







### 3.3 Wheat Plant Height

Wheat varieties exhibited differences in plant height at all sampling dates, but most significantly at the final stage (Table 4).

**Table 4:** Effect of variety and weeding regime on plant height of wheat

9 DULHW \	3 O D Q W K H L J K W F P		
	'\$6	'\$6	+DUYHVW
%\$5, JRP	F	G	DE
%\$5, JRP	EF	FG	DEF
%\$5, JRP	EF	EF	DEF
%\$5, JRP	D	D	D
%\$5, JRP	EF	FG	FG
%\$5, JRP	EF	FG	EF
%\$5, JRP	D	D	EF
%\$5, JRP	DE	D	FG
%\$5, JRP	EF	E	G
%\$5, JRP	D	D	G
& 9			
/HYHO RI VLJQLILFDQFH			
:HHGLQJ UHJLPH			
:HHG IUHH	D	D	D
:HHG \	D	E	E
& 9			
/HYHO RI VLJQLILFDQFH			

Other details are same as Table 3.

At harvest, plant height ranged from 84 to 98 cm. BARI gom 24 appeared as the tallest variety, which was marginally taller than BARI gom 21, whilst BARI gom 29 was the shortest in stature closely followed by BARI gom 30 (Table 4).

At all the growth stages, plant height of wheat varied significantly among wheat varieties studied. Weed infestation reduced plant height of wheat at all the growth stages (Table 4). The magnitude of reduction in plant height varied with growth phases, and reduction rate in weedy treatment followed a declining trend with the advancement of crop growth stages. However, weedy treatment at harvest recorded more than 4% reduction in plant height compared to weed free treatments. Presence of weed markedly decreased plant height by 5 and 5.5% at 15 and 30 DAS, respectively. At harvest, BARI gom 21 and BARI gom 22 suffered the greatest height loss in weedy treatment as compared with weed free one. The reduction percentages were 6.7 and 8.5, respectively. Such loss is understandable as both the cultivars had greater reduction in height at earlier stage. In other words, those cultivars had slower growth rate at earlier stage, which resulted in such reduction. Conversely, BARI gom 24 and BARI gom 30 performed better in weedy circumstances as the reduction in plant height were 2.4 and 2.7%, respectively during harvest. The reduction percentage for both BARI gom 24 and BARI gom 30 was mostly 4.5% during earlier stage.

The interaction effect of weeding regime and variety produced significant influence on plant height (Table 5).

**Table 5:** Interaction effect of variety and weeding regime on plant height of wheat

:HHGLQJ UHJLPH \	3 O D Q W K H L J K W F P		
	'\$6	'\$6	+DUYHVW
%\$5, JRP	E	E H	D
%\$5, JRP	E	EFG	D G
%\$5, JRP	DE	EF	D G
%\$5, JRP	D	D	DE
%\$5, JRP	DE	E H	E J
%\$5, JRP	DE	EF	D H
%\$5, JRP	D	D	D H
%\$5, JRP	DE	D	E J
%\$5, JRP	DE	E	H I J
%\$5, JRP	DE	D	H I J
%\$5, JRP	E	H	D H
%\$5, JRP	E	GH	F I
%\$5, JRP	DE	EFG	D I
%\$5, JRP	DE	D	DEF
%\$5, JRP	E	FGH	G J
%\$5, JRP	DE	FGH	F J
%\$5, JRP	DE	D	E J
%\$5, JRP	DE	D	F J
%\$5, JRP	E	E F	J
%\$5, JRP	DE	D	I J
& 9			
/HYHO RI VLJQLILFDQFH			

Other details are same as Table 3.

At harvest, BARI gom 24 appeared as the tallest variety whilst BARI gom 29 and BARI gom 30 were the shortest ones. At earlier stage, BARI gom 30 was the tallest one closely followed by BARI gom 24, and BARI gom 21 was with the shortest stature. Plant height at 30 DAS maintained a strong negative correlation with weed dry weight (Figure 6). Early plant height at 30 DAS appeared to be the most important trait in predicting weed biomass (R<sup>2</sup>=0.58) (Figure 6).

**Figure 6:** Relationship between plant height 30 DAS and weed dry matter

### 3.4 Yield Parameters of Wheat

All yield-contributing characters were significantly influenced by variety, weeding regime and their interaction (Table 6 and 7).

**Table 6:** Effect of variety and weeding regime on different yield contributing characters and yield of wheat

9 DULHW \	6 S L N H V P						6 S L N H V P					
	6 S L N H V P		6 S L N H V P		6 S L N H V P		6 S L N H V P		6 S L N H V P		6 S L N H V P	
%\$5JRP	H	D	G	FG	G	I	G	H	H	H	H	
%\$5JRP	GH	G	FG	EFG	E	H	F	F	F	F	F	
%\$5JRP	FG	EF	FG	H	J	H	I	I	I	I	I	
%\$5JRP	DE	DEF	DEF	DE	D	D	D	D	D	D	D	
%\$5JRP	FGH	DE	EFG	F	E	F	F	F	F	F	F	
%\$5JRP	FG	DEF	G	G	G	F	F	F	F	F	F	
%\$5JRP	DE	DE	D	D	GH	E	E	E	E	E	E	
%\$5JRP	D	D	DE	DE	F	DE	DE	DE	DE	DE	DE	
%\$5JRP	FGH	H	EFG	H	I	G	H	H	H	H	H	
%\$5JRP	DE	DEF	DEF	D	D	D	D	D	D	D	D	
& 9												
/HYROVLJ												
:HHGLQJ 5HJLPH												
:HHG IUHH	D	D	D	D	D	D	D	D	D	D	D	
:HHG \	E	E	E	E	E	E	E	E	E	E	E	
& 9												
/HYROVLJQLILFDQFH												

Here, \*= Significant at 5% level of probability, NS= Not significant. Other details are same as Table 3.

**Table 7:** Interaction effect of variety and weeding regime on yield contributing characters and yield of wheat

Interaction (variety × weeding regime)	Spikes m <sup>-2</sup>	Spike length (cm)	Spikelets spike <sup>-1</sup>	Grains spike <sup>-1</sup>	1000-grain weight (g)	Grain yield (t ha <sup>-1</sup> )	Straw yield (t ha <sup>-1</sup> )	
Weed free	BARI gom 21	147.0a-d	16.97ab	16.73abc	42.33abc	41.10jk	2.56d	3.14cde
	BARI gom 22	150.0a-d	15.73abc	16.57abc	46.67a	42.83gh	2.98bc	3.70bc
	BARI gom 23	143.3a-d	16.03ab	15.33abc	37.67bcd	36.03i	1.94ef	2.42fg
	BARI gom 24	157.7ab	16.40ab	17.30abc	47.33a	49.27a	3.66a	4.54a
	BARI gom 25	144.0a-d	17.03ab	16.40abc	44.00abc	47.10bc	2.97bc	3.75bc
	BARI gom 26	144.7a-d	16.73ab	15.37abc	42.67abc	44.00efg	2.72c	3.34cd
	BARI gom 27	158.0ab	16.60ab	18.27a	48.33a	43.90efg	3.34ab	4.16ab
	BARI gom 28	159.3a	17.37a	17.90ab	47.33a	46.33c	3.48a	4.27ab
	BARI gom 29	141.3a-d	12.50de	16.63abc	37.67bcd	41.03ijk	2.16de	2.76def
	BARI gom 30	152.0abc	15.20abc	18.60a	48.67a	47.97b	3.53a	4.30ab
Weedy	BARI gom 21	85.00h	14.43bcd	14.57bc	36.33cd	40.40jk	1.25h	1.57i
	BARI gom 22	98.33gh	13.13cde	15.33abc	44.00abc	42.03hij	1.80efg	2.19fgh
	BARI gom 23	118.0ef	14.50bcd	14.50c	33.67d	35.17l	1.39gh	1.71hi
	BARI gom 24	132.7de	15.80abc	16.43abc	44.67ab	47.30bc	2.80c	3.48c
	BARI gom 25	107.7fg	15.77abc	15.67abc	42.33abc	45.23de	2.04ef	2.55ef
	BARI gom 26	120.0ef	15.23abc	14.33c	38.33bcd	43.07fgh	2.01ef	2.56ef
	BARI gom 27	134.3cde	16.50ab	17.33abc	47.00a	42.37ghi	2.67cd	3.38cd
	BARI gom 28	141.0bcd	16.37ab	17.47abc	45.33ab	44.73def	2.86bc	3.51c
	BARI gom 29	112.3fg	11.17e	15.87abc	34.33d	39.50k	1.52fgh	1.88ghi
	BARI gom 30	122.7ef	14.47bcd	17.63abc	47.33a	45.80d	2.65cd	3.29cd
CV%	6.87	9.12	10.25	9.16	2.11	11.14	10.71	
Level of significance	**	**	**	**	**	**	**	

Other details are same as Table 3.

BARI gom 28 produced the highest number of spikes  $m^{-2}$  (150.2) closely followed by BARI gom 27 (146.2), BARI gom 30 and BARI gom 24 (145.2) (Table 6). The lowest spikes  $m^{-2}$  was obtained from BARI gom 21 (116.0) and this was significantly lower than any varieties studied followed by BARI gom 22 (124.2) (Table 6). Higher spikes  $m^{-2}$  (149.7) was found in weed free treatment than weedy treatment (117.2). In case of interaction, the highest spike  $m^{-2}$  (159.3) was produced by BARI gom 28 under weed free condition, and the lowest one (85.0) was in BARI gom 21 under weedy condition (Table 7). The highest spike length was obtained from BARI gom 28 (16.9 cm) followed by BARI gom 27 (16.6 cm), while the lowest one was obtained from BARI gom 29 (11.8 cm) (Table 6). As expected, higher spike length (16.1 cm) was found in weed free treatment compared with weedy treatment (14.7 cm) (Table 6). In case of interaction, the highest spike length was produced by BARI gom 28 (17.4 cm) under weed free condition followed by BARI gom 25 (17.0 cm) in the same condition, while the lowest one was observed in BARI gom 29 (11.2 cm) under weedy condition (Table 7). The highest number of spikelets  $spike^{-1}$  (17.8) was recorded with BARI gom 27, which was marginally higher than that (17.6) produced by BARI gom 28 (Table 6). On the other hand, the lowest number of spikelets  $spike^{-1}$  (14.9) was obtained from BARI gom 26 (Table 6). Higher number of spikelets  $spike^{-1}$  (16.9) was found in weed free treatment than weedy treatment (15.9). In case of interaction, the highest number of spikelets  $spike^{-1}$  (18.6) was produced by BARI gom 30 under weed free condition followed by BARI gom 27 under the same condition, while the lowest one (14.3) was observed in BARI gom 26 under weedy condition (Table 7). The highest number of grains  $spike^{-1}$  (48.0) was obtained from BARI gom 30, which was marginally higher than that (47.7) obtained from BARI gom 27 (Table 6). Those values were closely followed by BARI gom 28, BARI gom 24 and BARI gom 22 (Table 6). On the other hand, the lowest number of grains  $spike^{-1}$  (35.7) was obtained from BARI gom 23 followed by BARI gom 29 (36.00). Weed free condition resulted in higher number of grains  $spike^{-1}$  (44.3) compared with weedy condition (41.33). In case of interaction, the highest number of grains  $spike^{-1}$  (48.7) was produced by BARI gom 30 under weed free condition (Table 7) which was statistically identical with those produced by many other varieties including BARI gom 24, BARI gom 22, BARI gom 27 and BARI gom 28 under weed free condition, and surprisingly those varieties produced statistically similar number of grains  $spike^{-1}$  under weedy conditions. On the other hand, the lowest number of grains  $spike^{-1}$  was recorded with BARI gom 23 (33.3) under weedy condition (Table 7). BARI gom 24 and BARI gom 30 gave the highest 1000-grain weight of 48.3 g followed by BARI gom 25 (46.2 g). The lowest 1000-grain weight (35.6 g) was obtained from BARI gom 23 (Table 6). Higher 1000-grain weight (44.0 g) was found in weed free condition compared to weedy condition (42.5 g). In case of interaction, the highest 1000-grain weight was found in BARI gom 24 (49.3 g) in weed free condition followed by BARI gom 30 under same condition. The lowest 1000-grain weight (35.2 g) was produced by BARI gom 23 in weedy condition, which was statistically identical with the same variety under weed free condition (Table 7).

### 3.5 Grain and straw Yield of Wheat

The grain and straw yields were significantly influenced by variety, weeding regime and their interaction (Table 6 and 7). The highest grain yield ( $3.23 t ha^{-1}$ ) was obtained from the varieties BARI gom 24 and BARI gom 30 (Table 6). The lowest grain yield (1.67) was obtained from BARI gom 23 followed by BARI gom 29 and BARI gom 21 (Table 6). Similar to other parameters weed free treatment gave higher grain yield ( $2.94 t ha^{-1}$ ) than weedy treatment ( $2.10 t ha^{-1}$ ) (Table 6). In interaction, the highest grain yield was produced by BARI gom 24 ( $3.66 t ha^{-1}$ ) in weed free condition, which was statically identical with BARI gom 28 ( $3.48 t ha^{-1}$ ) and BARI gom 30 ( $3.53 t ha^{-1}$ ) under the same condition. BARI gom 21, on the other hand, produced the lowest grain yield ( $1.25 t ha^{-1}$ ) in weedy condition followed by BARI gom 23 under same condition (Table 7). The wheat varieties BARI gom 24 and BARI gom 30 produced the highest straw yield of  $4.01 t ha^{-1}$ , whereas the lowest one ( $2.07 t ha^{-1}$ ) was obtained from BARI gom 23 (Table 6). Like previous parameters higher straw yield ( $3.64 t ha^{-1}$ ) was found in weed free treatment than weedy treatment ( $2.61 t ha^{-1}$ ). For interaction, wheat variety BARI gom 24 produced the highest straw yield ( $4.54 t ha^{-1}$ ) in weed free condition followed by BARI gom 30 ( $4.30 t ha^{-1}$ ), BARI gom 28 ( $4.27 t ha^{-1}$ ) and BARI gom 27 ( $4.16 t ha^{-1}$ ) under the same condition (Table 7). On the other hand, BARI gom 21 under weedy condition produced the lowest straw yield ( $1.57 t ha^{-1}$ ) followed by BARI gom 23 ( $1.71 t ha^{-1}$ ) under same condition.

### 3.6 Relative Yield Loss (%)

The lower the relative yield loss the higher the degree of weed tolerance, since weed tolerance refers to the ability to maintain high yield in the presence of weed competition. The wheat varieties showed wide diversity in relative yield loss, which ranged from 17.8% to 51.2% (Figure 7). The relative yield loss was lowest in BARI gom 28 (17.8%) followed by BARI gom 27, BARI gom 30 and BARI gom 24 which exhibited high weed tolerance. BARI gom 21, on the contrary, showed the lowest tolerance to weeds with the maximum yield penalty of 51.2%. Lower tolerance was also showed by BARI gom 22 with a yield loss of 39.3% and by BARI gom 25 with a yield loss of 31.2% (Figure 7).

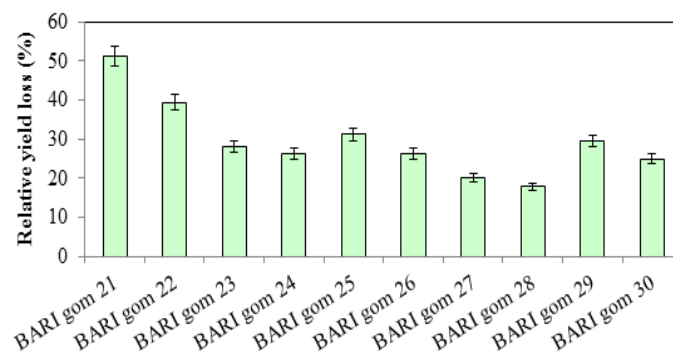


Figure 7: Effect of variety on relative yield loss (%) of wheat

### 4. DISCUSSIONS

The wheat varieties evaluated in this study varied not only in their yield attributes and yield performance but also in their weed suppressing ability. Competitive ability of a crop can be used as an important tool in integrated weed management [21, 25–27]. Crop species even varieties of the same species differ in their ability to compete for resources [14, 20, 28–30]. Among the wheat varieties studied in this research, BARI gom 27 allowed the minimum weed growth while BARI gom 21 allowed maximum weed growth. However, BARI gom 28 appeared as the most weed competitive variety allowing only 20% relative yield loss followed by BARI gom 27 with relative yield loss of 20% while BARI gom 21 appeared as the weakest competitor against weeds resulted in the highest relative yield loss of 51%. BARI gom 24 produced the highest grain yield under both weed free and weedy conditions which confirms that there is no trade off between yield potential and weed competitiveness of a crop. A study also opined that high yield potential and strong weed competitiveness can be combined together [21]. Weed competition negatively and markedly affected all the yield attributes which cumulatively impaired wheat grain yield. Working with eight Bangladeshi wheat cultivars, a researcher also reported that BARI gom 24 (Prodip) had the highest competitive ability against weeds followed by BARI gom 21 (Shatabdi), BARI gom 22 (Sufi), BARI gom 20 (Gourab), while BARI gom 23 (Bijoy) was the weakest competitor. In this study, the wheat variety performed better in weed free condition is likely to perform fairly better under weedy condition [5]. A study also obtained similar findings in case of rice grown under aerobic soil condition [21]. In fact, differences in surrounding species do not bring any change in the competitive ability of a particular species. The performing ability of a particular species due to intra specific (wheat-wheat) or inter specific (wheat-weed) competition may vary in degree but not in kind.

Crop competitiveness is a sum of interaction of several plant attributes for example, plant height, early visual vigor, leaf area index (LAI), tillering ability, canopy structure, crop ground cover, and so on [7, 15]. Early visual vigor is one of the most important characters contributing to crop competitiveness. Cultivar that efficiently utilizes resources during early stage of growth has higher competitive ability against weed. Early visual vigor can be determined on the basis of early seedling size, germination percent, and early crop biomass, therefore early visual vigor could be an important selection protocol while screening wheat varieties/germplasms for weed competitiveness [25, 31]. In our experiment, BARI gom 27 appeared as the most vigorous with early visual vigor scores of 8 followed by BARI gom 28 (7.8) and BARI gom 30 (7.8). Lower relative yield loss was also obtained from these three cultivars indicating their higher weed competitiveness. On the other hand, BARI gom 21 was the least vigorous

scoring around 3.6 and enjoyed the highest yield penalty due to poor competitive ability against weeds. A study also found that durum wheat that possessing high early biomass accumulation and greater photosynthetic active radiation was the best competitors against weeds [32]. They also reported a strong negative correlation between first leaf length and width, and seedling biomass accumulation with grain yield loss and weed dry matter. Similar results have been reported in barley, oats, and wheat [33].

Plant height is also one of the most extensively reported and desired attributes with respect to crop competitiveness [21, 34–37]. In this research, early growth in terms of plant height is confirmed as an important trait associated with weed competitiveness. Hence, it is noteworthy that within 15 DAS, the varieties attained 14% - 21% of their respective ultimate plant height with BARI gom 30 topping the list (20.5%) closely followed by BARI gom 27 (19.7%), BARI gom 24 (18.4%) and BARI gom 28 (18%). At early growth stages (15 DAS and 30 DAS), BARI gom 30 was the fastest growing cultivar consistently performed better in height gain but thereafter declined its growth substantially to become a shorter variety at harvest stage. Contrastingly, BARI gom 21 was the slower growing cultivar at earlier stage with poor gain in height, which however, dramatically improved afterward producing the second tallest cultivar next to BARI gom 24. BARI gom 27, BARI gom 24 and BARI gom 28 had considerably greater plant height at early stages of growth, which the former retained till the end, while the latter declined a bit. Conversely, BARI gom 25, BARI gom 22 had the least height at the earlier stage. A study reported that faster developing varieties were better weed suppressors than the slower [38]. A group of researchers also demonstrated the importance of early height over mature height in suppressing weeds [39]. Normally, taller varieties are more competitive than shorter ones [14, 27]. Another group of researchers also observed that taller varieties reduced weed growth to a greater extent by capturing more light than shorter cultivars [40, 19]. However, two shorter varieties were also appeared as strong competitors against weeds suggesting that competitive ability of a cultivar does not depend only one traits, it is the combination of more than one [40]. Varietal differences in weed suppressive ability is reflected by the differences in growth traits especially early faster growth which can be successfully assessed by early plant height and early visual vigor. Early root competition for soil resources might also play a vital role in determining weed competitiveness of a crop [21]. However, the regression analysis showed that early plant height and early visual vigor could explain weed dry matter by 59 and 71%, respectively.

## 5. CONCLUSION AND RECOMMENDATIONS

Present findings confirm that selection of weed suppressive variety could play an important role in sustainable weed management of wheat. Strong weed suppressive ability of a variety does not always ensure high yields. Hence, breeder should always focus on the development of a variety that has both high yielding ability and strong weed suppressive potential. To date, Wheat Research Center (WRC), Bangladesh Agricultural Research Institute (BARI) has released more than 30 wheat varieties. Unfortunately, none of them has been claimed or reported as a weed suppressive variety. On the other hand, as no variety in our study produced very high yield compared to that of other wheat growing countries, therefore it is recommended to develop new high yielding and strongly weed competitive wheat varieties that can be successfully grown throughout Bangladesh with least weed management. However, the present findings are based on a one-year experiment, and therefore, further research considering more wheat varieties and potential advanced lines should be conducted at different agro-climatic conditions to confirm the findings of the present study before final recommendation

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

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