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Phenology, growth and yield of wheat varieties as affected by soil types and high temperature stress

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Varietal adaptability to environmental fluctuations is important for the stabilization of wheat production on both varieties and soil types. Soil properties and temperature stress may affect growth response and yield of wheat in Bangladesh. In this context, a pot experiment was conducted with four wheat varieties and four soil types, which was collected from different AEZ's of Bangladesh. Each pot contains 6 kg of soil for every soil types. A 0.45 g of urea, 0.54 g TSP, 0.15g MOP, 0.36 g gypsum, 0.225g boron was added at the rate of 150 kg Urea/ ha, 180 kg TSP/ ha, 50 kg MOP/ ha, 120 kg Gypsum/ ha, and 7.5 kg Boric acid/ ha of land for each pot. As it was a completely randomized block design (CRD), 10 to 15 days interval the experimental pot was exchanged from one place to another to avoid positional error. Watering was done 1 to 2 days interval. Plant was thinned 8 plants per pot. Different growth and yield parameters like plant height, no. of grain per panicle, 1000 grain weight, grain yield, straw yield, harvest index was calculated. From the experiment it was found that the wheat variety BARI gom-28 performed better among all other variety and different AEZ.

Introduction

Crop production will need to increase remarkably over the next 40 years to support an extra two billion population by 2050 (Ma and Ryan 2010). Accounting for a fifth of humanity's food, wheat is second after rice as a source of calories in the diets of consumers in developing countries and is first as a source of protein (Braun et al., 2010).Recently, some advanced wheat genotypes were released as varieties by Wheat Research Center of Bangladesh Agricultural Research Institute. These varieties were developed for optimum as well as late sown condition i.e., these genotypes have some heat tolerant characteristics (WRC, 2009). The newly developed varieties need to be evaluated for their agronomic performance under different environmental conditions. The present study was therefore, undertaken to evaluate the performance of wheat varieties under different soil pH and climatic condition, to find out the suitable variety for optimum growth and yield under various soil pH spectrum as well as adaptability in different agro-ecological zones.

Nutrient availability in soil depends on the pH value of soils. On the basis of pH, soil are classified as alkaline, neutral and acidic having pH range 6.6 to 7.4 (Hausenbuiller, 1972). Most

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of the plant nutrients are highly available in neutral soil having pH 6.6 to 7.4. But soil acidity is a major growth limiting factor for plant in many region of the world (Adams, 1980).

High temperature stress results in faster senescence of foliage, poor assimilate synthesis, reduced translocation of photosynthesis to the developing grain and greater respiratory losses (Khatib and Paulsen, 1984). The net effect of heat stress at this stage lowers kernel weight due to a reduced grain-filling period, grain-filling rate or the combined effect of both (Tashiro, and Wardlaw, 1989). Therefore, heat stress is a major factor limiting productivity and as such sowing time has a major bearing on wheat yield.

Understanding the phenology, growth and yield of wheat varieties which affected by soil types and high temperature is necessary to facilitate the development of wheat varieties. Most of the studies consider only varietal performance irrespective to climate as well as soil physical and chemical properties. Plants take their nutrients mostly from soil. It is well known that the optimum plant growth and crop yield depends not only the total amount of nutrients present in the soil at a particular time but also on their availability which in turn is controlled by physico-chemical properties like: soil texture, organic carbon and calcium carbonate, cation exchange capacity, pH and electrical conductivity of soil (Bell and Dell, 2008). Soil plays a major role in determining the sustainable productivity of an agro-ecosystem (Kumar and Babel, 2011). Therefore, it is necessary to conduct experiment in different agro-ecological collected soil in same environment to quantify soil types and high temperature stress.

However, no study was undertaken to determine growth and yield response of said other wheat varieties that grown under various soil pH spectrum as well as high temperature stress condition. Therefore, this was undertaken to evaluate phenology, growth and yield response of wheat varieties like BARI Gom 28, BARI Gom 27, BARI Gom 26 and Prodip that grown under various soil pH spectrum collected from several agro-ecological zones (AEZ's) in Bangladesh. The hypothesis of this study is that BARI Gom 28 will be performed best among all other varieties under different soil pH and high temperature stress condition.

Materials and Methods

Soil

Four types of soil were used in this experiment. The soil was collected from four selected AEZ (Agro Ecological Zone) in Bangladesh. Soil was collected from Ghoraghat-Dinajpur (AEZ-27), Tanor-Godagari (AEZ-11), Neamatpur-Naogaon (AEZ-26), Rajshahisadar area (AEZ-11).

Agro-Ecological Zones (AEZ`s) of Bangladesh

Agro-Ecological Zones (AEZ's) of Bangladesh determined on basis of some definite characteristics and they are physiographic (it is defined as soil parent materials and land forms of a particular area), hydrology (it is determined on the basis of water holding capacity of soil and the water level of agricultural land), cropping pattern (it is done on the basis of Length of Rabi and kharif season and major and minor agricultural crops which are cultivated in a particular area), season (it is done on the basis of the depth and duration of seasonal flooding in a particular area), soil types and tidal activity.

Wheat varieties

Four recently BARI released wheat varieties were used as a testing plant in this experiment. These were BARI Gom 26, BARI Gom 27, BARI Gom 28 and Prodip.

Experimental design

The experiment was conducted by completely randomized design (CRD). A completely randomized design (CRD) is one where the treatments are assigned completely at random so that each experimental unit has the same chance of receiving any one treatment. For the CRD, any difference among experimental units receiving the same treatment is considered as experimental error. The experiment consisted of four soil types (Soil pH 7.1, 7.3, 7.8 and 8.2) and four wheat varieties with three replications. The experimental design was 4 Soil pH × 4 wheat varieties × 3 replications.

Pot Filled With Soil

Germination Stage

Booting Stage

Heading Stage

Anthesis Stage

Maturity Stage

Fig. 1. Photographic view different growth stages of the pot experiment

The other properties of soil are given as below:

Experimental procedure

A 72 kg of soil was taken from each type of soil that collected from several AEZ of Bangladesh. Then basal dose of fertilizers was mixed with those collected soil. For each pot 0.45 g urea, 0.54 g TSP, 0.15g MOP, 0.36 g gypsum, 0.225g boron was added at the rate of 150 kg Urea/ ha, 180 kg TSP/ ha, 50 kg MOP/ ha, 120 kg Gypsum/ ha, and 7.5 kg Boric acid/ ha of land. A 2.4 g of urea were given after 20 days of sowing as top dressing. Every pot was filled with 6 kg of soil and kept some space for watering to the plants.

Seed germination

A 10 number of seeds for every variety were sown in each pot. After placement of seed, some soil was placed over the seed. Water was sprayed to the less moisture soil, so that seed can germinate properly. Seedlings proliferation occurred after 4-5 days of seed sowing.

Watering

Watering was done one day interval by spraying during seedlings growth stage. As it was a completely randomized block design, so 10-15 days interval the experimental pot was exchanged from one place to another to avoid positional error. As a result every plant was able to get the sunlight equally throughout the experimental period.

Plant growth condition

Due to pot experiment, tillering of plant was absent and every single plant was growing simultaneously. Some grass were grown in every pot, they were removed carefully. As it was a pot experiment, wheat plants were not grown as like as field wheat. Plants were grown with day temperature of 23°C, night temperature of 18°C, 11 h dark, 13 h light conditions and average light intensity was 270 μM photons/m^2/s.

Table 1. Physical and chemical properties of the collected soils

Soil pH	N (%)	P (ppm)	K (Col/kg)	S (ppm)	Zn (pH)	OM (%)
7.1	0.03	11.5	0.59	29.5	0.28	0.51
7.3	0.04	1.0	0.15	4.2	0.13	0.75
7.8	0.03	2.2	0.26	2.2	0.13	0.48
8.2	0.04	1.0	0.15	4.2	0.13	0.75

Plant harvest

Plant was harvested at the ground level. Harvest was done according to the maturity of the plant. After 115 days, most of the plants were harvested with matured. A 5 number of selected plants were harvested at soil level and tagged for necessary data collection.

Collection of weather data

The maximum and minimum mean air temperature (° C), total rainfall (mm), relative humidity (%), number of rainy days and sunshine hours during the experimental period were recorded from weather yard of Regional Station, Bangladesh Wheat Research Center, Shyampur, Rajshahi, Bangladesh.

Grain yield and yield contributing characters

The collected samples were bundled separately, tagged properly and then dried in the sunshine. After separation of grain, grain and straw were weighed separately for each treatment for recording the number of grains per spike counted. Grain weight was determined 1000 grains. Spike length, number of effective tillers plant^{-1}, number of non-effective tillers plant^{-1}, number of grains spike^{-1}, 1000 grain weight, grain yield, straw yield, harvest index (%) etc. were also calculated.

Measurements of soil physical and chemical properties

The pH of various soils was determined in hydroxyl water using a soil-to-solution ratio of 1:2.5. Organic carbon of the soil samples was determined by wet oxidation method (Walkley and Black, 1934). Soil organic matter content was determined by multiplying the percent value of organic carbon with the conventional Van-Bemmelen's factor of 1.724 (Piper, 1950). The nitrogen content of the soil sample was determined by distilling soil with alkaline potassium permanganate solution (Subhaiah and Asija, 1956). The distillate was collected in 20 ml of 2% boric acid solution with methylred and bromocresol green indicator and titrated with 0.02 N sulphuric acid (H_2SO_4) (Podder*et. al.*,2012). Soil available S (ppm) was determined by calcium phosphate extraction method with a spectrophotometer at 535 nm (Petersen 1996). The soil available K was extracted with 1N NH_4OAC and determined by an atomic absorption spectrometer (Biswas*et. al.* 2012). The available P of the soil was determined by spectrophotometer at a wavelength of 890 nm. The soil sample was extracted by Olsen method with 0.5 M $NaHCO_3$ as outlined by Huq and Alam (2005). Zn in the soil sample was measured by an atomic absorption spectrophotometer (AAS) after extracting with DTPA (Soltanpour and Workman, 1979).

Statistical analysis

Combined analysis of the data of both sites were performed according to four soils × four wheat varieties in completely randomized design (CRD) using the Genstat 12.1.0 computer software. The means were compared using the least significant diference (LSD) test after establishing significance level through ANOVA technique (Stel *et. al.*, 1997).

Results

Effect of soil pH and wheat varieties on plant height at harvest

The plant height did not differ significantly from soil to soil as well as among wheat varieties. At soil pH 7.1, the plant height of prodip, BARI Gom 26, 27 and 28 were 59.27, 62.67, 64.07 and 65.53 cm, respectively. As like as, plant height of prodip, BARI Gom 26, 27 and 28 were 60.13, 61.17, 62.20 and 63.0 cm respectively for soil pH 7.3. Similarly, for soil pH 7.8, the plant height of prodip, BARI Gom 26, 27 and 28 were 62.93, 63.20, 64.40 and 64.47 cm, respectively. Regardless of that the plant height of prodip, BARI Gom 26, 27 and 28 for soil pH 8.2 was 56.80, 61.87, 62.07 and 62.20 cm, respectively (Fig. 2; Table 2).

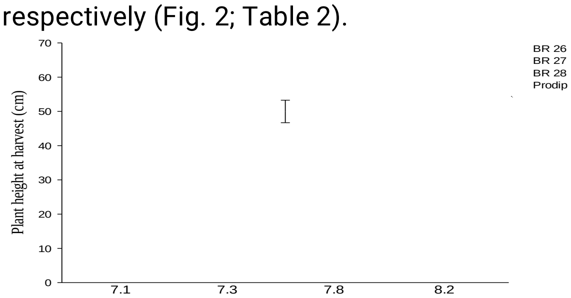

Fig. 2. Effect of soil pH and wheat varieties on plant height after harvest. Vertical bar represents LSD (P = 0.05) for soil pH × wheat varieties interaction.

Table 2. Significance levels for the main and interactive effect of soil pH and wheat varieties on growth response wheat plant that grown under various soil pH.

Source of variation	Plant height	Spike length
Soil pH	n.s.	n.s.
Wheat varieties	n.s.	***
Soil pH × Wheat varieties	n.s.	n.s.

Where n.s. and *** represent probability of > 0.05 and ≤ 0.001, respectively. Values were means of three replicates for wheat varieties and soil pH.

Effect of soil pH and wheat varieties on spike length

In general, the BARI Gom 28 has the highest spike length among all the wheat varieties. The BARI Gom 28 generated significantly (P ≥ 0.05) higher spike length than prodip in all soil pH except the soil pH of 7.3. In soil pH 7.3, the spike length did not differ significantly among wheat varieties (Fig. 3; Table3).

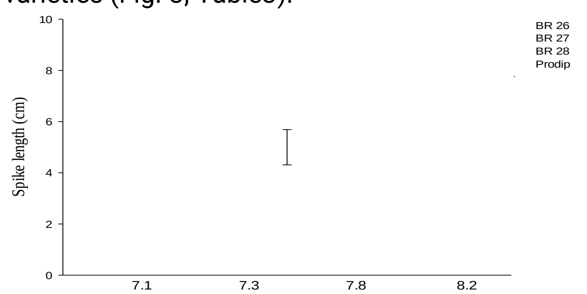

Fig. 3. Effect of soil pH and wheat varieties on grain per spike that grown in pot. Vertical bar represents LSD (P = 0.05) for soil pH × wheat varieties interaction.

Spikelet spike^{-1}

In general, spikelet per spike did not differ significantly among various soil pH. The spikelet spike^{-1} also did not differ significantly among various wheat varieties. However, the spikelets spike^{-1} for BARI released wheat varietiy BARI Gom-28 was higher than prodip at all soil pH. The spikelet spike^{-1} was higher in BARI Gom 28 followed by BARI Gom 27, BARI Gom 26, prodip respectively (Fig. 4).

Effect of soil pH and wheat varieties on grains spike^{-1}

Interestingly, grains spike^{-1} significantly (P ≤ 0.05) differed among different wheat varieties. However, at soil pH 7.2, the grains spike^{-1} was similar for BARI Gom 26, BARI Gom 27 and BARI Gom 28 wheat varieties, respectively. As like as, these BARI released varieties were significantly (*P* ≥ 0.05) higher than prodip in the soil pH 7.2 (Fig. 5; Table 3).

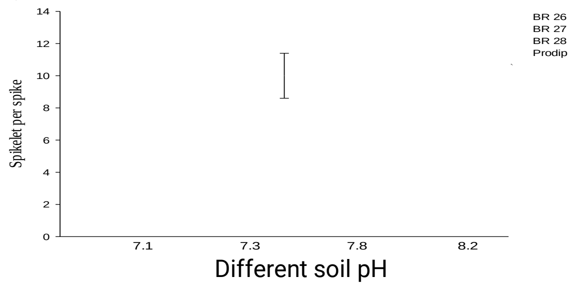

Fig. 4. Effect of soil pH and wheat varieties on spikelet per spike that grown in pot. Vertical bar represents LSD (P = 0.05) for soil pH × wheat varieties interaction.

In general, the grain per spike tended to decrease with the increase in soil pH under various wheat varieties. The BARI Gom 28 produced maximum grain per spike at soil pH 7.3 followed soil pH 7.1, soil pH 8.2 and soil pH 7.8, respectively (Fig. 5; Table 3).

pH. The yield of BARI Gom 28 was significantly (*P* ≥ 0.05) higher than prodip at soil pH 7.8 and soil pH 8.2. The grain yield was higher in BARI Gom 28 and lower in prodip at all soil pH. The grain yield of BARI Gom 28 was higher followed by BARI Gom 27, BARI Gom 26 and prodip respectively at all soil pH (Fig. 6; Table 3).

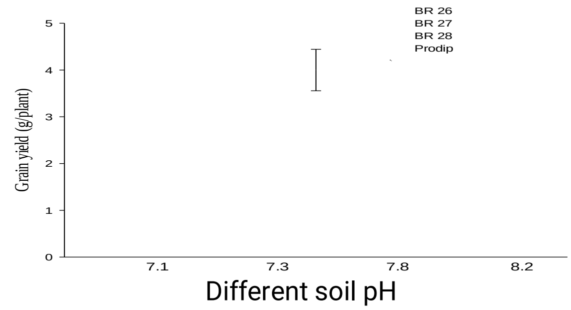

Fig. 6. Effect of soil pH and wheat varieties on grain yield that grown in pot. Vertical bar represents LSD (*P* = 0.05) for soil pH × wheat varieties interaction.

Effect of soil pH and wheat varieties on straw yield

Table 3. Significance levels for the main and interactive effect of soil pH and wheat varieties on yield response of wheat plant that grown under various soil pH.

Source of variation	Grain per spike	Spike length	Spikelet per spike	Grain yield	Straw yield
Soil pH	n.s.	n.s.	*	***	*
Wheat varieties	***	***	**	***	*
Soil pH × Wheat varieties	n.s.	n.s.	n.s.	n.s.	n.s.

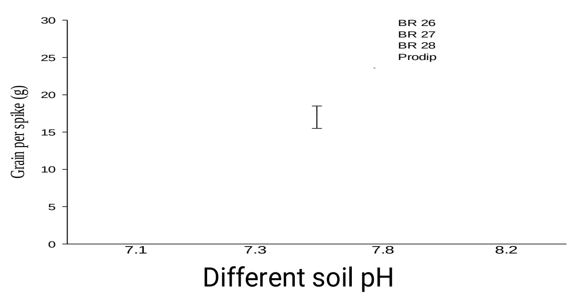

Fig. 5. Effect of soil pH and wheat varieties on grain per spike that grown in pot. Vertical bar represents LSD (*P* = 0.05) for soil pH × wheat varieties interaction.

Effect of soil pH and wheat varieties on grain yield

On average, the grain yield performance was best in soil pH 7.1 followed be soil pH 7.3, soil pH 8.2 and soil pH 7.8 among all varieties. However, the yield of BARI Gom 28 was similar at all soil

In general, the straw yield of different wheat varieties tended to be decline with the increase of soil pH. The straw yield of different varieties tended to be highest at soil pH 7.1 and lowest at the soil pH 8.2. The straw yield of BARI Gom 28 was highest followed by BARI Gom 27, BARI Gom 26 and prodip under various soil pH (Fig. 7; Table 3).

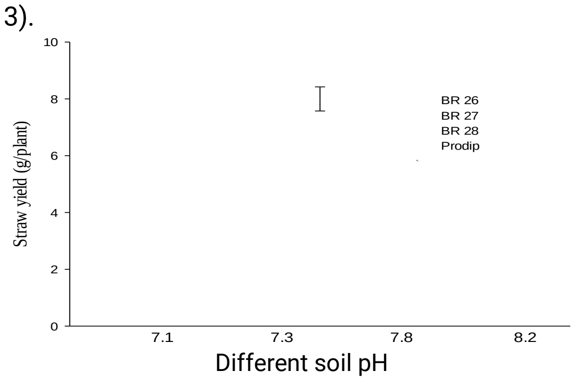

Fig. 7. Effect of soil pH and wheat varieties on straw yield that grown in pot under several soil pH. Vertical bar represents LSD (*P* = 0.05) for soil pH × wheat varieties interaction.

Discussion

Soil pH dynamics relevant to wheat varieties

The maximum growth response and yield of wheat was found in soil pH 7.1 for the BARI Gom 28 compared to other wheat varieties. The plant height was higher in BARI Gom 28 among all other varieties at soil pH 7.1 (Fig. 2). The, grain spike^{-1} was higher in same pH soil for BARI Gom 28 (Fig. 5; Table 3). Similarly, spike length was higher in BARI Gom 28 at lower soil pH that used in this experiment. This could the reason for near neutral soil pH. This soil pH is very useful for optimal plant growth. Another reason was that the BARI Gom 28 was considered as heat tolerant variety (Hossain and Silva 2012). As temperature was high during experiment period, so the BARI Gom 28 performed better under heat stress condition among all other varieties. This finding suggests that the BARI Gom 28 growth and yield performance, resulting from the close to neutral soil pH, was a general chemical reaction and nutrient uptake from soil that occurred throughout the soil mass. Likewise, the high pH soil is responsible for its oxidation. Thus, most readily available form of micronutrients converts into less soluble form after oxidation. Hence, the availability of micronutrients is reduced at higher pH level. Besides, at high pH level micronutrients are also precipitated as insoluble form which reduces its availability (Kumar and Babel 2011).

Varietal performance

The highly significant ($P \leq 0.001$) for different varieties yield parameters like grain per spike, spike length and growth yield performance in this study indicates that the growth and yield responses of BARI Gom 28, BARI Gom 27, BARI Gom 26 and prodip were dependent on the level of both soil types and high temperature stress. The different relative growth and yield responses among wheat varieties can readily be seen with the BARI Gom 28. With prodip, BARI Gom 26, and BARI Gom 27, there were no significant differences among these varieties there were no growth and yield for any measurement (Fig. 2 to 7), with wheat varieties being suppressed by the heat stress. The lowest growth and yield performance of prodip variety is due to its sensitivity to heat. However, it is highly tolerant to Bipolaris leaf blight and resistant to leaf rust. In contrast, the highest growth and yield performance of BARI Gom 28 could be due to its tolerant to terminal heat stress in late seeding. The BARI Gom 28 is also resistant to leaf rust and tolerant to Bipolaris leaf blight (BARI Annual Report, 2012). Regardless of that the danger posed by the Ug99 strain of stem rust to global wheat production is widely recognized, including in Bangladesh. BARI Gom- 27 is the first Ug99 resistant wheat variety was a major step to countering the threat of this disease in Bangladesh. Subsequently, the variety Francolin (also known as BARI Gom 27) was released in March, 2012.

Effect of soil types on wheat varieties

A different type of soils has varied growth and yield response on wheat varieties. This could be due to the fact that the collected various soil samples were from different agro-ecological zones of Bangladesh. Several report stated that the soil organic status is remarkably declining in different agro-ecological zones in Bangladesh. Each agro-ecological zone has their own climatic, environmental, soil physical and chemical properties that may affect growth and yield of different wheat varieties (Faisal and Parveen,2004). There were significantly higher growth and yield in the BARI Gom 28 compared with BARI Gom 27, BARI Gom 26 and prodip with the most soil pH. These occurred with soil pH 7.1, soil pH 7.3, soil pH 7.8 and soil pH 8.2 treatments (Fig. 2 to 7). These findings were responsible for the highly significant ($P<0.001$) varietal variation (Table 3). My findings clearly demonstrated that the BARI Gom 28 were superior in growth and yield response than among other wheat varieties in different soil types. Likewise, grain yield of wheat varieties tended to be varied due to varietal difference under different soil types that collected from different Agro-Ecological Zone (AEZ's).

Conclusion

The present research work was carried out to evaluate the phenology, growth and yield of wheat varieties which affected by different soil types. The experiment contains four modern wheat varieties viz. BARI Gom 26, BARI Gom 27, BARI Gom 28 and prodip and four types of soil. Soil was collected from Ghoraghat-Dinajpur (AEZ-27), Tanor-Godagari (AEZ-11), Neamatpur-Naogaon (AEZ-26), Rajshahi sadar area (AEZ-11), which pH was 7.1, 7.3, 7.8, and 8.2. A completely block design was used for the experiment. The treatment was repeated for three times. Thus, the findings indicated that the BARI Gom 28 have the potentials to be adapted under various soil pH conditions in different agro-ecological zone. The BARI Gom 28 could be promoted for the expansion of wheat production in Bangladesh.

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