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Adaptation of winter Barley (*Hordeum vulgare*) cultivars to climate change in southern part of Bangladesh

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ABSTRACT

The present study was conducted at Rural Development Academy (RDA) Agricultural Farm, Kotalipara, Gopalgonj located in southern area of Bangladesh during 01 November, 2023 to 28 March, 2024 to compare the yield performance of important barley varieties and to identify the best adaptive variety of Barley for this area of Bangladesh. Five Barley variety viz. V_1= BARI Barley-5, V_2= BARI Barley-6, V_3= BARI Barley-7, V_4= BARI Barley-8, V_5= BARI Barley-9 were used for the experiment. Maximum plant height during harvesting, maximum number of tillers per plant and maximum number of effective tillers per plant were recorded with V_1 (100.00cm), V_5 (3.99) and V_3 (2.95) respectively. BARI Barley-5 performed the maximum spike length (10.90cm), maximum number of spikelet of spike (60.45), maximum number of seeds per spike (48.05) and maximum thousand seed weight (31.74gm). As a result BARI Barley-5 gave the maximum grain yield (2.72 t/ha). BARI Barley-5 (94.25 days) and the BARI Barley-8 (95.75 days) was comparatively short duration crop than other varieties. This characteristic of the crop will help to introduce the new cropping pattern in this region and it will the dependency on monocropping. As a result, it can be decided that the BARI Barley-5 was the best variety in terms of grain yield and short duration. It can be concluded that the BARI Barley-5 was the best variety for this AEZ-14 and it can be extended to the local area of Gopaganj district.

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INTRODUCTION

Barley is a millet crop belongs to the genus *Hordeum* and the grass family, Poaceae (also known as Gramineae). Barley was first domesticated about 10,000 years ago in the area of the Middle East known as the Fertile Crescent (Badr *et al.* 2000). The genus Hordeum has centres of diversity in central and south western Asia, western North America, southern South America, and in the Mediterranean (Von Bothmer 1992). Barley (*Hordeum vulgare*) is one of the most significant cereal crops in the world. It is the fifth cereal crops grown in the world after maize, wheat, rice and soyabean (Miralles *et al.,* 2001; Ofsu-Amin and Leitch, 2009). It is a staple food in several countries including Morocco, India, China and Ethiopia (OECD, 2004). It is a winter season grain crop and used as fodder which also grown to improve soil fertility. In the last century barley was mainly cultivated and used for the purpose of human food supply but now-a-days, it is extensively cultivated as animal feed, malt products and human food.

The production of barley was 136 million tons and the area of cultivation covered about 566,000 km² (FAOSTAT, 2009). Barley is also used to produce starch, either for food or for the chemical industry (OECD 2004). In addition, barley has some useful by-products such as straw which is mainly used for animal bedding materials in developed countries, but also for animal feed in developing and under-developed countries (Akar *et al.*, 2003). There are some health benefits of barley such as lowering of blood cholesterol, with b-glucans (Behall *et al.*, 2004), and the glycemic index (Cavallero *et al.*, 2002) by barley has been reported widely (Pins and Kaur, 2006). Barley is also used for production of soft drinks in the form of Barley juice in some developing countries such as in India. It is cultivated successfully in a wide range of climate. This crop has potentials for growing under drought and saline conditions. It requires less input like fertilizer, irrigation, and insecticides (Alam *et al.,* 2007a). But the area of cultivation of barley is gradually decreasing in Bangladesh (FAO, 1993-2002). In 2012 to 2013, the production of barley in Bangladesh was 7000 metric tons (USDA, 2013). Climate change has become a threat to lives and the earth's capacity to produce food. According to National Adaptation Programme of Action (NAPA) for Bangladesh, crop agriculture ranks highest in terms of physical vulnerability. The coastal area of Bangladesh contain more than 30% of country's cultivable land, of which 98% coastal area is covered through tidal floodplains.

The average crop yields are very low in the coastal belt area; resulting from high salinity, land erosion, low soil fertility and drought in the dry season. The Barley cultivation is possible in certain location of Bangladesh e.g. Bagerhat, Khulna, Barishal, Pirojpur, Gopalganj, Faridpur etc. Barley is a stress tolerant and saline adaptive crop suitable for coastal area. Local farmer said that the cultivation time of barley is early November in winter season, free from salinity intrusion. Soil can be protected from dusting and exposing to sunlight through barley production. It does not require much irrigation to yield. If a proper water supply is ensured for irrigation next to storage from monsoon rainfall in existing canals and on-farm reservoirs. Barley has good prospects for coastal area and it also provides economic improvement and sustainability to the local people. Major causes of less cultivation in Bangladesh are lack of high yielding and hull-less varieties. However, barley cultivation can be popularized among growers, if the crop could be made suitable for cultivation in the areas where it grows well and rice, wheat and maize cannot be grown profitably for the stress environment (Alam *et al.,* 2007b). In Bangladesh, more than 30% of the net cultivable land is in the coastal area. Of the 2.85 million ha of coastal and off-shore areas, about 1.0 million ha of arable land are affected by varying degrees of soil salinity (Karim *et al.,* 1990). Many barley species have adapted to extreme environments and many have tolerance to cold and saline conditions (Von Bothmer, 1992). The soils are at present mono-cropped with rice in kotalipara upazila. About 6-8 months most of the lands remain under water and water is little saline in kotalipara upazila. Cropping intensity and production levels are much lower in this region than the other parts of the country (BBS, 2001). Under these circumstances the present research work was taken to evaluate the yield

potential of five BARI Barley varieties in this region. The yield of different variety varied significantly due to different Agro-Ecological Zones (AEZs). The productivity and quality of barley can be improved by detecting the proper variety for proper region. For this reason, five important barley varieties were selected for the experiment to find out the best variety for the Gopalganj district of Bangladesh. Hence, the specific objectives of the present study were-To estimate and compare the yield performance of important barley varieties in this region (AEZ-14), to find out the best adaptive barley variety for this region (AEZ-14) and to extend the barley cultivation at local area.

MATERIALS AND METHODS

The field study was conducted at Rural Development Academy (RDA), Kotalipara, Gopalgonj during 01 November, 2023 to 28 March, 2024. The location of the site is between21°51´and 23°10´ north latitude and between 89°56´ and 90°10´ east longitude.

This area is under the Agro Ecological Zone (AEZ)-14. The topography of the farm area is medium high land and the soil type is sandy loam. The temperature ranges from 12.1 °C to 36.1 °C. Heavy rainfall occurs during rainy season.

Five improved food barley variety viz. BARI Barley-5, BARI Barley-6, BARI Barley-7, BARI Barley-8 and BARI Barley-9 were included used for the study. Seed was collected from Bangladesh Agriculture Research Institute (BARI), Joydebpur, Gazipur, Bangladesh. The four cross ploughing was done by a rotary plough by four times and raised plot was prepared.

The seed was sown during 20 November, 2023. Seed was sown in broadcasting method and seed rate was 120 kg/ha. Before sowing the plot was prepared by cleaning the wastage from the field. Total 20 plots were prepared. The size of the plot was (6.5m×8m) and about 50 cm drain was kept between two plots. The trail was laid out on Randomized Completely Block Design (RCBD) with 4 replications of five important varieties.

Varieties were-

V_1= BARI Barley-5

V_2= BARI Barley-6

V_3= BARI Barley-7

V_4= BARI Barley-8

V_5= BARI Barley-9

Fertilizer was used as the recommendation of Krishi Projukti Hatboi (2019). Urea 180 kg/ha, Triple Super Phosphate (TSP) 125 kg/ha, Muriate of Potash (MoP) 120 kg/ha, Zypsum 60 kg/ha, Zinc Sulphate 5 kg/ha will be the fertilizer dose. All fertilizers and ½ of Urea were applied as a basal dose during land preparation. Rest of Urea was splited in two parts. One was applied after 30 days of seed sowing and another was applied after 60 days of seed sowing. Thinning and weeding were done to maintain the optimum population. Irrigation is very much important for barley cultivation. Irrigation was performed properly during tillering, booting heading and the early stage of growth. The crop was attacked by fungal disease which was controlled by spraying proper fungicide. Harvesting of the crop was done at appropriate time.

Data collection was a very important for a research work. In case of the present study data was recorded on the following parameters: Plant height (cm) during harvesting, Crop duration, Total number of tillers per plant, Effective tillers per plant, Spike length (cm), Number of spikelet of spike, Seeds per spike, Thousand Seed weight (gm), Grain yield (t/ha), Straw yield (t/ha), Biological yield (t/ha), Harvest index (%). All data was taken carefully at proper time. Data was collected from the experimental plot and data was analyzed by using STAR (Statistical Tool for Agricultural Research) software. The mean values for all the parameters were calculated and the analysis of variance was performed. The significance of the difference among the treatment means was estimated by the at 5 % levels of probability.

RESULT AND DISCUSSION

Plant height during harvesting (cm)

Plant height during harvesting was varied 100cm to 69.45cm (Table 1). Maximum plant height during harvesting was recorded with V_1 (100.00cm).

The minimum plant height during harvesting was recorded in V_3 (69.45cm) which was statistically similar with V_4 (72.55cm). As a result, the BARI Barley-5 gave the maximum plant height during harvesting and the BARI Barley-7 gave the lowest plant height during harvesting. Azad *et al.* (2019) observed that, the plant height of BARI Barley-5, BARI Barley-6, BARI Barley-7, BARI Barley-8 and BARI Barley-9 were 90-100cm, 85-90cm, 50-65cm, 73cm and 100cm respectively.

Table 1. Plant height during harvesting (cm), Total number of tillers per plant, Effective tillers per plant, Spike length (cm), Number of spikelet of spike, Seeds per spike.

Variety	Plant height (cm) during harvesting	Total number of tillers per plant	Effective tillers per plant	Spike length (cm)	Number of spikelet of spike	Seeds per spike
BARI Barley-5 (V_1)	100.00a	3.91	2.85	10.90	60.45a	48.05a
BARI Barley-6 (V_2)	79.97c	3.82	2.70	10.00	54.45b	42.90b
BARI Barley-7 (V_3)	69.45d	3.65	2.95	9.47	51.90b	35.50c
BARI Barley-8 (V_4)	72.55cd	3.97	2.85	9.75	53.15b	41.40b
BARI Barley-9 (V_5)	90.55b	3.99	2.90	9.12	46.65c	35.75c
CV (%)	6.66	16.91	16.64	7.88	6.23	5.34
F-test	*	NS	NS	NS	*	*

In a column, figure with same letter do not differ significantly; *Significant at 5% level of significance;
NS= Non Significant
Source: Data was collected from the experimental plot and data was analyzed by using STAR (Statistical Tool for Agricultural Research) software.

Total number of tillers per plant

Total number of tillers per plant was varied 3.99 to 3.65 (Table 1). Maximum number of tillers per plant was recorded with V_5 (3.99) and the minimum number of tillers per plant was recorded with V_3 (3.65) which was statistically similar with V_1 (3.91), V_2 (3.82) and V_4 (2.85). As a result, the BARI Barley-9 gave the maximum total number of tillers per plant and BARI Barley-7 gave the minimum total number of tillers per plant but there was no significant different among the varieties at 5% level of significance.

Effective tillers per plant

The number of effective tillers per plant was varied from 2.95 to 2.70 (Table 1). The maximum effective tillers per plant was recorded with V_3 (2.95) and the minimum number of effective tillers per plant was recorded with V_2 (2.70) which was statistically similar with V_1 (2.85), V_4 (2.85) and V_5 (2.90). As a result, the BARI Barley-7 gave the maximum total number of effective tillers per plant and BARI Barley-6 gave the minimum total number of effective tillers per plant but there was no significant different among the varieties at 5% level of significance. About 3.0 effective tillers per plant were observed by Azad *et. al.* (2019) in BARI Barley-9.

Spike length

Spike length was investigated from 10.90cm to 9.12cm (Table 1). The Maximum spike length was found in V_1 (10.90cm) and the minimum spike length was found in V_5 (9.12cm) which was statistically similar with V_2 (10.00cm), V_3 (9.47cm) and V_4 (9.75cm). As a result, the BARI Barley-5 gave the maximum spike length and BARI Barley-9 gave the

minimum spike length, although there was no significant difference was found among the varieties at 5% level of significance. According to Azad *et. al.* (2019), the spike length of BARI Barley-5 and BARI Barley-9 were 10-12cm and 8.9cm respectively. Yesmin *et. al.* (2014) found that the spike length of barley was about 11.8 cm.

Number of spikelet of spike

The number of spikelet of spike was varied from 60.45 to 46.65 (Table 1). The maximum number of spikelet of spike was recorded with V_1 (60.45) and the minimum number of spikelet of spike was recorded in V_5 (46.65). The V_2 (54.45), V_3 (51.90) and V_4 (53.15) were statistically identical in case of number of spikelet of spike. As a result, the BARI Barley-5 gave the highest number of spikelet of spike and the BARI Barley-9 gave the lowest number of spikelet of spike. Yesmin *et. al.* (2014) found that the spikelets of spike were 62.24 that support our findings.

Number of seeds per spike

The number of seeds per spike was varied from 48.05 to 35.50 (Table 1). The maximum number of seeds per spike was recorded with V_1 (48.05). The minimum number of seeds per spike was recorded in V_3 (35.50) which were statistically similar with V_5 (35.75). The V_2 (42.90) and the V_4 (41.40) were statistically identical in case of number of seeds per spike. As a result, the BARI Barley-5 gave the highest number of seeds per spike and the BARI Barley-7 gave the lowest number of seeds per spike. Azad *et. al.* (2019) observed that, the number of seeds per spike was BARI Barley-5, BARI Barley-6, BARI Barley-7, BARI Barley-8 and BARI Barley-9 were 60-65, 48-65, 38-48, 58 and 38 respectively.

Table 2. Thousand Seed weight (gm), Grain yield (t/ha), Crop duration, Straw yield (t/ha), Biological yield (t/ha), Harvest index (%).

Variety	Thousand Seed weight (gm)	Crop duration (days after sowing)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (ton/ha)	Harvest index (%)
BARI Barley-5 (V_1)	31.74a	94.25c	2.72a	4.61a	7.33a	37.12ab
BARI Barley-6 (V_2)	31.47ab	98.25a	2.28ab	4.78a	7.06a	32.30b
BARI Barley-7 (V_3)	30.63ab	97.75a	2.01b	3.04c	5.05c	39.81a
BARI Barley-8 (V_4)	29.06c	95.75bc	2.14b	3.07c	5.21c	41.07a
BARI Barley-9 (V_5)	30.16bc	96.75ab	1.96c	4.10b	6.06b	32.34b
CV (%)	2.54	1.32	5.96	11.67	29.25	8.71
F-test	*	*	*	*	*	*

In a column, figure with same letter do not differ significantly; *Significant at 5% level of significance;
NS= Non-Significant. Source: Data was collected from the experimental plot and data was analyzed by using STAR (Statistical Tool for Agricultural Research) software.

Thousand seed weight (gm)

The thousand seed weight was varied from 31.74gm to 29.06gm (Table 2). The maximum thousand seed weight was recorded with V_1 (31.74 gm). The minimum thousand seed weight was found in V_4 (29.06gm) which was statistically similar with V_5 (30.16gm). The V_2 (31.47gm), V_3 (30.63gm) and V_5 (30.16gm) were also statistically identical in case of thousand seed weight. As a result, the BARI Barley-5 gave the highest thousand seed weight and the BARI Barley-9 gave the lowest thousand seed weight.

According to Azad *et. al.* (2019), the thousand seed weight of BARI Barley-5, BARI Barley-6, BARI Barley-7, BARI Barley-8 and BARI Barley-9 was 36-38gm, 35-38gm, 30-40gm, 34-38gm and 36gm respectively.

Crop duration (days)

The duration of crop was varied from 94.25 days to 98.25 days (Table 2). The maximum crop duration was recorded with V_2 (98.25 days) which was statistically identical with V_3 (97.75 days) and V_5 (96.75 days). The minimum crop duration was recorded in V_1 (94.25 days) which was statistically similar with V_4 (95.75 days). As a result, the BARI Barley-5 and the BARI Barley-8 was comparatively short duration crop than other varieties. The crop duration of BARI Barley-6, BARI Barley-7 and BARI Barley-8 were 98-102 days, 95-105 days and 95 days respectively was observed by Azad *et.al.* (2019).

Grain yield (t/ha)

Yield is an important factor in case of crop cultivation. The grain yield was varied from 2.72 t/ha to 1.96 t/ha (Table 2). The maximum grain yield was recorded with V_1 (2.72 t/ha) which was statistically similar with V_2 (2.28 t/ha) but statistically dissimilar with the others varieties. The minimum grain yield was found in V_5 (1.96 t/ha). The V_3 (2.01 t/ha) and V_4 (2.14 t/ha) were also statistically identical in case of grain yield. As a result, it can be decided that the BARI Barley-5 was the best variety in terms of grain yield. Azad *et. al.* (2019) reported that, the average grain yield of BARI Barley-5, BARI Barley-6, BARI Barley-7, BARI Barley-8 and BARI Barley-9 were 2.5-3.0 t/ha, 2.5-2.75 t/ha, 2.0-2.50 t/ha, 2.20-2.51 t/ha and 2.2 t/ha respectively. Yesmin *et. al.* (2014) reported that the grain yield of barley was about 2.22 t/ha.

Straw yield (t/ha)

The straw yield was varied from 4.78 t/ha to 3.04 t/ha (Table 2). The maximum straw yield was recorded with V_2 (4.78 t/ha) which was statistically similar with V_1 (4.61 t/ha). The minimum straw yield was found in V_3 (3.04 t/ha) which was statistically identical with V_4 (3.07 t/ha). As a result, the BARI Barley-6 produced more straw yield and BARI Barley-7 produced lowest straw yield.

Biological yield (t/ha)

Biological yield is the total biomass production. It comprises with grain yield and straw yield. The biological yield was varied from 5.05 t/ha to 7.33 t/ha (Table 2). The maximum biological yield was recorded with V_1 (7.33 t/ha) which was statistically similar with V_2 (7.06 t/ha). The minimum biological yield was found in V_3 (5.05 t/ha) was statistically identical with V_4 (5.21 t/ha). This result was similar with the findings of Yesmin et.al. (2014). As a result, it can be said that the BARI Barley-5 produced the maximum biomass and the biomass is important for animal feed and bedding materials.

Harvest index (%)

Harvest index is the ratio of economic yield and biological yield. The harvest index was varied from 41.07% to 32.30% (Table 2). The maximum harvest index was recorded with V_4 (41.07%) which was statistically similar with V_3 (39.81%) and V_1 (37.12%) but statistically dissimilar with the others varieties. The minimum harvest index was found in V_2 (32.30%) which was statistically identical with V_5 (32.34%). So, the BARI Barley-8 gave more harvest index and the BARI Barley-6 gave lowest harvest index.

CONCLUSION

The result of the present investigation emphasized significant variations in the agronomic traits of the five barley varieties tested under the Agro-Ecological Zone (AEZ-14) of Gopalganj district. Within the varieties, BARI Barley-5 flowed as the best cultivar for most of the measured traits. It recorded the maximum plant height (100.00cm), spike length (10.90cm), number of spikelet of spike (60.45), seeds per spike (48.05) and thousand seed weight (31.4gm) in BARI Barley-5 demonstrating its robust growth and productive potential. The highest plant height and spike length of BARI Barley-5 make it a promising variety for maximizing yield potential in

this area. On the other hand it is very important that BARI Barley-5 variety demonstrated relatively short crop duration (94.25 days) which could offer benefits for farmers looking for a quicker turn around crop, allowing for a shorter cropping cycle and better integration into diverse cropping system. However, in terms of total number of tillers per plant, effective tillers per plant and spike length point out that these factors may not be primary determinants of the performance for this specific area. BARI Barley-5 also performed that the highest grain yield (2.72 t/ha) and biological yield (7.33 t/ha).

This point marks BARI Barley-5 an excellent choice for farmers in AEZ-14 as it offers both high grain production and substantial biomass, which can be valuable for both food security and additional uses such as fodder on soil improvement. As a result BARI Barley-5 is recommended as the most suitable variety for cultivation in the Gopalganj district under the prevailing agro-ecological conditions. Its superior yield and biomass production refers to an ideal choice for enhancing food production and farmers income. The extension of this variety for local farmers should be accompanied by adequate training and support to ensure optimum cultivation practices and maximum benefit from the crop. Therefore, this high yielding variety is recommended for production in the tested environment of southern area of Bangladesh.

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