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Optimization of Minituber Size and Planting Distance for the Breeder Seed Production of Potato

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Abstract: Six grades of potato minitubers (<5 mm, 5-10 mm, 10-15 mm, 15-20 mm, 20-25 mm and > 25 mm) and four planting distance (25 cm, 20 cm, 15 cm and 10 cm) with a potato variety Diamant were taken in an study during 2013-14 at the Tuber Crops Research Centre of Bangladesh Agricultural Research Institute, Gazipur, Bangladesh. The objective was to observe the effect of minituber grades and planting distance on growth, seed yield, increase ratio and seed potential of potato. The largest minitubers (>25 mm) planted at widest distance (25 cm) produced maximum number of tubers per plant (18.7). The highest number of tubers per m^2 (306.7) was obtained with largest minitubers (>25 mm) planted at the closest plant spacing 10 cm, while it was lowest (64.0) in smallest size minituber (<5 mm) with the widest distance 25 cm. A significant increase ratio was found ranged from 14 (largest minituber with the closest planting distance) to 297 (smallest minituber with widest planting distance). The maximum percentage (53%) of 'A grade' seed (28-55mm size) was obtained from the pea size (5-10 mm) minituber size planted at 15 cm distance. The highest seed potential (39.8) was in >25 mm size minituber planted at 10 cm distance. The lowest (4.4) was in <5 mm size minituber when planted at 25 cm distance. Seed sizes increasing from <5 mm to >25 mm had significant increase ratio ranged from 12 to 269. The highest economic return (9.4) would occur for the pea size (5-10 mm) minituber when planted at 15 cm spacing.

Keywords: Minituber, Breeder Seed and Potato

1. Introduction

Unavailability of certified seed tubers is a major constraint to potato production in Bangladesh. This compels most farmers to use planting materials from informal sources such as previous harvests from own field, local markets and neighbours. Bangladesh Agricultural Research Institute (BARI) has the national mandate to produce basic seed tubers (Breeder's seed) but can only supply less than 1% of the national requirements. BADC and other private seed potato producer can supply maximum 5% quality seed (Hossain *et al.*, 2008). It is recorded that in 2012-2013, BADC supplied 19,322 M tons of seed potato which is only 4.12% of total quality seed [1].

Minitubers are usually defined as the progeny tubers produced on *in vitro* derived plantlets [17]. The size of minitubers may range from 5-25 mm and a range in weight between 0.1-10 gm and sometimes higher. Larger mini-tubers also have become common ([8],[17]). Minituber production has significantly reduced the number of generations required to produce commercial seed potatoes. This has reduced exposure to pathogens during field multiplication, resulting in healthier tubers in seed crops. Experience in production of single-hill, first generation, seedling screening material in the variety development program has shown that minitubers as small as 1-2 g can produce viable productive plants [13]. The optimizing of plant density is one of the most important subjects of potato production, because, it affects to seed cost, plant development, yield, and quality of the crop [4]. In practice, plant density in potato crop is manipulated through the number and size of the seed tubers planted [3]. Widely spaced plants allow better separation at harvest to isolate tubers from individual hills. The low population provides individual plants an advantage in access to moisture, nutrients, and sunlight. To optimize production from pre-nucleus minitubers, plants populations should closely mirror populations typically used for seed production [16]. Therefore, many studies have been conducted to establish the optimal combination of seed size and planting distance for a certain environment ([18], [5], and [4].

A lot of research work has been done to evaluate the performance of potato seed tubers but little information exists on the field performance of minituber for the breeder's seed production of potato. Therefore, the present study was conducted to evaluate the field performance of different size potato minituber and planting distance for the production of breeder's seeds of potato.

2. Materials and Methods

2.1. Site, Soil and Season of the Experiment

The experiment was conducted at the net house of Tuber Crops Research Centre, BARI, Gazipur during November, 2013 to March 2014. The location of the experimental site was to the 34 km north from Dhaka city (24.38^0 N latitude and 90.13^0 longitudes) at 8.4m above the sea level. The soil of the experimental field was grey terrace contained pH 6.4. This area is moderately drought prone, and face drought both winter and late winter season. The experimental site is situated in a sub- tropical climate zone and characterized by no rainfall during December to March.

2.2. Planting Materials and Date of Planting

Diseases free well sprouted seed potato minitubers of Diamant variety were used as planting material for the experiment. Mini-tubers were planted on 6th November, 2013.

2.3. Crop Management

The field was ploughed 3-4 times to a depth of 25 cm. Full doses of well rotten cow dung (10 t ha^{-1}), TSP (220 kg ha^{-1}), MP (270 kg ha^{-1}), Gypsum (120 kg ha^{-1}), Boric acid (6 kg ha^{-1}) and half doses of Urea (175 kg ha^{-1}) were applied at the time of final land preparation. The rest half dose of Urea (175 kg ha^{-1}) was applied as side dressings at 30 DAP followed by earthing-up and light irrigation. First earthing up was done at 30 DAP when the plant attained a height of about 15-20 cm from the base, second earthing-up was done after 20 days of first earthing up. Before first earthing up, Urea was applied. Irrigation was applied 3 times. First one was applied just after planting, second one was just after earthing up at 30 DAP, and last one was on 55 DAP. During land preparation, Furadan 5G was applied @10 kg ha-1 as basal during land preparation and Admire (0.2%) was sprayed in two installments at 45 and 60 DAP to control insects. The crops were also sprayed alternatively with Dithane-M 45 (0.2%) and Secure (0.1%) at 15 days interval to prevent the late blight infection of potato. The field was netted during the entire growing period to protect the plants from the insect infestation specially aphids which is the vector of different viruses. Seeds were planted at row distance of 60 cm row and planting distance of 25, 20, 15 and 10 cm. Haulm pulling was done at 75 DAP by hand. Hardening and setting up of skins of tubers were allowed for 10 days under the soil there after crop was harvested at 85 DAP. Tubers were collected carefully with the help of spade without any injury.

2.4. Design and Treatments of the Experiment

The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. First of all the entire experimental field was divided into three blocks, representing three replications. Each block again divided into twenty four unit plots. The treatment was assigned randomly to unit plots of each block. The size of a unit plot was 3.0 m × 2.4 m. There were six grades of minitubers based on minituber diameter (S_1/Under size = <5 mm, S_2/pea size=5-10 mm, S_3/small size=10-15 mm, S_4/medium size = 15-20 mm, S_5/large size = 20-25 mm and S_6/extra-large= > 25 mm) based on minituber diameter and four planting distance (D_1=25 cm, D_2=20 cm, D_3=15 cm and D_4=15 cm) which formed twenty four treatment combinations. Treatment combinations were as follows-

S_1D_1, S_1D_2, S_1D_3, S_1D_4, S_2D_1, S_2D_2, S_2D_3, S_2D_4, S_3D_1, S_3D_2, S_3D_3, S_3D_4, S_4D_1, S_4D_2, S_4D_3, S_4D_4, S_5D_1, S_5D_2, S_5D_3, S_5D_4, S_6D_1, S_6D_2, S_6D_3 and S_6D_4.

2.5. Climatological Data

Air temperature and humidity, precipitation, evaporation, soil temperature and ground water table were recorded throughout the crop period (Table 1).

Table 1. *Climatological data of 2013-14 crop season.*

Month	Air Temperature (° C)			Humidity (%)	Rain Fall (mm)
	Max.	Min.	Av.		
2013-14					
November	26.60	22.43	24.52	80.47	8.44
December	19.90	15.45	17.68	89.05	0.00
January	15.20	11.58	13.39	90.80	0.00
February	23.85	19.08	21.47	89.89	8.43
March	31.16	26.09	28.62	76.70	29.84

2.6. Data Collection

Data on different growth and yield contributing characters were recorded from the sample plants of each plot during the course of experiment. The sampling was done randomly. The plants in the outer row were excluded during random selection. Five plants were randomly selected from each plot to record the data on the following parameters: Plant emergence, plant height, leaf area, number and weight of tubers per plant, yield (kg m^{-2}), and percentage of different grades of tuber by number, seed potentials and seed increase ratio.

2.7. Statistical Analysis

To find out the significance of experimental results, the collected data on different parameters were analyzed statistically by using MSTAT-C program. The mean for all the treatments were calculated and analysis of variance for each parameter was performed by F-test. The mean separation was done by DMRT at 5% level of probability.

3. Results and Discussion

3.1. Plant emergence (%)

Analysis of variance indicated that the interaction effect of minituber size and planting distance had significant influence on emergence rate at 30 DAP (Table 2). The highest emergence rate was found in large minituber with 25 cm planting distance (94.1%), which was statistically identical to other planting distance and extra-large. The lowest emergence rate (61.8%) was obtained from under-size minituber at 10 cm planting distance, which was statistically at par with 15 cm planting distance (62.7%). In an average emergence performance of the under-size minituber at any planting distance is very low compared to other sizes. These results support the findings of Rykbost and Charlton (2004); Karafyllidis *et al*. (1997) and El Amin *et al*. (1996).

Table 2. *Interaction effect between minituber size and planting distance on percent plant emergence*

Minituber size	Planting distance (cm)				Mean
	25	20	15	10	
Under size	69.9	68.9	62.7	61.8	65.8
Pea	79.4	75.8	77.8	78.2	77.8
Small	82.5	80.4	83.8	83.2	82.5
Medium	89.4	82.9	87.6	84.9	86.2
Large	94.1	89.2	90.5	91.4	91.3
Extra-large	91.1	89.4	88.1	88.8	89.4
Mean	84.4	81.1	81.8	81.4	
LSD $_{(0.05)}$					
Planting distance (P)	8.72				
Minituber size (M)	7.99				
P x M	21.35				

3.2. Plant Height (cm)

The tallest plant (85.9 cm) was produced by extra-large size minituber when planted at 25 cm distance; shortest (50.2 cm) plant was produced by under-size mintuber with 25 cm (Table 3). Jagroop et al. (1993) found taller plants with large size normal seed tubers planted at closer spacing. Probably the plant height was the highest in the larger size minituber due to the presence of more reserve food which caused rapid growth of plants earlier. Similar findings have also been reported by Zakaria (2003) but his research was on the effect different size of microtuber on plant height.

Table 3. *Interaction effect between minituber size and planting distance on plant height (cm)*

Minituber size	Planting distance (cm)				Mean
	25	20	15	10	
Under size	50.2	59.8	58.4	57.8	56.6
Pea	71.7	66.5	64.3	70.7	68.3
Small	65.7	68.7	62.0	67.7	66.0
Medium	70.4	69.5	65.5	70.7	69.0
Large	71.1	71.0	71.3	65.3	69.7
Extra-large	85.9	72.2	79.8	68.8	76.7
Mean	69.2	68.0	66.9	66.8	
LSD $_{(0.05)}$					
Planting distance (P)	2.97				
Minituber size (M)	4.85				
P x M	9.69				

3.3. Leaf Area (cm^2)

Generally, yield was positively correlated to leaf area and was increased linearly as leaf area increased. Planting distance had significant difference on the leaf area production of plants derived from minituber (Table 4). Extra-large minituber contributed the highest leaf area values across all population density levels in comparison to other seed minitubers. The trend was such that the bigger the seed piece, the greater the leaf area. There was increase in leaf area with increase in minituber size and planting distance. The leaf area was highest in largest minituber with planting distance 25 cm but lowest in smallest mini-tuber with closest planting distance 10 cm. These results are in conformity with the findings of Akhtar *et al.* (2010). Lower leaf area index and radiation interception in small seed size undoubtedly reduced production of assimilates.

Table 4. *Interaction effect between minituber size and planting distance on leaf area*

Minituber size	Planting distance (cm)				
	25	20	15	10	Mean
Under size	837.7	814.3	797.0	785.7	808.7
Pea	924.0	891.3	849.0	831.0	873.8
Small	966.0	948.3	933.7	912.0	940.0
Medium	1042	1031	1008	991.0	1018.0
Large	1233	1210	1173	1150	1191.5
Extra-large	1414	1385	1353	1280	1358.0
Mean	1069.5	1046.7	1019.0	991.6	
LSD $_{(0.05)}$					
Planting distance (P)	120.6				
Minituber size (M)	130,2				
P x M	124.8				

3.4. Tuber Number per Plant and per m^2

Minituber size and planting distance interacted significantly and affected the number of tuber per plant (Table 5 & 6). The tuber number per plant increased with increase in minituber size in each planting spacing. The extra-large minituber planted at widest distance (25 cm) produced maximum number of tuber per plant (18.7) which was statistically similar to 20 cm (18.0)) and 10 cm (18.4) of same groups respectively. Number of tubers per plant was the lowest in smallest minituber with closest planting distance 10 cm (8.10). Larger minituber have higher amount of reserve food and interplant competition for space, light, water and nutrient is less in the wider spacing that can contribute the increase number of tuber per plant. The number of tubers per m2 was increased with increase in minituber size with closer planting distance (Table 16). The highest number of tuber per m2 was obtained with extra-large minitubers planted at the 10 cm distance (306.7), while it was lowest in under-size minituber with the widest distance 25 cm (64.0). The results were in conformity with the findings of Haverkort *et al.* (1991) who found increasing number of tubers per plant with increase in size of microtuber. The same information was reported by Rykbost and Charlton (2004) and Karafyllidis *et al.* (1997). These results are in conformity with the findings of Tuku (2000) who reported that higher yield was associated with proper nutrients and water availability to the plant and more tuber weight. Gopal *et al.* (2007) after conducting similar study also proposed that selection for tuber yield can be practiced at the minituber level in potato breeding processes. Zkaynak & Samanci (2006) worked on field performance of three weight classes of small minitubers ranging from 6.0 - 18.0 g was studied in two years at different planting dates. The heavy minitubers gave higher values than light minitubers for tuber yield, tuber weight, tuber number and stem number.

Table 5. *Interaction effect between minituber size and planting distance on tuber number per plant*

Minituber size	Planting distance (cm)				
	25	20	15	10	Mean
Under size	9.6	9.6	10.8	8.1	9.5
Pea	11.5	12.9	10.3	10.0	11.2
Small	12.5	10.7	10.4	9.6	10.8
Medium	11.5	10.4	11.5	13.9	11.8
Large	13.1	14.8	13.7	15.7	14.3
Extra-large	18.7	18.0	14.4	18.4	17.4
Mean	12.8	12.7	11.9	12.6	
LSD $_{(0.05)}$					
Planting distance (P)	0.85				
Minituber size (M)	1.40				
P x M	2.09				

Table 6. *Interaction effect between minituber size and planting distance on tuber number per m^2*

Minituber size	Planting distance (cm)				
	25	20	15	10	Mean
Under size	64.0	84.8	120.8	151.0	105.2
Pea	76.4	114.1	114.0	166.7	117.8
Small	83.5	94.1	90.3	173.4	110.3
Medium	76.4	91.8	127.3	231.0	131.6
Large	87.1	130.7	152.4	262.1	158.1
Extra-large	124.5	158.9	160.0	306.7	187.5
Mean	85.3	112.4	127.5	215.2	
LSD $_{(0.05)}$					
Planting distance (P)	14.42				
Minituber size (M)	18.28				
P x M	7.57				

3.5. Tuber Weight per Plant and per m^2

Minituber size and planting distance interacted significantly and there was a significant influence on tuber weight per plant (Table 7 & 8)). Tuber yield per plant increased significantly with increase in minituber size and planting distance. The maximum tuber weight per (985.0 g) plant was obtained from the extra-large minituber with planting distance 25 cm and minimum tuber weight per plant (119.0 g) was found from the under-size minituber with closest planting distance 10 cm which was statistically similar to other spacing of the same size. Different trend was observed in weight of tuber per m^2. The highest weight of tubers per m^2 (8.50 kg) was obtained from the largest minitubers with closest planting distance 10 cm which was at par with large size minituber with closest planting distance 10 cm (8.29 kg). The lowest weight of tuber per m2 (0. 99 Kg) was found in under-size with widest spacing 25 cm.

Table 7. *Interaction effect between minituber size and planting distance on tuber weight per plant (g)*

Minituber size	Planting distance (cm)				
	25	20	15	10	Mean
Under size	148.4	147.2	126.0	119.4	135.3
Pea	719.6	641.0	615.7	469.7	611.5
Small	670.2	584.4	552.7	476.9	571.1
Medium	688.2	600.2	495.9	390.5	543.7
Large	811.1	757.6	651.7	497.3	679.4
Extra-large	985.0	831.3	694.9	509.9	755.3
Mean	670.4	593.6	522.8	410.6	
LSD $_{(0.05)}$					
Planting distance (P)	3.09				
Minituber size (M)	3.88				
P x M	7.57				

Table 8. *Interaction effect between minituber size and planting distance on tuber yield (kg m^{-2})*

Minituber size	Planting distance(cm)				
	25	20	15	10	Mean
Under size	0.99	1.30	1.40	1.99	1.42
Pea	4.80	5.66	6.84	7.83	6.28
Small	4.47	5.16	6.14	7.95	5.93
Medium	4.59	5.30	5.51	6.51	5.48
Large	5.41	6.69	7.24	8.29	6.91
Extra-large	6.57	7.34	7.72	8.50	7.53
Mean	4.47	5.24	5.81	6.85	
LSD $_{(0.05)}$					
Planting distance (P)	0.22				
Minituber size (M)	0.27				
P x M	0.53				

3.6. Seed Potential

From the calculation, the seed potentials of minituber of the different sizes planted at different spacing ranged from 4.4 to 39.8 (Table 9). The highest seed potential (39.8) was found in extra-large size minituber planted at 10 cm distance. The lowest seed potential (4.4) was in under-size minituber when planted at 25 cm distance. However, the yield (both number and weight per plant) of under-size and extra-large size minituber was negligible.

3.7. Increase Ratio

Results observed in this trial demonstrated that extremely high increases ratios as minituber size decreased and a large reduction in this ratio as minituber size increased (Table 9). Effects of increasing minituber size on yield are attributed to a combination of increases in both number and size of daughter tubers. Seed sizes increasing from under-size to extra-large size had significant increase ratio ranged from 12 to 269. Rykbost and Charlton (2004) reported 65 to 317 increase ratios from the minituber size ranged from 1.2 g to 13.6 g. They also reported that a typical seed increase expectation is 15 or 20 to 1 but in the irrigated production, the increase ratio is likely to be 20 to 1. The similar results were found by Masarirambi *et al*. (2012) and Islam *et al*. (2012).

Table 9. *Interaction effect between minituber size and planting distance on seed potential and increase ratio*

Minituber size	Seed potential				Increase ratio			
	Planting distance (cm)				Planting distance (cm)			
	25	20	15	10	25	20	15	10
Under size	0.99	1.30	1.40	1.99	130	119	93	72
Pea	4.80	5.66	6.84	7.83	269	223	210	155
Small	4.47	5.16	6.14	7.95	90	75	72	60
Medium	4.59	5.30	5.51	6.51	47	41	34	26
Large	5.41	6.69	7.24	8.29	26	25	21	16
Extra-large	6.57	7.34	7.72	8.50	22	19	16	12
Mean	4.47	5.24	5.81	6.85	97.33	83.67	74.33	56.83

3.8. Economic Analysis

Significant variation in partial budget analysis was observed in different treatment combinations (Table 10). In seed production of potato from mini tuber total variable cost (TVC) was highest in extra-large minituber when planted at 10 cm distance (Tk.161.88).The highest gross net return Tk. 224.09 was found in the same treatment but it BCR was 1.4 which was lower than other treatment combinations. The lowest net return Tk. 18.57 was found in under-size planted at 25 cm distance and its BCR was also lowest (1.5). Closer planting required more labour involvement and higher seed rate/ha which resulting high TVC and lower the BCR in breeder seed production by using mini tuber as has been reported by Mamun (2012). The result suggests that the highest economic return (9.4) would occur for the 1-4 g small minituber when planted at 15 cm spacing if the price per kilogram of the minitubers is equal for all sizes. Pricing compensation for larger seed sizes would need to be large for much lower production potential. Production of basic seed from minituber is very costly.

Table 10. *Partial budget analysis of potato for different treatment combinations of minituber size*

Treatment		Total material cost (Tk.)	Total non-material cost (Tk.)	Total variable cost (Tk.)	Gross return (Kg/m^2)		Net return (Tk/m^2)	BCR
Minituber size	Planting distance				Seed	Non-seed		
Under size	60 × 25	5.33	6.75	12.08	13.01	5.56	18.57	1.5
	60 × 20	5.60	6.95	12.55	15.76	7.62	23.38	1.9
	60 × 15	5.89	7.15	13.04	15.57	8.81	24.38	1.9
	60 × 10	6.58	7.35	13.93	18.01	13.90	31.90	2.3
Pea	60 × 25	7.84	6.75	14.59	107.48	12.17	119.65	8.2
	60 × 20	8.92	6.95	15.87	118.21	17.20	135.41	8.5
	60 × 15	10.06	7.15	17.21	139.78	21.81	161.59	9.4
	60 × 10	12.84	7.35	20.19	155.22	26.56	181.78	9.0
Small	60 × 25	14.51	6.75	21.26	107.56	8.85	116.41	5.5
	60 × 20	17.75	6.95	24.70	119.92	11.63	131.55	5.3
	60 × 15	21.17	7.15	28.32	144.08	13.37	157.45	5.6
	60 × 10	29.51	7.35	36.86	181.45	19.02	200.47	5.4

Treatment		Total material cost (Tk.)	Total non-material cost (Tk.)	Total variable cost (Tk.)	Gross return (Kg/m^2)		Net return (Tk/m^2)	BCR
Minituber size	Planting distance				Seed	Non-seed		
Medium	60 × 25	24.51	6.75	31.26	112.79	8.30	121.09	3.9
	60 × 20	30.99	6.95	37.94	130.62	9.46	140.08	3.7
	60 × 15	37.83	7.15	44.98	136.75	9.52	146.27	3.3
	60 × 10	54.51	7.35	61.86	156.94	12.79	169.73	2.7
Large	60 × 25	44.52	6.75	51.27	127.21	11.70	138.91	2.7
	60 × 20	57.48	6.95	64.43	161.00	13.23	174.23	2.7
	60 × 15	71.16	7.15	78.31	170.31	15.63	185.94	2.4
	60 × 10	104.52	7.35	111.87	190.13	19.52	209.65	1.9
Extra-large	60 × 25	64.53	6.75	71.28	161.96	14.79	176.75	2.5
	60 × 20	83.97	6.95	90.92	179.18	15.66	194.84	2.1
	60 × 15	104.49	7.15	111.64	187.80	15.80	203.61	1.8
	60 × 10	154.53	7.35	161.88	207.88	16.21	224.09	1.4

Breeder's Seed price = 30 Tk/kg and non-seed price = 10 Tk./kg

4. Conclusion

Breeder seed production of potato was affected by minituber size and planting distance. Larger size of minituber produced more number of tubers with increased yield when it was planted in greater distance. But, the higher seed yield potential was found in larger sized with closer planting of minituber. So, it can be concluded that pea size minituber with 15 cm planting distance might have the highest economic return. However, based on the yield and net return, gross return, small size minituber at 10 cm planting distance may be used for cost effective production of breeders' seeds of potato.

Appendixes

Appendix 1. *Meteorological conditions of the experimental site during January 2012 to December 2013*

Month	Air Temperature (ºC)		Humidity (%)	Rain Fall (mm)
	Max.	Min.		
January	21.42	16.77	89.20	1.68
February	24.33	19.68	85.25	0.00
March	28.81	24.60	81.61	13.63
April	31.95	27.12	82.83	38.68
May	31.47	25.89	83.84	162.43
June	34.00	25.80	84.53	247.34
July	32.19	25.94	85.07	363.60
August	31.16	25.94	86.29	590.30
September	31.70	27.47	86.57	206.46
October	29.74	26.70	85.29	182.43
November	26.60	22.43	80.47	8.44
December	19.90	15.45	89.05	0.00
Ave./total	28.61	23.65	85.00	1814.94

Source: Weather station, BARI, Gazipur

Appendix 2. *Meteorological conditions of the experimental site during January 2013 to December 2014*

Month	Air Temperature (ºC)		Humidity (%)	Rain Fall (mm)
	Max.	Min.		
January	15.20	11.58	90.80	00.0
February	23.85	19.08	89.89	8.43
March	31.16	26.09	76.70	29.84
April	32.13	28.2	76.53	57.11
May	31.40	27.90	82.0	252.23
June	32.06	29.26	85.96	369.53
July	32.32	27.67	83.45	269.13
August	32.0	25.90	85.58	138.65
September	30.38	26.53	89.46	212.65
October	30.67	27.06	87.41	187.01
November	27.76	23.76	85.66	00.0
December	24.80	16.58	90.70	55.19
Ave./total	29.46	24.81	85.34	1579.77

Source: Weather station, BARI, Gazipur

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