher LUE followed by the variety BARI wheat-26. The lower LUE was recorded for BARI wheat-27 where the variety BARI wheat-24 ranked intermediate.

### 3.9 Yield Contributing Characters, Yield and Harvest Index

Wheat varieties exhibited significant differences in their performance for yield components (Table 2). The variety BARI wheat-23 produced higher numbers of fertile spike while the BARI wheat-24 produced lower. In contrast, the variety BARI wheat-27 produced higher number of unfertile spikes per hill while the BARI wheat-25 gave lower number. The variety BARI wheat-23 had larger spike length followed by BARI wheat-25 while the BARI wheat-23 had the smaller spike.

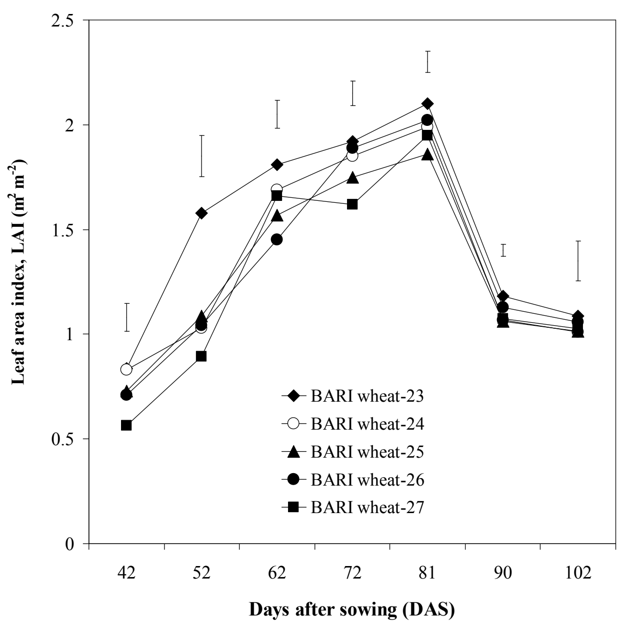


**Fig. 5. Seasonal time course of leaf area index (LAI) in the growing crop canopy of five BARI wheat varieties at different days after sowing (DAS). Vertical bars indicate the LSD at *P*<0.05**

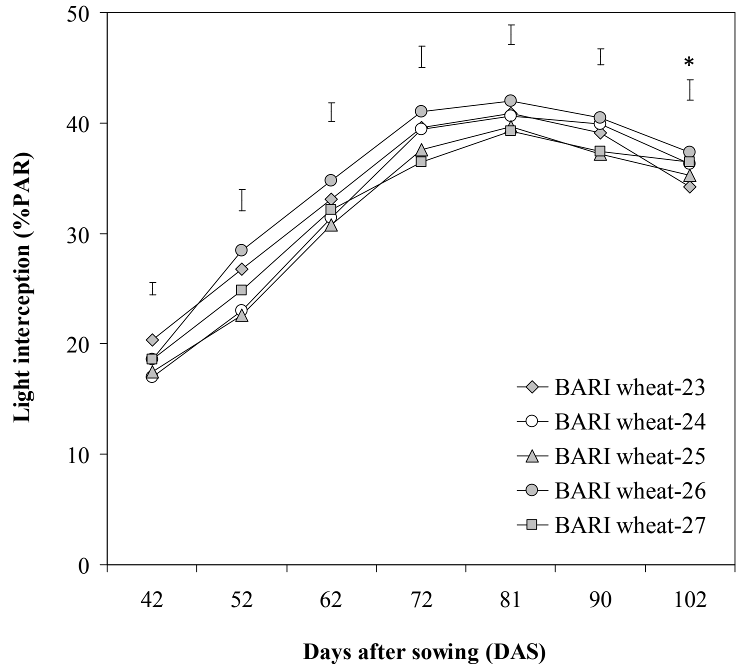


**Fig. 6. Light interception by the developing crop canopy of five BARI wheat varieties at different days after sowing (DAS). Vertical bars indicate the LSD at $P$<0.01 ($^*P$<0.05)**

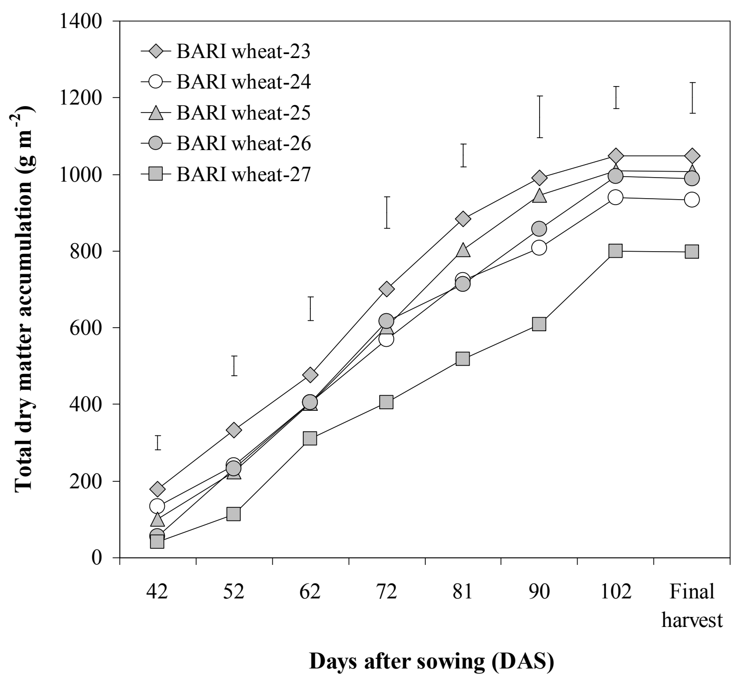


**Fig. 7. Total dry matter accumulation by the developing crop canopy of five BARI wheat varieties at different days after sowing (DAS). Vertical bars indicate the LSD at $P$<0.01**

The variety BARI wheat-25 produced higher number of grains per spike and lower by the BARI wheat-27; while the other varieties ranked intermediate. The variety BARI wheat-23 produced higher grain weight per spike while the BARI wheat-27 gave lower grain weight per spike. The variety BARI wheat-23 produced larger grain as reflected from higher 1000-grain weight (47.57 g) while the BARI wheat-27 offered the smaller grain (Table 2). Although the other varieties ranked in middle for grain weight per spike and 1000-grain weight but difference with BARI wheat-23 was not statistically significant.

The higher biological yield was obtained from the variety BARI wheat-25 as well as BARI wheat-26 or BARI wheat-23 and lower biological yield was found from the BARI wheat-27 (Fig. 11). The variety BARI wheat-23 produced higher grain yield (2.287 t/ha) followed by the BARI wheat-25 (1.983 t/ha) and lower grain yield was produced by the BARI wheat-27 (1.573 t/ha) while the remaining varieties showed intermediate performance. The higher harvest index was obtained from the BARI wheat-23 while lower from the BARI wheat-26. Although the other varieties ranked intermediate performance in this regard but the difference with BARI wheat-26 was found statistically insignificant.

### 3.10 Relationship between RUE and Yield

A close correlation was observed between LUE and yield (Fig. 12). That is the seed yield increases with LUE. For example, BARI wheat-27 produced lower seed yield due to its lower LUE as compared to other varieties.

**Table 2. Yield contributing characters of five varieties of wheat**

| Wheat varieties | No. fertile spike hill$^{-1}$ | No. unfertile spike hill$^{-1}$ | Spike length (cm) | No. grain spike$^{-1}$ | Grain wt spike$^{-1}$ (g) | 1000-grain wt (g) |
|---|---|---|---|---|---|---|
| BARI wheat-23 | 3.587 a | 1.110 d | 10.07 a | 36.49 ab | 23.76 a | 47.57 a |
| BARI wheat-24 | 2.427 b | 1.540 b | 9.090 b | 35.22 b | 22.56 a | 49.42 a |
| BARI wheat-25 | 2.697 b | 1.180 d | 9.590 ab | 38.98 a | 22.74 a | 47.82 a |
| BARI wheat-26 | 2.627 b | 1.360 c | 9.167 b | 36.41 ab | 21.94 a | 46.18 a |
| BARI wheat-27 | 2.693 b | 1.693 a | 7.737 c | 24.71 c | 14.58 b | 37.65 b |
| $LSD_{0.05}$ | 0.618 | 0.145 | 0.780 | 2.56 | 2.20 | 3.12 |

*Similar lower case letters within a column do not differ significantly at 5% level of probability*

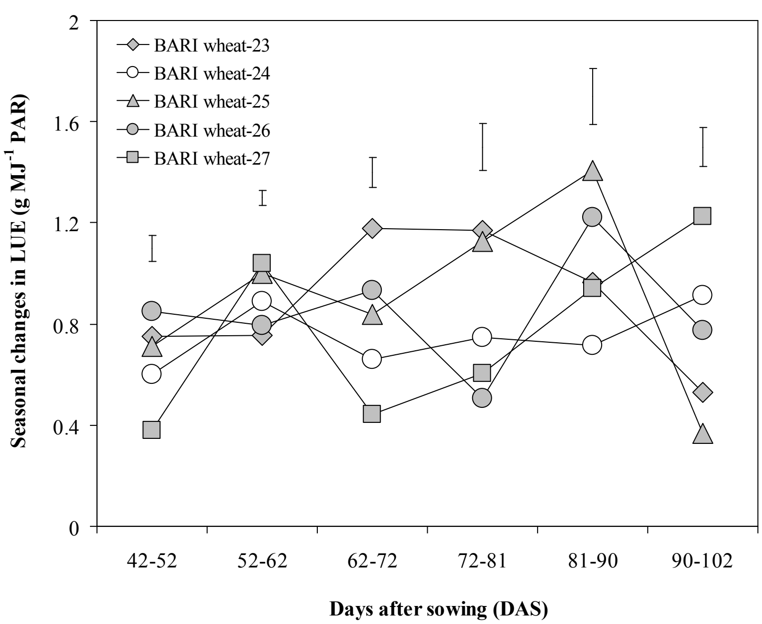


**Fig. 8. Temporal and seasonal changes in RUE (LUE) of five BARI wheat varieties at different days after sowing (DAS). Vertical bars indicate the LSD at *P*<0.05**

## 4. DISCUSSION

The experimental wheat varieties developed by the Bangladesh Agriculture Research Institute (BARI) showed significant variation in plant height, tiller number, leaf area index (LAI), light interception and its use (i.e. light-use efficiency, LUE) for dry matter accumulation as well as yield attributes and yield. In general, LAI started to increase from 42 DAS that reached to a peak at 81 DAS. A drop of LAI value was observed among the varieties from 90 DAS, due to yellowing or senescence of leaf canopy. As a result, there was almost no green leaf area at physiological maturity. The variability of LAIs found from 0.56 to 2.53 for tested wheat varieties were similar to that of the findings reported else [16-18].

Dry matter accumulation per unit land area is a prerequisite for crop production. In other word, accumulation of dry matter of a crop is the ultimate output of light interception and its efficiency of use. Therefore, radiation or light interception and its proper utilization had significant effect on total plant dry matter accumulation. The amount of total dry matter (TDM) produced by a crop, growing under non-limiting conditions, is almost related to the amount of photosynthetically active solar radiation (PAR) intercepted by its green leaf area [12,13] and the efficiency with which the light energy is converted to TDM [8]. Greater amount of light interception was recorded during 72-102 DAS, when TDM accumulation was also found higher than those of earlier harvests. When grain filling occurs or leaf senescence began, the loss of dry matter took place until the physiological maturity of crops [16,19]. The variety BARI wheat-23 was the most efficient utilizer of solar radiation for dry matter and grain production followed by BARI wheat-25 while the performance of BARI wheat-27 was found poor. Miranzadeh [18] and Jahfari [20] also confirmed our findings for LUE while studying with wheat cultivars.

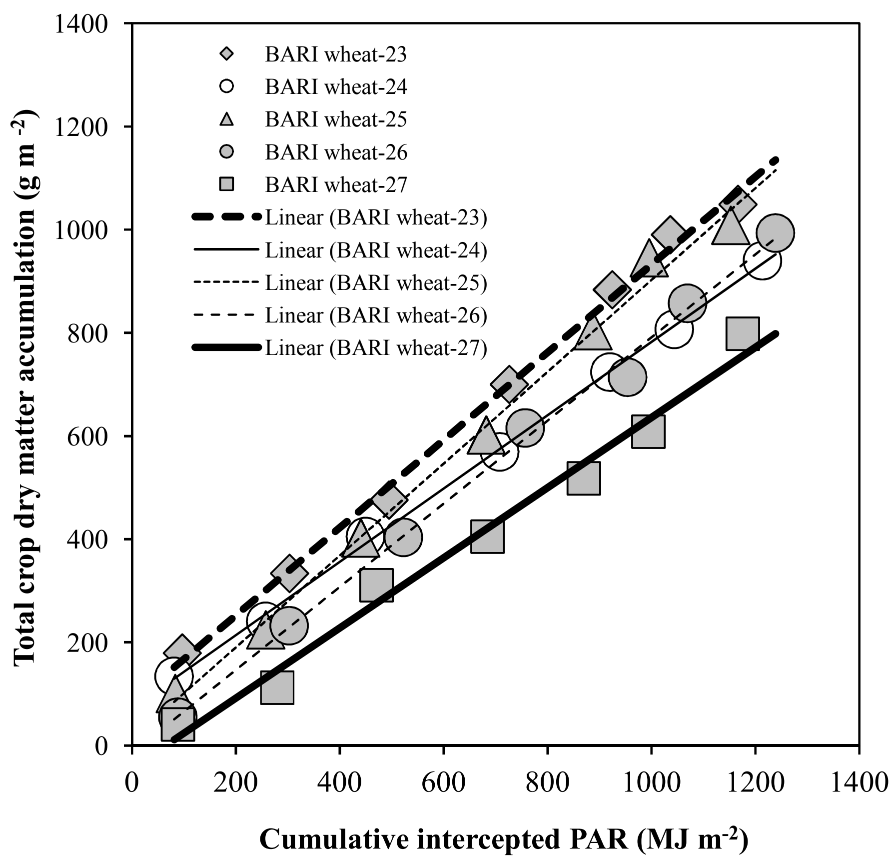


**Fig. 9. Relationship between cumulative intercepted PAR and total crop dry matter accumulation over the growth period in the five BARI wheat varieties. Linear regressions are shown for the different varieties**

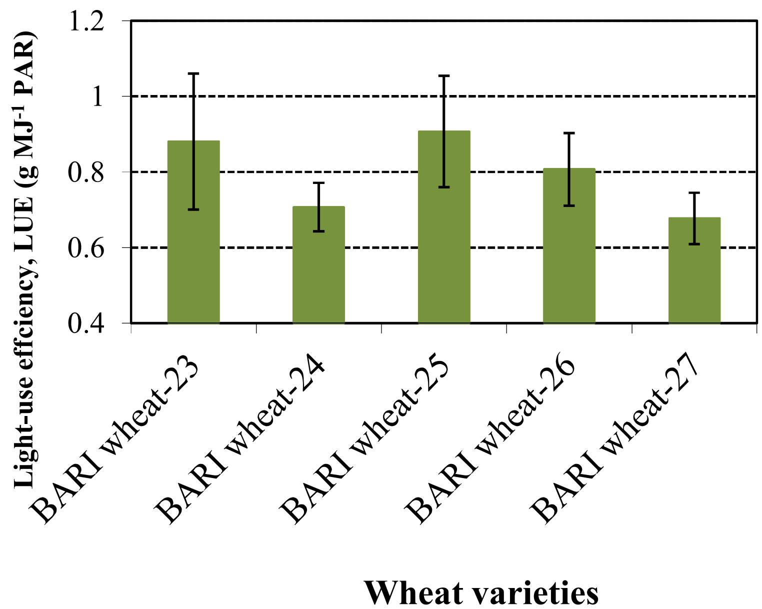


**Fig. 10. Seasonal mean light-use efficiency (LUE) of five BARI wheat varieties. Vertical bars indicate the standard deviation from the mean**

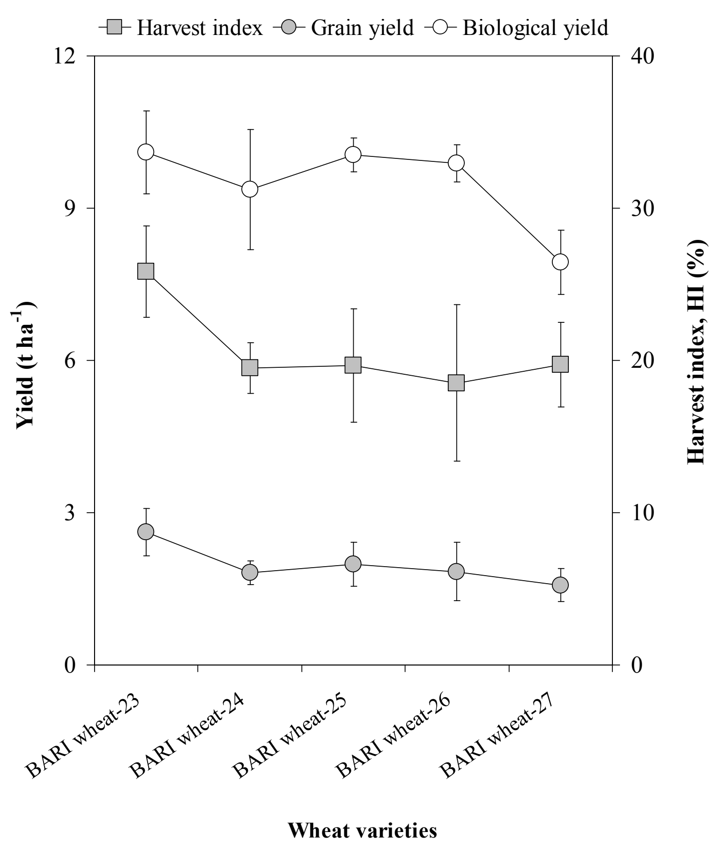


**Fig. 11. Biological yield (BY), economic yield (i.e. grain yield) and harvest index (HI) of five BARI wheat varieties. Vertical bars indicate the standard deviation from the mean**

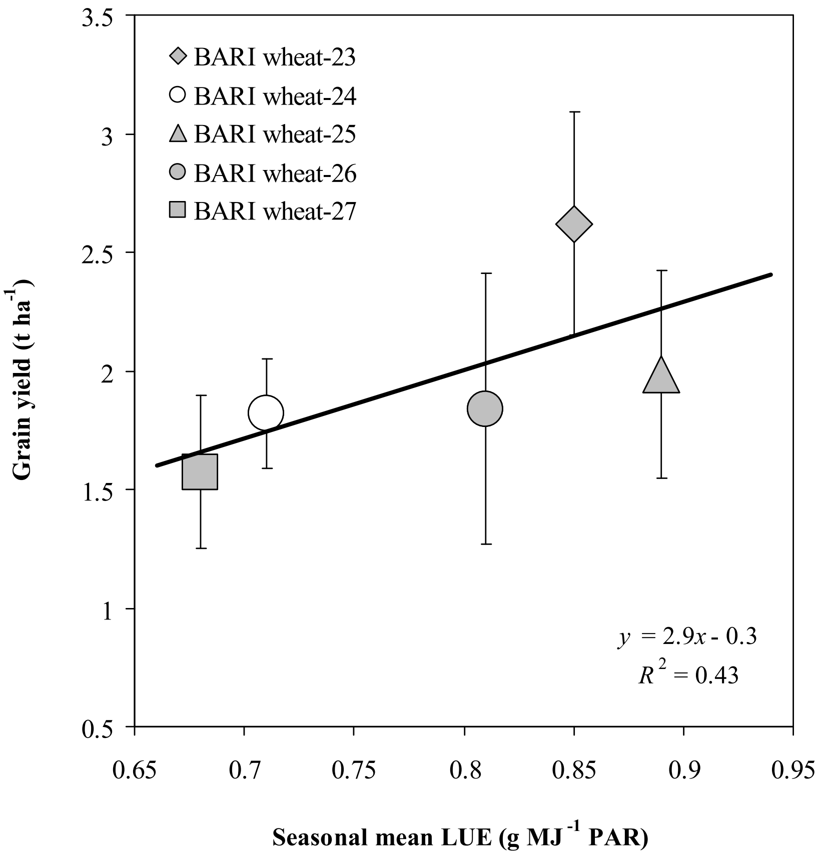


**Fig. 12. Relationship between LUE and grain yield across five varieties of wheat. Vertical bars indicate the standard deviation from the mean**

It is quite visible from the data presented in this study that varieties exhibited a remarkable difference in their performance for agronomic parameters and yield components. The taller plants were obtained from BARI wheat-23 followed by BARI wheat-24 and the variety BARI wheat-27 produced the shorter plants. The results have been confirmed by the previous published reports [21-23] where the authors have also reported the significant variation of crop stature among the wheat varieties studied. The variety BARI wheat-23 proved to be superior for tillers production while BARI wheat-24 produced smaller number of tiller among the varieties. However, the varieties BARI wheat-26 and BARI wheat-27 produced statistically similar number of tiller per hill. Jahfari [20] and Mattas et al. [22] have also reported similar result while studying the varietal performance for fertile tillers. The variety BARI wheat-23 bear the larger spike and BARI wheat-27 produced the shorter among the varieties. The variety BARI wheat-24 and BARI wheat-26 did not differ significantly for spike length. The higher number of fertile spike per plant was observed in BARI wheat-23 which reflects its higher grain yield. The lower number of fertile spike per plant was obtained from BARI wheat-24. The results have been confirmed by Ehsan et al. [24] who have also reported the significant differences among the varieties on spike number per plant. The maximum number of unfertile spike per plant was counted from BARI wheat-27 but variety BARI wheat-23 exhibited minimum number of unfertile spike. Mohammad et al. [23], Ehsan et al. [24] and Shafiq [25] also reported significant variations among the wheat varieties for production of fertile spike, number of unfertile spike and spike length. It is clear from the data presented that varieties had significant effects on 1000-grain weight, grain yield and biological yield, number of grains/spike and grain weight/spike.

The variety BARI wheat-24 had bold grains and thus proved superior for 1000 grains weight and it was followed by BARI wheat-23 and BARI wheat-25. The variety BARI wheat-27 had the smaller grains among the tested varieties thus proved poor for 1000 grains weight. However, BARI wheat-23 and BARI wheat-25 did not differ significantly for 1000 grains weight. The variety BARI wheat-23 produced higher grain yield followed by BARI wheat-25 and lower grains mass was produced by BARI wheat-27. The maximum numbers of grain per spike were counted from BARI wheat-23 followed by BARI wheat-26 but variety BARI wheat-27 was found poor for this character. Again the maximum grain weight per spike was counted from BARI wheat-23 but variety BARI wheat-27 exhibited poor performance while there was no significant different between BARI wheat-24 and BARI wheat-25.

The difference in TDM accumulation in the tested five wheat varieties is supported by Nasim et al [26] they observed a wide range of TDM production in the eleven wheat varieties including two advance lines such as Inqlab-91, Chakwal-97, Iqbal-2000, Uqab-2000, Ufaq-2000, Wafaq-2000, SH-2002, AS-2002, Bhakkar-2001, 95153 and 97052 varieties. The higher biomass value for varieties suggests its importance for animal feeds as they offer higher straw production. The variation in individual grain weight (i.e. 1000-grain weight), biological yield, grain yield, and harvest index (HI) of the tested wheat varieties in this study was supported by Mattas et al. [22], Mohammad et al. [23] and Alam et al. [27], who have reported significant variations among the wheat varieties for the examined traits.

The observed light-use efficiency (LUE) from the tested wheat varieties seems little bit lower than the LUE of wheat crops reported else [28-33]. Such lower value in LUE in this study is mainly due to lower stand density. A proper plant to plant spacing (5 cm) in a row was strictly maintained in this study whereas continuous seeding within a row is reported where LUE showed higher values. Under this lower plant population density the growing crops not only showed poor potentiality in achieving the best value of LUE but also limited to the grain yield [30,33] along with other canopy characters like LAI. Therefore, a study on the effect of plant population density on LUE in wheat varieties is highly recommended.

## 5. CONCLUSION

It is concluded from the results of the present study that the variation in canopy development, light interception and its use, and yield performance obtained from the different varieties of wheat was found significant. Among the varieties, the BARI wheat-23 showed better performance and BARI wheat-27 showed poor performance for the examined traits while the other varieties ranked in middle. The BARI wheat-23 and BARI wheat-25 varieties showed better performance for producing higher grain yield due to the greater interception of photosynthetically action radiation (PAR) by their canopies as well as better utilization of that solar energy into crop biomass and higher partitioning of accumulated biomass towards grain.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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