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Performance of New Wheat Yield in Bangladesh's Three Hill Districts (Bandarban, Rangamati, and Khagrachari)

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ABSTRACT

An experiment was completed to examine the performance of high yield and heat tolerant wheat types under rising temperatures in hill districts of Bandarban, Rangamati Khagrachari (South Asia). During the Rabi season (November to March each year), the trial was done at 3 hill regions (districts) in Farmer's field, Bangladesh throughout two crop seasons (2020-21 and 2021-22) at various locations in one upazilla in each of the 3 (three) hill region (districts). We use freshly announced high yield wheat varieties for optimal sowing and heat tolerance as an adaptation strategy in hills suffering from terminal heat stress. BARI Gom 30, BARI Gom 32, BARI Gom 33, WMRI Gom 01, and WMRI Gom 02 were the five high yielding heat tolerant wheat types. BARI Gom 33 (3.16 t/ha) has produced the highest crop output, followed by BARI Gom 30 (3.09 t/ha). WMRI Gom 02 (3.00 t/ha), BARI Gom 32 (2.97 t/ha) and lowest performance was WMRI Gom 01(2.87 t/ha) in last years. The difference in wheat crop output and biological yield was considerable, but the rest of the characteristics were unimportant. BARI Gom 33 was the yielded and adapted variety of the greatest likened to the others. WMRI Gom 01 had an insignificant benefit cost ratio (BCR) of 1.06, whereas BARI Gom 33 had the maximum BCR of 1.22 in alliance with five types tested, BARI Gom 33 was the high yielding and most adaptable.

Keywords: Wheat Performance, and Hill Districts (Khagrachari, Rangamati, Bandarban), in Bangladesh.

INTRODUCTION:

Wheat (*Triticum aestivum* L.) contributes for 25% of global grain production and is one of the greatest momentous sources of carbs, proteins, fibers, and vitamins, contributing for 20% of daily calories and 25% of protein consumption globally (FAO FAOSTAT, 2019). During the growing season, wheat is only the crops that is most affected by rising average temperatures (Semenov and colleagues, 2011; Teixeira *et al*., 2013). Wheat is only Bangladesh's most significant second cereal crops, with direct economic and food security implications. Wheat types with a high grain yield, acceptable nutrient and processing quality, and thermal tolerance to biotic and abiotic stress are desirable (Mondal *et al.,* 2016). End-of-life temperature oppression is final for food security. Bandarban, Rangamati, and Khagrachari are mountainous and coastal areas with temperatures that are consistently 1 to 5^{0}C higher than the rest of the places. Hilly higher minimum average temperatures may have reduced grain yield, causing early heading, maturity, and plant height (Ali *et al*, 2021). Hill Bangladesh's districts are currently attempting to establish themselves as a minor wheat growing and consuming region. The Hill Tracts make up around a tenth of the country and are made up of 75% upland (hill), 20% undulating bumpy land, and 5% valley plain area (Rahman *et al.*, 2015). Due to a lack of spatter water essential for boro rice farming, a vast undulating rough plain and valleys lie fallow during the winter. Wheat requires less than one-fourth the extent of water than rice does, so maxi-mum of the available water provision in those places can be applied to grow wheat. The hill regions' physical and environmental circumstances differ from those of the country's traditional wheat-growing regions.

Three hilly districts on Bangladesh's west coast, where the crop growing season is short and high temperatures (over 30^{0}°C) occur late in the advanced corn intromission filling stage. Throughout the crop season, the hilly areas of Bangladesh are warmer, with maximum temperatures ranging from 25 to 30^{0} degrees Celsius during corn repletion filling. In locations where high temperatures are persistent, early maturity to prevent high temperature stress has been suggested as a viable crop adaptation method (Joshi *et al*., 2007; Mondal and colleagues, 2013). According to several studies, wheat yield performance differed depending on soil type (Rahman *et al.,* 2013, Tang *et al*., 2003), air temperatures (Rahman *et al*., 2005), and management circumstances (Rahman *et al.,* 2005; Rahman *et al.,* 2002; Timsina and Cornor, 2001). At the hill region, there may be varietal differences in response to changes in height and environment. Wheat cultivars that provide higher yields at higher elevations, such as Bandarban, Rangamati, and Khagrachari, could be deemed adaptable in hilly region. Recently created wheat varieties have showed good tolerance to a wide range of climates and hilly terrain (WRC, BARI, 2007).

Around 24% of the world's population requires urgent assitance in increasing wheat production and guaranteeing food security. For this, lbidem there is a great desire in Bandarban, Rangamati, and Khagrachari to prioritize the creation of innovative wheat varieties that are high yielding and adaptable. The goal of this research was to assess the accomplishment of newly released varieties under a difference of stress circumstances for identify specific varieties for optimum conditions and high yield.

MATERIALS AND METHODS:

Experiment Location and Weather Condition

During the rabi season an experiment was undertaken in 3 (three) hill District farmers field of Ali Kadam upazilla under Bandarban, the Rajasthali upazilla under Rangamati, and Maniksari upazilla under Khagrachari the in the years 2020-21, 2021-22. Bandarban (latitude 22.20"N, longitude 92.22"E) Rangamati (latitude 22.66"N longitude 92.18"E) Khagrachari (latitude 23.14"N, longitude 91.95"E) (November 30 to March 5th 2020-2021 and November 30 March 5th 2021-2022). In the hilly area, all meteorological data was gathered from the local District weather observation center. The data includes the monthly mean maximum, lowest air heat and inpouring. The studies took place over a two-year period in Bangladesh's less important wheat-producing areas of, Bandarban, Rangamati, and Khagrachari. In the last week of November, the seeds will be buried. Local factors dictate the shape of the plot and how it is handled. Due to natural temperature stress, (15-35^{0}c) this variety faces uphill temperature stress during the wheat growth season. Average monthly meteorological data from sowing to harvest are given in the hilly region of Bangladesh (**Table 1**). The average temperature trend has been perfectly constant over the final two years. The coldest month in the crop seasons of 2021 and 2022 was January, with a gradual increase until April. Temperatures were warmer on average in March. The coolest months for wheat growing and grain filling were December, January, and February. Maximum and minimum temperatures were available for the years 2020, 2021, and March 2022. This location's typical maximum temperature was 3-10^{0}C higher than comparable wheat-growing areas around the country, from November 30 to March 5 in 2020-2021 and November 30 to March 5 in 2021-2022. The humidity ranged from 60% to 87% out the specified time periods. In Khagrachari, we determined that the mean heat ranged from 16 to 26^{0}. Precipitation in the exam region was approximately nil in January, November 2020, whilst it was around 10mm in March, April 2021. In November and December 2021, rainfall averaged 8mm over two days during the rabi season. In the research region of Rangamati, precipitation was roughly 5mm in 4 days in the moon of December 2020, March, and April 2021. 7mm in 4 days in November, December, and April 2022. Rangamati's coldest month was December 2021. It was merely wet in Bandarban in December 2020. Other second season November 2021 and April 2022 was only 5mm rains in 2days. December 2021 and January 2022 was the lowest (15^0c) but no rains.

Table 1: Weather Condition of Bangladeshi Hills during Rabi Season (Nov-April) in 2020-21 and 2021-22.

Weather Information in 3 (three) Hill District (Monthly Average) Khagrachari, Rangamati, Bandarban											
Khagrachari District (2020-21)				**Rangamati District (2020-21)**				**Bandarban District (2020-21)**			
Month	High Tem	Low Tem	Rains (mm)	Month	High Tem	Low Tem	Rains (mm)	Month	High Tem	Low Tem	Rains (mm)
Nov 2020	26^0c	16^0c	0	Nov 2020	22^0c	15^0c	0	Nov 2020	23^0c	16^0c	1
Dec 2020	26^0c	14^0c	0	Dec 2020	22^0c	14^0c	1	Dec 2020	22^0c	15^0c	0
Jan 2021	27^0c	15^0c	0	Jan 2021	21^0c	15^0c	0	Jan 2021	21^0c	15^0c	0
Feb 2021	31^0c	17^0c	1	Feb 2021	24^0c	17^0c	0	Feb 2021	25^0c	19^0c	2
Mar 2021	34^0c	21^0c	2	Mar 2021	34^0c	21^0c	1	Mar 2021	32^0c	24^0c	2
Apr 2021	35^0c	25^0c	7	Apr 2021	35^0c	22^0c	2	Apr 2021	35^0c	27^0c	0

Weather Information in 3 (three) Hill District (Monthly Average) Khagrachari, Rangamati, Bandarban											
Khagrachari District (2021-22)				**Rangamati District (2021-22)**				**Bandarban District (2021-22)**			
Month	High Tem	Low Tem	Rains (mm)	Month	High Tem	Low Tem	Rains (mm)	Month	High Tem	Low Tem	Rains (mm)
Nov 2021	29^0C	20^0C	1	Nov 2021	21^0c	15^0c	1	Nov 2021	22^0c	15^0c	1
Dec 2021	27^0C	17^0C	1	Dec 2021	22^0c	14^0c	1	Dec 2021	21^0c	14^0c	0
Jan 2022	23^0C	15^0C	0	Jan 2022	27^0c	15^0c	0	Jan 2022	27^0c	15^0c	0
Feb 2022	19^0C	12^0C	1	Feb 2022	39^0c	13^0c	0	Feb 2022	29^0c	13^0c	0
Mar 2022	27^0C	20^0C	2	Mar 2022	34^0c	21^0c	0	Mar 2022	34^0c	21^0c	2
Apr 2022	29^0C	21^0C	0	Apr 2022	35^0c	22^0c	4	Apr 2022	35^0c	22^0c	2

Experiment Soil Types

The soils in the study field were strongly acidic (p^H 4.8-5.1), with higher levels of Fe, Al, and Mn in the surface soil (0-15 cm depth), as well as a deficiency in several essential plant nutrients such as nitrogen (Total N = 0.08-0.09%), phosphorus (Olsen P = 5.5-6.5 ppm), and potassium (K = 0.17-0.21 meq/100g). The ground was high in sulfur and zinc, but the amount of accessible boron was minimal. **Table 2** shows the physical and chemical data of the ground prior to conducting the experiment. (Data gathered from local SRDA offices in three Bangladeshi hill districts).

Table 2: Physical and chemical data of the first soil achieve from the player are listed in (0-15 cm).

Districts	Particle Density (g cm-3)	Bulk Density (g cm-3)	Porosity (%)	Soil Moisture of Field Capacity	Soil Moisture of Sowing (%)	Textural Class
Khagrachari	2.42	1.48	42.75	28.15	21.04	Clay Loan
Rangamati	2.40	1.46	42.71	28.11	21.08	Clay Loan
Bandarban	2.39	1.47	42.73	28.08	21.02	Clay Loan

Table 3: Chemical substance of initial soil collected from surface layer (0-15 cm).

Chemical Properties	p^H	OM	Total N (%)	P	S	B	Zn	Cu	Fe	Mn	K	Ca	Mg
				µg g-1					Mean 100g[1]				
2020-21 (Khagrachari)	4.8	1.12	0.09	5.1	36	0.18	3.8	3.1	104	16	0.17	4.7	2.1
2021-22 (Khagrachari)	5.1	0.98	0.08	6.5	41	0.6	4.1	3.1	97	16	0.21	5.1	2.0
Critical				7	14	0.20	2.0	1.0	10	5	0.20	2.0	0.8
2020-21 (Rangamati)	4.7	1.9	0.9	5.0	35	0.17	3.2	3.1	101	15	0.17	4.9	2.2
2021-22 (Rangamati)	5.2	0.97	0.8	6.3	39	0.7	4.12	3.0	97	15	0.22	5.12	0.7

Critical				7	14	0.20	2.0	1.0	10	5	0.20	2.0	0.8
2020-21 (Bandarban)	4.6	1.8	0.8	4.98	34	0.12	3.0	3.2	100	16	0.18	4.81	2.0
2021-22 (Bandarban)	5.3	0.98	0.7	6.0	38	0.5	4.11	3.1	99	16	0.23	5.16	2.0
Critical				7	14	0.20	2.0	1.0	10	5	0.20	2.0	0.8

Experiment Design

During the 2020-21 and 2021-22 Rabi seasons, researchers used a randomized complete block design (RCBD) with five treatments and three replications to perform their study. Plant to plant spacing in the main field is 1 inch, and line to line spacing is 20cm. The main plot is 5m x 4m in size. All genotype lines provided stable corn output under watered regular planted conditions (Hill environmental stress). This study includes five recently released exalted growth and heat stress tolerant wheat cultivars.

Treatments	Details
T_1	BARI Gom 30
T_2	BARI Gom 32
T_3	BARI Gom 33
T_4	WMRI Gom 01
T_5	WMRI Gom 02

MATERIALS AND METHODS:

Experiment Procedures

In three mountainous environments in Bangladesh, high yielding heat tolerant wheat varieties were tasted. Locations, planting and harvest dates, and plots are all caught into calculated. Management practices were founded on national yield trial procedures that were followed at each individual plot. In Bangladesh, wheat is typically planted in November/1st week December and harvested in March/early April. The ones that is most relevant to the grounds that have been investigated. Optimum is a productive, irrigated environment in which wheat grows at a regular temperature. The five cultivated were completed for prepare the ground. For final land preparation in primary years, add 4kg/ decimal lime to the soil before 7 days. Manure and fertilizers' were applied prior to land cultivation at the recommended dose of 230 kg/ha Urea, 150 kg/ha TSP, 120 kg/ha MoP, 130 kg/ha Sulphur, 10 kg/ha Zink, and 8 kg/ha Boron. Before the area was cultivated, the others chemical fertilizer was combined and dispersed on the land 120kg/ha seed rate on November 30, 2020, and the one date in 2022, seed was planted. By the crop plants season, three irrigations were provided at the (CRI stage) crown root initiation, tillering, and corn filling stages. Two-thirds urea and the whole amount of all fertilizers were treated as a basal, and one-third urea was applied as a top dress at the CRI (crown root initiation) stage. In the research field and laboratory, however, the center five rows were harvested (1m^2) for growth and output contributing features were filed from five plants from each plot. Weeding, mulching, and plant thinning management were done as demanded in the soil p^h inter-cultural operations. The crop season's data was recorded. on the crop, participants gave data on plant population (PP), heading days (HD), anthesis (AN), plant height (HD), Spike/ m^2, spike let/spike, days to maturity (MD), 1000 grain weight, grain yield (GY), and biological yields (BY). The amount of days from the date of sowing/first irrigation until 50% of the flag leaf spikes had formed was applied condition HD. The appearance of MD in the peduncles of 52% of the spikes indicated senescence. Plots were collected at maturity on March 5th to deter-mine GY. For appraisement of the least significant difference (LSD) at a 5% level of importance, all parameters were examined using statistic-10 software. We evaluated a great figure of all data in three hill locations.

RESULTS AND DISCUSSION:

Plant populations

Environment has different effects on plant outgrowth and improvement depending on the plant species. In a growing climate change scenario, air temperatures above the optimum range for many species are more likely to exceed the optimum range. (Prasad *et al.,* 2001) found the same thing (Prasad *et al.,* 2002). Few plants died in the study field after 10 to 14 days for sluggish climatic conditions. BARI Gom 33 has not discovered any dead plants in the plats in this condition. The high number of plant population was 189 in the treatment t_3 BARI Gom 33 in 2020-21 years and 179 in 2021-22 years, among Bandarban conforming to the study (**Table 4, 5** and **6**). The treatment t_1 BARI Gom 30 had the second highest quantity of plant population (143) in 2020-21 and (150) in 2021-22 in Khagrachari. Treatment t_4WMRI Gom 01 (130) had the abominable quantity in 2020-21 and (115) in 2021-22 in Khagrachari. In two years, BARI Gom 32 (136) and (128) were discovered. WMRI Gom 02 was in 139 and 146 in Khagrachari. No meaningful distinction in plant population was audited among different hill location. Plants have several mechanisms for adapting to heat stress. The 3 (three) leading strategies that allow plants to live and thrive in high-temperature environments are avoidance, escape, and tolerance. Heat tolerance is described as a plant's ability to survive, grow, and generate an economic crop under temperature impact position (Ali *et al*, 2022; Padam *et al.,* 2020)

Table 4: Yield and Yield Subscription Parameters of Bandarban (Ali Kadam) During 2020-21 and 2021-22.

Treatment	2020-21 Plant population	2021-22 Plant population	2020-21 Heading (days)	2021-22 Heading (days)	2020-21 Anthesis (days)	2021-22 Anthesis (days)	2020-21 Plant Height (cm)	2021-22 Plant height (cm)	2020-21 Spike/ m^2	2021-22 Spike/ m^2
T_1 BARI Gom 30	143	134	56	56	61	61	95	94	179	169
T_2 BARI Gom 32	136	132	56	55	61	60	95	94	171	160
T_3 BARI Gom 33	189	179	57	56	62	61	97	97	191	186
T_4 WMRI Gom 01	130	126	55	55	60	60	94	94	148	145
T_5 WMRI Gom 02	139	134	56	56	61	60	95	94	150	147
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV	1.87	2.58	1.40	1.70	1.12	1.41	0.54	0.74	1.99	2.87

Continued Table 4: Yield and Yield Subscription Parameters of Bandarban (Ali Kadam) During 2020-21 and 2021-22).

Treatment	2020-21 S Let/m^2	2021-22 S Let/m^2	2020-21 Days to Maturity	2021-22 Days to Maturity	2020-21 1000 gw (g)	2021-22 1000gw (g)	2020-21 Grain Yield(t/ha)	2021-22 Grain Yield(t/ha)	2020-21 Biological Yield (t/h)	2021-22 Biological Yield (t/h)
T_1 BARI Gom 30	14	13	89	88	42	41	3.09	3.03	7.98	7.99
T_2 BARI Gom 32	14	12	87	86	41	40	2.95	2.97	7.78	7.96
T_3 BARI Gom 33	16	16	92	91	48	47	3.16	3.14	8.45	8.37
T_4 WMRI Gom 01	13	12	82	80	40	39	2.70	2.87	7.69	7.79
T_5 WMRI Gom 02	13	12	86	82	41	40	2.98	3.00	7.89	7.97
LSD (0.05)	NS	NS	NS	NS	NS	NS	*	*	*	*
CV	3.04	3.53	5.01	4.66	1.84	1.89	0.05	0.04	0.05	0.05

Table 5: Yield and Yield Contributing Parameters of Rangamati (Rajasthali) During 2020-21 and 2021-22.

Treatment	2020-21 Plant population	2021-22 Plant population	2020-21 Heading (days)	2021-22 Heading (days)	2020-21 Anthesis (days)	2021-22 Anthesis (days)	2020-21 Plant Height (cm)	2021-22 Plant height (cm)	2020-21 Spike/m^2	2021-22 Spike/m^2
T_1 BARI Gom 30	143	133	56	56	61	60	95	95	179	163
T_2 BARI Gom 32	136	128	56	55	61	61	95	95	171	151
T_3 BARI Gom 33	189	172	57	57	62	62	97	97	191	181

T_4 WMRI Gom 01	130	124	55	55	60	60	94	94	148	138
T_5WMRI Gom 02	139	140	56	56	61	60	95	95	150	146
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV	1.87	3.06	1.40	0.87	1.12	0.92	0.54	0.52	1.99	2.88

Continued Table 5: Yield and Yield contributing Parameters of Rangamati (Rajasthali) During 2020-21 and 2021-22.

Treatment	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
	S Let/ m^2	S Let/ m^2	Days to Maturity	Days to Maturity	1000 gw (g)	1000gw (g)	Grain Yield (t/h)	Grain Yield (t/h)	Biological Yield (t/h)	Biological Yield(t/h)
T_1 BARI Gom 30	14	13	89	87	42	39	2.89	2.99	7.98	7.98
T_2 BARI Gom 32	14	12	87	86	41	35	2.70	2.90	7.78	7.91
T_3 BARI Gom 33	16	16	92	90	48	44	3.16	3.15	8.45	8.12
T_4WMRI Gom 01	13	12	82	81	40	35	2.10	2.85	7.09	7.90
T_5WMRI Gom 02	13	13	86	83	41	38	2.28	2.95	7.19	7.96
LSD (0.05)	NS	NS	NS	NS	NS	NS	*	*	*	*
CV	3.04	3.74	5.01	3.07	1.84	7.89	0.05	0.04	0.05	0.05

Table 6: Yield and Yield Contributing Parameters of Khagracha (Maniksari) During 2020-21 and 2021-22.

Treatment	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
	Plant population	Plant population	Heading (days)	Heading (days)	Anthesis (days)	Anthesis (days)	Plant Height (cm)	Plant height (cm)	Spike/ m^2	Spike/m^2
T_1 BARI Gom 30	143	150	56	54	61	61	95	94	179	180
T_2 BARI Gom 32	136	128	56	55	61	61	95	94	171	179
T_3 BARI Gom 33	189	178	57	56	62	62	97	97	191	186
T_4 WMRI Gom 01	130	115	55	55	60	61	94	94	148	154
T_5WMRI Gom 02	139	146	56	55	61	61	95	94	150	173
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV	1.87	2.14	1.40	2.85	1.12	1.22	0.54	0.55	1.99	5.02

Continued Table 6: Yield and Output Contributing Parameters of Khagrachari (Maniksari) During 2020-21 and 2021-22).

Treatment	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
	S Let/m^2	S Let/m^2	Days to Maturity	Days to Maturity	1000 gw (g)	1000 gw (g)	Grain Yield (t/h)	Grain Yield(t/h)	Biological Yield (t/h)	Biological Yield (t/h)
T_1 BARI Gom 30	14	14	89	88	42	41	2.89	2.43	7.98	8.12
T_2 BARI Gom 32	14	12	87	86	41	36	2.70	2.40	7.88	7.92

T_3 BARI Gom 33	16	15	92	91	48	45	3.16	2.91	8.15	8.28
T_4 WMRI Gom 01	13	12	82	80	40	35	2.50	2.34	7.72	7.79
T_5WMRI Gom 02	13	13	86	82	41	38	2.78	2.40	7.95	7.95
LSD (0.05)	NS	NS	NS	NS	NS	NS	*	*	*	*
CV	3.04	4.12	5.01	4.66	1.84	2.50	0.05	0.05	0.04	0.05

Days to heading

In general, temperatures in Bangladesh's highland districts are hot (22-35^{0}c) in the central of the day from February to April. Days till the emergence/heading of the ear peep are a developmental stage by what means the head, spike, or ear emerges from its enclosing sheath. Ear emergence or heading refers to the alteration from partial to full appearance (Acevedo *et al.,* 2002). According to Tewolde *et al.* (2006), earlier heading is serviceable under high temperature stress because over verdant leaves are preserved during anthesis, resulting in a lesser yield drop. High temperature also shortened the time of each developmental phase in wheat, to in conformity with Spink *et al.* (1993). BARI Gom 33 is a day or two later than the other kinds in the trial, regardless of location. After one day, BARI Gom has 30 variants in three areas.

They have some adaptive power in the hill, which they can use to their advantage. In 3(three) hill region (districts), WMRI Gom 01, BARI Gom 32, and WMRI Gom 02 are the same days (56 days) (**Table 4, 5** and **6**). To prevent terminal exalted heat stress (25-35°C), hilly environment-adapted cultivars had lengthy heading periods followed by short periods and high rates of grain filling, as executed in the field. In hilly stress circumstances, 'BAR Gom 33, BARI Gom 32, and WMRI Gom 02' outperformed the other cultivars.

Days to anthesis/flowering

Anthesis, or blossoming, is the key developmental stage when yellow anthers are clearly seen on spikes (Acevedo *et al.* 2002). High temperatures are most harmful when blooms are first seen, according to growth chamber and greenhouse research, and sensitivity lasts for 10-15 days (Foolad, 2005). In this study, BARI Gom 33 (62 days) took longer to attain anthesis in plots than the other kinds, but WMRI Gom 01 took less time (60 days). Due to temperature impact, all of the types had a shorter time to complete anthesis. BARI Gom 30, BARI Gom 32, WMRI Gom 02 takes same days (61 days) in 3 (three) hill region (districts) of Bangladesh. WMRI 01 required 17.03% less time (reduction 17.03%) to reach anthesis than BARI Gom 33 (reduction 10.35%). A study by Nahar *et al.* (2010) is compared, which used wheat cultivars.

Plants height

Under continuous heat growth conditions, plant height was severely lowered for all wheat genotypes, with varied degrees of reduction. Plant height fluctuated under terminal heat due to phenotypic and combination influences of growth circumstances. Heat stress may have delayed plant development and photosynthetic period in a sowing scenario, resulting in a reduction in plant height. Wheat genotypes differed substantially in their yielding on plant height (Mattas *et al.,* 2011; Mohammad *et al.,* 2011; Ford and Throne, 2001). Plant height differences induced by different genotypes may be linked to genotype genetic conditions. The plant height of BARI Gom 33 was (97 cm) in two years with all hill district which was satisfied. The lowest plants were Plant height of WMRI Gom 01 (94cm) in 3 (three) hill region (districts). BARI Gom 30, BARI Gom 32 and WMRI Gom 02 was (95 cm) in both years subsequently. The plants height of wheat varieties was not statistically significant by the hilly exalted heat in normal growing of all hill districts. Finding from experiment BARI Gom 33 was developed to the highest plants height in both seasons.

Spike/m^2

The highest spike/m^2 (191) was gotten in treatment T_3 of BARI Gom 33 in two years of the experiment in Bandarban, Khagrachari and Rangamati and (186) Bandarban, Khagrachari (181) in Rangamati in 2021-22. (Sections 04, 05, and 06 of the table) Therapy T_1 BARI Gom 30 (179) in all hill location, t_5 (150) in all hill locations, and t_2 (171) in 2020-21 and Ban (160), Kha (179), and (151) Ran in 2021-22. Treatment t_1

BARI Gom 30 (179) in 2020-21 with all regions and (169) Ban, (180) Kha and (163) Ran. t_5 (150) in 2020-21 with all hill location and (147) Ban, (169) Kha, (146) Ran) in 2021-2022 years treatment t_2 (171)all exam field in 2020-21 and (150) Ban, (179) Kha and (151) Ran) in 2021-22 In years treatment t_4 of WMRI Gom 01 had the insignificant spikes per m^2 (148) in 2020-21 with all location and (145) Ban, (154) Ran and (154) Kha in 2021-22. The study's findings suppose that the higher frequency of spikes is for exceptional adaptation in three hilly districts. We discovered that the cultivar BARI Gom 33 produces an excellent yield when subjected to hilly stress. Grain yield is heavily influenced by the amount of spikes/m^2. The amount of grains spiked/m^2 is disc ermined by the daytime of the spike, which is definite by one's genetic makeup. Environmental factors that existed at the time of the growth increment in the amount of grains. Genetic differences were most likely to blame for variances in the number of spikes per m^2 between cultivars and varietals (Islam, 1995). According to O'Toole and Stockle, (1991) vulnerability to high temperatures increases as vegetative development and tillering continue towards the end of the GSI (Emergence to double ridges) stage. High temperature sensitivity reveals itself during this phase as a retrenchment in GS1 length, as well as a retrenchment in leaf area and growth (Shpiler and Blum, 1986). High temperatures reduce the overall amount of leaves and spike-bearing tillers during this time (Midmore *et al.,* 1984).

Spike Let/Spike

The amount of spikelet’s/spike is an significant element in grain output. The extent of the spike and genetic make-up, for environmental elements present during the growth stage, all influence the amount of spikelet’s/spikes. The amount of spikelet’s/spikes has an influence on wheat grain output, and it varies depending on growing conditions. Maximum spikelet (16) was observed with the treatment t_3 BARI Gom 33 in both years, according to data in (**Table 4, 5** and **6**).

The treatment t_1 BARI Gom 30 (14) in two years with 3 hills. Ensured by the treatment t_2 BARI Gom 32 (14) in 2021-22 and (12) in 2021-22 years. These two genotypes may have a full time of good growth, development and a more favorable heat temperature than other genotypes, according to research (Ali *et al.,* 1882). The treatment t_4 WMRI Gom 01 (13) in 2020-21 year and (12) in 2021-22 year resulted in a lower number of spikelet’s/spikes in all varieties (**Table 4, 5** and **6**). It could be for the heat making it difficult for it to grow and develop. Both years of the experiment, the second spikelet (14) was discovered in treatment t_1, t_2. In the treatment t_5 WMRI Gom 02, the third spikelet’s/spike found was treatment t_5 (13) in 2020-21 and (12) in 2021-22. Distinction amount of spikelet’s/spikes between cultivars and varietals were most likely for genetic differences (Islam, 2004).

Days to Maturity

High temperature decreased the physiological swelling and output contribution in wheat cultivars. Physiological maturity needs maximum duration to complete her life. Physiological maturity always means the time periods when get yellow color of standard leaf and spike (Hanft and Wych, 1982). From the study we found highest physiological maturity of the cultivars was treatment t_3 BARI Gom 33 (92) in 2020-21 and (91) in 2021-22 years (**Table 4, 5** and **6**) pursued by the treatment t_1 BARI Gom 30 was (89) days in 2020-21 and (88) days in 2021-22 years. Third position was treatment t_2 BARI Gom 32 (87) days in 2020-21 and (86) days in 2021-2022 years. Fourth condition was the treatment t_5 WMRI Gom 02 (86) days and (82) days in 2021-22 years. The last physiological maturity was treatment t_4 WMRI Gom 01 (82) days and (80) days in double years of hill (**Table 4, 5** and **6**).

Stress shortens a crop's maturation period. In wheat, Asana and Williams, (1965) discovered that for 1^0 C raise in heat during the grain-filling phase, the daytime of grain-filling decreased by around 3-days, regardless of cultivar. According to (Owen, 1971) and (Saini and Aspinal, 1982), temperatures above 30°C during floret formation cause 70% sterility, which leads to fewer grains spike. The large wheat output could be to blame for the spikelet increase. Due to inherent differences between the cultivars, the days to physiological of wheat cultivars also revealed a large range (Shahzad *et al.,* 2007).

High temperatures expedite the development, shorten the length, and lower the life rhythm of cultivars from implantation to harvest, according to Fischer (1990).

1000 grain weight

In our current study we have found treatment t_3 BARI Gom 33 produce highest 1000 kernel weight (48g)in 2020-21with all location and (47g) Bandarban, (44g) Rangamati and (45g) Khagrachari in 2021-22 year. The lowest 1000 grain weight found the treatment t_4 WMRI Gom 01(40g) all location in 2020-21 and (39g) Bandarban (35g) Rangamati (35g) Khagrachari (**Table 4, 5** and **6**). First it may be favorable for BARI Gom 33 and other side unfavorable for WMRI Gom 01. BARI Gom 33 consumes high temperature particularly in kernel filling stage but other varieties was less? The last periods the head was extremely lofty at the kernel filling stage which finally alleviated yield and shorten of every improvement phage. Second highest 1000 kernel yield was BARI Gom 30 (42g) in two years with all location. (41g) Bandarban, (39g) Rangamati and (41g) Khagrachari in two years, follow by BARI Gom 32 (41g) all position in 2020-21 and (40) Bandarban, (35g) Rangamati, (36g) Khagrachari in double years. Fourth 1000 kernel yield was (41g) in 2020-21of all position and (40g) Bandarban, (38g) Rangamati and (38) Khagrachari in 2021-22 years. According to Sofied *et al.* (1977), a favorable temperature associated with a full corn filling duration resulted in exalted grain weight.

Due to exalted temperatures throughout the outgrowth stage, especially after grain filling, lower 1000 kernel weight was WMRI Gom 01(40g) and (35g) both years recorded in mountainous environments. The observations of Spink *et al.* (2000) and Shahzad *et al.* (2002), who also showed a drop in 1000 kernel weight with high temperature, back up this claim. Previously, comparable outcomes have been recorded (Qamar *et al.*, 2004; Subhan *et al.*, 2004).

Grain yield

Heat stress, alone or in combination with drought, was established to be a frequent restriction in many temperate cereal crops throughout the anthesis and grain-filling stages by Guilioni *et al.* (2003). For example, heat stress, shortened the time of kernel filling and slowed kernel growth, resulting in up to 7% weight and density losses in spring wheat kernels. Temperature impact had an important force on all five kinds in our study, resulting in a significant shortening in kernel production. The pace of decline, on another way, differed between genotypes. According to Hasan (2002), each 1°C increase in average mean air heat during anthesis to maturity compared to the normal growing condition reduces grain yield by 2.6 to 5.8% in heat-tolerant genotypes and 7.2% in heat-sensitive genotypes. Our hilly experiment among the varieties BARI Gom 33 (3.16t/ha Bandarban, Rangamati and Khagrachari in 2020-21 and 3.14t/ha Bandarban, 3.15 t/ha Rangamati and 2.91t/ha Khagrachari in 2021-22) gives the highest kernel yield (**Table 4, 5** and **6**). The second grain yield performance was BARI Gom 30 (3.09t/ha and 3.03 t/ha Bandarban, 2.89 t/ha and 2.99 t/ha Rangamati, 2.89t/ha and 2.43 t/ha Khagrachari) in 2020-21 and 2021-2022 season. Third kernel yield was WMRI Gom 02 (2.98t/ha and 3.00 t/ha Bandarban, 2.28 t/ha and 2.95 t/ha Rangamati, 2.78 t/ha and 2.40 t/ha Khagrachari) in 2020-21 and 2021-2022 season.

The lowest kernel yield was established in the experiment WMRI Gom 01 (2.70 t/ha and 2.87 t/ha Bandarban, 2.10 t/ha and 2.85 t/ha Rangamati, 2.50 t/ha and 2.34 t/ha Khagrachari) in 2020-21 and 2021-2022 season. Best performance of BARI Gom 33 in hilly region was yield and production. Followed by BARI Gom 30, WMRI Gom 02, BARI Gom 32 and WMRI Gom 01.When it came to phonological stage variation in connection to growth and yield, BARI Gom 33 was the best, followed by BARI Gom 30 and WMRI Gom 02, with the highest yield and dry matter output of all five kinds. In our study, changes in weather conditions (**Table 1**) were reflected in phenollogy, crop growth, development, eventually under optimum hill circumstances, which is common among different crops (Martiniello and Teixeira da Silva 2011; Hossain *et al.,* 2011; Hakim *et al.*, 2012; Hossain *et al.,* 2012a, 2012b). The same kinds yielded in a different order, according to Nahar *et al.* (2010).

Biological yield

Temperatures above 26.7°C lowered the season of grain progress and dry phenomenon buildup, according to Toru and Wardlaw, (1988). Different cultivars in hill had a substantial impact on straw yield, following to the statistics. When it comes to cultivars, the highest score was achieved by BARI Gom 33 (8.45t/ha and 8.37t/ha Bandarban, 8.45 t/ha and 8.12 t/ha Rangamati, 8.15 t/ha and 8.28 t/ha Khagrachari) in 2020-2021 and 2021-2022 years. Follow BARI Gom 30 (7.98 t/ha and

7.99 t/ha Bandarban, 7.98 t/ha and 7.98 t/ha Rangamati, 7.98 t/ha and 8.12 t/ha Khagrachari) in 2020-21 and 2021-2022 years. WMRI Gom 02 (7.89 t/ha and 7.97 t/ha Bandarban, 7.19 t/ha and 7.96 t/ha Rangamati, 7.95 t/ha and 7.95 t/ha Khagrachari) in 2020-21 and 2021-2022 years. The lowest biomass output was established WMRI Gom 01 (7.69 t/ha and 7.79 t/ha Bandarban, 7.09 t/ha and 7.90 t/ha Rangamati, 7.72 t/ha and 7.79 t/ha Khagrachari) in 2020-21 and 2021-2022 seasons. For hostile weather condition (high temperature) for physiological growth. On optimum sowing, WMRI Gom 01 had the lowest yield, pursued by BARI Gom 32 and WMRI Gom 02. It could be because to the exalted heat during the vegetative period (**Table 4, 5** and **6**). According to Kumer *et al.* (1994), straw yield declined as a end of an hostile condition (high heat) during the vegetative period; as a result, crops grew thin and produced fewer tillers, lowering straw yield. Because of his heat tolerance, BARI Gom 33 produces the most biomass. Heat-tolerant optimal planting, according to Donaldson *et al.* (2001), resulted in a higher straw produce due to the increased amount of tillers. These findings concur with those of Matuz and Aziz, (1991)

Economic Analysis

We evaluated the BCR (benefit cost ratio) by counting the average output of the last year (Bandarban, Rangamati and Khagrachari). t_1= 2.82 (3.03+2.99+2.43), treatment t_2 = 2.76 (2.97+2.90+2.40), treatment t_3 = 3.07 (3.14, 3.15, and 2.91) treatment t_4 = 2.70 (2.87+2.87+2.34) and t_5 = 2.78 (3.00+2.95+2.40) treat-ments. A basic economic analysis was conducted. Fix-ed value refers to the costs of land preparation, labor, seed, fertilizer, and irrigation that were consistent across all treatments. The prices of urea, triple super phosphate (TSP), potash murate (MoP), Gypsum, Born, and zinc sulfate were all considered variable expenses. The farm gate prices of the items were gathered from farmers and local market places to compute gross return, net return, and benefit cost ratio (BCR). The remainders of the managements were treated in the one way. Total cost was considerate by adding fixed and variable costs (Total cost= Fixed cost + Variable cost). The gross return was calculated using the major product's farm gate selling price. The BCR was determined by dividing the gross return by the total cost (gross margin). According to our economic study, the total cost of production is 50,500 taka/ha (all treatment is same). Treatment t_3 out putted the highest gross return of 61,400 taka followed by treatment t_1 yielding 56,400 takas (**Table 7**) T_5, and T_2, yielded the third and fourth gross returns, respectively. Treatment t_4 yielded the lowest gross return of 54,000 taka. The benefit cost ratio (BCR) is calculated using the formula gross return/total value of outturn. The highest BCR (treatment=t_3) is 1.22. t_1 therapy follows (1.12). Treatment t_4 has the lowest BCR (1.06).for out-come, we can state that BARI Gom 33 is superior to others in 3 (three) hill regions (Districts) (Bandarban, Rangamati and Khagrachari) of Bangladesh.

Table 7: Economic analysis of high yield heat tolerant wheat varieties in 3 (three) hill regions (districts) (Bandarban, Rangamati and Khagrachari) during Rabi season in 2020-21 and 2021-22 (average).

Treatment	Gross return	Total cost of production (TK/ha)	Gross margin (TK/ha)	Benefit cost ratio (BCR)
T_1	56,400/-	50,500/-	5,900/-	1.12
T_2	55,200/-	50,500/-	4,700/-	1.09
T_3	61,400/-	50,500/-	10,900/-	1.22
T_4	54,000/-	50,500/-	3,500/-	1.06
T_5	55,600/-	50,500/-	5,100/-	1.10

Local market wheat price 20/-, t_1=BARI Gom 30, t_2= BARI Gom 32, t_3= BARI Gom 33, t_4= WMRI Gom 01, t_5= WMRI Gom 02.

CONCLUSION:

The conclusion is that hilly temperature had important dominance on kernel output and component. For the analyzed elements of high yield, BARI Gom 33 and BARI Gom 30 outperformed WMRI Gom 02, BARI Gom 32, and WMRI Gom 01 significantly. Wheat requires heat tolerant genes to achieve high yield and tolerance levels. For consequence, BARI Gom 33 is suggested for high yield in Bandarban, Rangamati, and Khagrachari. BARI Gom 30 came in second, WMRI Gom 02 came in third, BARI Gom 32 came in fourth, and WMRI Gom 01 came in fifth. Only under the correct temporal conditions, BARI Gom 33 is the best; followed by BARI Gom 30 in 3 (three) hill districts (Bandarban, Rangamati, and Khagrachari)

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CONFLICTS OF INTEREST:

According to the authors, they have no apparent conflicts of interest with regard to the study.

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