Progress. Agric. 19(1) : 13-21, 2008 ISSN 1017-8139

EFFECTS OF SOIL MOISTURE, NPK FERTILIZERS AND VARIETIES ON GRAIN GROWTH OF BARLEY (*Hordeum vulgare* L.)

M. S. I. Mollah, M. H. Rashid[1], M. S. Hossain[2] and M. Khalekuzzaman[2]
Institute of Biological Science (I.B.Sc), University of Rajshahi, Rajshahi-6205, Bangladesh

ABSTRACT

The experiments are conducted in the experimental field of the Department of Botany, Rajshahi University during the winter season of 2005-2006 to study the effects of soil moisture and NPK fertilizers on grain growth of four barley varieties (*Hordeum vulgare* L.) following split-split plot design. The highest grain growth parameters like, spikelet number, spike dry weight, grain number and grain dry weight, spike relative growth rate and grain relative growth rate were observed in the I_2 treatment at different days after anthesis. F_3 treatment produced the highest spikelet number, spike dry weight, grain number, grain dry weight, spike relative growth rate and grain relative growth rate but the control produced the lowest values. BHL-3 produced higher spikelet number and grain relative growth rate. BL-1 produced higher spike dry weight, grain number, grain dry weight and spike relative growth rate.

Key words : Soil moisture, Fertilizers, Varieties, Barley, Grain growth

NTRODUCTION

Barley is an important cereal crop cultivated successfully in a wider range of climate. It is the fourth grain crop both in area and production in the world after maize, wheat and rice. In Bangladesh, it is grown as a minor crop (rabi crop) mainly in the northern part of the country. It ranks third after rice and wheat as supplementary food and fodder crop in Bangladesh (FAO, 2002). In the whole world, now barley is an important crop for direct human consumption and for animal feed. The most important uses of barley are grain feed to livestock and poultry. It is also used in preparing "chapaties" and sometimes barley is mixed with gram or wheat for preparing better quality chapaties. Barley grain can be is used to prepare 'Sattu' (Barley flour is mixed with sugar and water). Grain is also broken and roughly ground into pearl barley to be used in soup. Diluted soup made from barley is used to feed the infants as Horlicks, Ovaltine, Robinson's barley, Hamilton's barley flour, Pancake mix, Viva and Multova etc. These are baby foods, for which in Bangladesh, several industries and pharmaceutical companies have to import a large amount of barley grain and malt extract for manufacturing baby patient's food and medicine.

Barley is high in carbohydrates with moderate amounts of protein, calcium and phosphorus. It is the source of B-vitamins, such as thiamin, riboflavin and niacin. It is also

[1] Department of Botany, University of Rajshahi, Rajshahi-6205, Bangladesh
[2] Department of G Engineering and Biotechnology, University of Rajshahi, Rajshahi-6205, Bangladesh

very good source of dietary fiber. It has 4.5% soluble and 9% insoluble fiber. Fiber in barley is more soluble than those of oat and wheat. Barley flour contains 13.5% total dietary fiber, while wheat flour contains only 9% total dietary fiber (BARI, 2003-2004). Huge amount of vitamin, protein and minerals are available in barley, which is useful to keep our body healthy and disease free (BARI, 2003-2004). Foods prepared from barley are useful for diabetic and high blood pressure patients. It is suggested that barley could be therapeutic diet for diabetic patient, a good diet for kidney patient and the referred diet after convalescence (Ikegami *et al.,* 1991).

In spite of all these positive facts about barley, the barley cultivation trend in the country is consistently down word. The area and production of barley for the fiscal year 1991-92 were 40,000 acres and 10,000 tons, whereas, it is 3,000 areas and 1,000 tons in 2004-2005 respectively. Thus, it is needed to cultivate barley to popularize among the growers. Barley through a minor crop of the country can play an important role in enhancing the food security of the country. The areas, where it grows well may be brought under barley cultivation. Whereas wheat, maize or rice cannot be possible to cultivate profitably due to saline or stress environment should be brought under barley cultivation (BARI, 2003-2004).

Proper land preparation, optimum time of sowing, recommended doses of fertilizer and irrigation are not usually practiced to raise the crop production. Thus, the productivity of this crop is very poor compared to that of the other countries. There are many reasons for this and these are lack of well developed irrigation facilities, increased cost of irrigation and fertilizers, lack of stress tolerant high yielding varieties (HYVs) and lack of saline tolerant HYVs etc. Among these, water being extremely limited in most of the barley growing areas and essentially demands high efficiency in it's use.

Again, farmers of Bangladesh use different fertilizers indiscriminately without adequate information concerning actual soil requirements. A clear understanding on use of different doses of NPK fertilizers and their utilization efficiency are pre-requisite to avoid indiscriminate use of fertilizers.

However, very little work has been done in Bangladesh to develop package of improved management practices required to achieve higher yield of this crop. Thus, the objectives of this investigations were-

i) to study the effects of soil moisture and NPK fertilizers on grain growth of barley.

ii) to assess optimum irrigation frequencies and to find out economic and optimum dose of NPK fertilizes.

iii) to find out a suitable variety of barley with respect to grain growth for higher yield.

MATERIALS AND METHODS

The experiment was conducted in the experimental field of the Department of Botany, University of Rajshahi during the period from November, 2005 to March, 2006 with for barley varieties namely BARI Barley-1, BARI Barley-2, BHL-3 and BL-1. The soil of the field was silty loam, having pH 7.5 as well as 35% moisture at field capacity. The experiment was arranged in split-split plot design with three replications. Each replicated field was divided into three main plots for irrigation treatment. Each main plot was divided into four sub-plots for fertilizer treatment. Each sub-plot was lastly divided into four sub-sub plots for four varieties of barley. Three levels of irrigation treatments (0,20, and 40 mm as I_0, $I_1$and I_2, respectively) were adopted at every 30 days interval for three times during the growing period of the crop. Four levels of fertilizer treatments were used. NPK levels (kg/ha) for N as area were 0, 40, 80 and 120; for P as TSP were 0, 25, 50 and 75 and lastly for K as MP were 0,15, 30 and 45. These recommended basal doses of fertilizers were applied as F_0, F_1, F_2 and F_3 at each split plot before sowing of seeds. Each split plot size was 4 m × 1.8m, having a plot to plot distance 1m, replication to replication distance 2 m, row to row 20 cm, and plant to plant 5 cm. Intercultural operations sere adopted as and when necessary.

For grain growth analysis, five grain harvests were done at equal interval of seven days after anthesis. For this, main spike per plant per treatment per variety per replication was selected, tagged with identifying marks to collect them at 7, 14, 21, 28 and 35 days after anthesis (DAA), At each harvest, the spikes were packed separately in labelled paper bags and were dried in oven for 72 hours at 85^0C. Various components of grain growth analysis were spikelet number, (SN), spike dry weight (SDW) in gm, grain number (GN) and grain dry weight (GDW) in gm, spike relative growth rate (Spike RGR) and relative growth rate (Grain RGR) were also determined from between two successive harvests of spike and grain growth stages by using the following formulae according to the classical technique of growth analysis (Radford, 1967).

$$RGR = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{t_2 - t_1}$$

Where, W_2 and W_1 are the spike or grain dry weights per spike (main tiller) at the later (t_2) and the former (t_1) grain growth harvest respectively.

Statistical analysis was carried out following to Gomez and Gomez, 1984.

RESULTS AND DISCUSSION

Effect of irrigation

Mean squares from the analysis of variance of Spikelet number, spike dry weight (g), grain number, grain dry weight (g), spike RGR (gg^{-1} day^{-1}), grain RGR (gg^{-1} day^{-1}) of four barley varieties as influenced by different soil moisture regimes and NPK fertilizers are shown in Table 1. The lowest spiketet number was produced by the non-irrigated plants. Irrigation increased the number of spikelets $spike^{-1}$, thus the I_2 treatment produced the highest spikelet number (46.188) (Table 2). This result is corroborated with okuyama and Igarashi (1990); Rahman *et al*. (2001); Haider (2002); Rahman (2004) in wheat. Irrigated plants had higher spike dry weight (g) than the rainfed plants. The rainfed plants had the lowest spike dry weight (0.534g) at 7 DNA. Rahman and Paul (1998) noticed similar findings in wheat. The highest number of grains spike^{-1}(35.813) was in the irrigated plants (I_2 treatment) and the lowest (21.563) was in the control (I_0 treatment). Similar results were also reported by Labuschagne and Van-Deventer (1992) and Rahman (2004) in wheat. The highest grain dry weight (1.166 g) was in the I_2 treatment and the lowest was in the control (0.309 g). Similar results were also stated by Machado and Paulsen (2001); Haider (2002); Rahman (2004) in wheat. Rainfed condition resulted on the lowest RGR of spike (0.025 gg^{-1} day^{-1}) at 14 DAA. I_2 treatment had the highest RGR of spike (0.079 gg^{-1} day^{-1}) at 7 DAA. Higher grain RGR was in the irrigated plants (0.071 gg^{-1} day^{-1}) at 7 DAA than those in the rainfed plants (0.021 gg^{-1} day^{-1}). This result is in agreement with Haider (2002) in wheat.

Table 1. Mean squares from the analysis of variance of Spikelet number, spike dry weight (g), grain number, grain dry weight (g), spike RGR (gg-1 day-1), grain RGR (gg-1 day-1) of four barley varieties as influenced by different soil moisture regimes and NPK fertilizers

Sources of variation	df	Days After Anthesis (DAA)				
		7	14	21	28	35
		Spikelet number				
Replication	2	2126.8**	2590.4**	2605.7**	2590.4**	2590.4**
Irrigation	2	22.000	5.671	9.015	5.671	5.671
Error (a)	4	5.083	10.734	14.078	10.734	10.734
Fertilizer	3	216.1**	171.1**	178.5**	171.1**	171.1**
I*F	6	5.963	14.921	8.890	14.921	14.921
Error (b)	18	13.819	17.057	18.504	17.057	17.057
Variety	3	3861.1**	4082.0**	4097.4**	4082.0**	4082.0**
I*V	6	6.199	2.296	1.890	2.296	2.296
F*V	9	32.5**	31.7**	33.4**	31.7**	31.7**
I*F*V	18	2.546	2.213	2.098	2.213	2.213
Error (c)	72	2.547	2.214	2.099	8.536	8.536
		Spike dry weight (g)				
Replication	2	0.082**	0.806**	1.803**	4.288**	4.414**
Irrigation	2	0.000004	0.002	0.003	0.002*	0.004
Error (a)	4	0.000002	0.003	0.006	0.000	0.003
Fertilizer	3	0.005**	0.020*	0.010	0.024	0.045**
I*F	6	0.0003	0.003	0.005	0.001	0.001
Error (b)	18	0.0006	0.006	0.013	0.023	0.008
Variety	3	2.102**	6.296**	10.488**	12.124**	11.396**
I*V	6	0.0001	0.0004	0.002	0.001	0.001
F*V	9	0.003**	0.013	0.008	0.021	0.016
I*F*V	18	0.0001	0.002	0.001	0.001	0.0003
Error (c)	72	0.001	0.009	0.017	0.031	0.014

Table 1 (Contd.)

Sources of variation	df	Days After Anthesis (DAA)				
		7	14	21	28	35
		Grain number				
Replication	2	1293.9**	1165.3**	1128.2**	931.0**	864.8**
Irrigation	2	1.6**	3.756	9.12*	7.9**	10.5**
Error (a)	4	0.063	1.663	0.908	0.063	0.203
Fertilizer	3	53.291	73.326	114.673	150.265	154.890
I*F	6	0.034	1.729	0.460	0.519	0.880
Error (b)	18	25.211	28.755	47.552	54.440	60.873
Variety	3	3242.4**	2831.7**	2717.4**	2531.3**	2457.8**
I*V	6	0.243	1.756	1.265	0.144	0.602
F*V	9	5.31*	4.053	6.8**	4.8**	6.0**
I*F*V	18	0.423	1.710	0.885	0.111	0.343
Error (c)	72	2.638	4.066	3.386	1.770	1.453
		Grain dry weight (g)				
Replication	2	0.086**	0.515**	0.674**	1.558**	2.718**
Irrigation	2	0.0001	0.0001	0.0011	0.0028	0.015**
Error (a)	4	0.0007	0.0001	0.0005	0.0002	0.0002
Fertilizer	3	0.011**	0.0021*	0.0126	0.105*	0.4228*
I*F	6	0.0004	0.00004	0.0007	0.0007	0.0022
Error (b)	18	0.0011	0.0006	0.0059	0.028	0.095
Variety	3	1.131**	1.851**	2.522**	4.438**	6.609**
I*V	6	0.0003	0.00004	0.0006	0.0006	0.0016
F*V	9	0.0033	0.0003	0.0056	0.0206	0.039**
I*F*V	18	0.0003	0.00004	0.0006	0.0001	0.0007
Error (c)	72	0.0018	0.00091	0.0006	0.0110	0.0124
		Spike RGR (gg^{-1} day^{-1})				
Replication	2	0.0042**	0.0004	0.0014**	0.0001	
Irrigation	2	0.00006	0.00001	0.00002	0.00001	
Error (a)	4	0.00008	0.00013	0.00005	0.00006	
Fertilizer	3	0.00005	0.0004*	0.00016	0.00031	
I*F	6	0.00007	0.00008	0.00007	0.00002	
Error (b)	18	0.00018	0.000	0.00011	0.00017	
Variety	3	0.0029**	0.0041**	0.0056**	0.0077**	
I*V	6	0.00001	0.00006	0.00011	0.00001	
F*V	9	0.0004*	0.00015	0.00012	0.0002	
I*F*V	18	0.00003	0.00006	0.00004	0.00001	
Error (c)	72	0.00017	0.00090	0.00023	0.00034	

Table 1 (Contd.)

Sources of variation	df	Days After Anthesis (DAA)				
		7	14	21	28	35
		Grain RGR (gg^{-1} day^{-1})				
Replication	2	0.0092**	0.0009**	0.0013**	0.0006**	
Irrigation	2	0.00004	0.000002	0.00004**	0.00013	
Error (a)	4	0.00010	0.000003	0.000001	0.00002	
Fertilizer	3	0.00076*	0.000002	0.0006**	0.0012**	
I*F	6	0.00011	0.000001	0.00002	0.00003	
Error (b)	18	0.00024	0.000050	0.0002	0.0002	
Variety	3	0.0175**	0.0005**	0.0013**	0.0006**	
I*V	6	0.00007	0.000001	0.00001	0.000001	
F*V	9	0.00039	0.00013	0.00018*	0.000095	
I*F*V	18	0.00004	0.000001	0.000001	0.000021	
Error (c)	72	0.00020	0.000001	0.000070	0.000074	

Table 2. Effect of irrigation on mean values of spikelet number, spike dry weight (g), grain number, grain dry weight (g), spike RGR (gg^{-1} day^{-1}) and grain RGR (gg^{-1} day^{-1}) at different days after anthesis

	Days after anthesis (DAA)					Days after anthesis (DAA)				
	07	14	21	28	35	07	14	21	28	35
	Spikelet number					Spike dry weight (g)				
I_0 (00 mm)	29.219	31.563	31.563	31.563	31.563	0.534	0.829	0.970	1.188	1.445
I_1 (20 mm)	35.969	40.094	40.094	40.094	40.094	0.593	1.032	1.251	1.575	1.863
I_2 (40 mm)	42.531	46.188	46.188	46.188	46.188	0.614	1.076	1.343	1.789	2.032
LSD (5%)	1.285	1.867	2.139	1.867	1.867	0.001	0.033	0.044	0.010	0.031
	Grain number					Grain dry weight (g)				
I_0 (00 mm)	25.438	23.563	22.406	21.688	21.563	0.309	0.411	0.511	0.592	0.699
I_1 (20 mm)	31.000	28.500	26.594	25.031	24.844	0.367	0.493	0.584	0.709	0.856
I_2 (40 mm)	35.813	33.656	32.000	30.281	29.875	0.392	0.618	0.744	0.951	1.166
LSD (5%)	0.143	0.735	0.543	0.145	0.257	0.015	0.004	0.013	0.013	0.008
	Spike RGR (gg^{-1} day^{-1})					Grain RGR (gg^{-1} day^{-1})				
I_0 (00 mm)	0.062	0.025	0.032	0.030		0.047	0.034	0.022	0.021	
I_1 (20 mm)	0.077	0.027	0.037	0.027		0.048	0.026	0.026	0.025	
I_2 (40 mm)	0.079	0.030	0.044	0.026		0.071	0.025	0.032	0.028	
LSD (5%)	0.005	0.006	0.004	0.004		0.006	0.001	0.001	0.001	

Effect of NPK fertilizers

Fertilizer applied plants produced higher number of spikilet $spike^{-1}$ than that of non-fertilized plants. F_3 treatment produced the highest spikelet number (49.875) and this number increased with the increase of NPK application (Table 3). Similar trend of the effects of fertilizer was noticed in barley by Alam (2003) and in wheat by Singh *et al.* (1992); Patel *et al.* (1995); Tarique (2003); Rahman (2004); Khaleque (2005). Higher spike dry weight (2.446 g) was produced by the fertilizer applied plants than that of the control. The non-fertilizer treatment resulted in the lowest spike dry weight (1.143 g) at 35 DAA. This result was also corroborated with Rahman (2004); Khaleque (2005) in wheat. F_3 Fertilizer plants produced the highest number of grains spike^{-1} (33.417) and the lowest was in no fertilizer application treatment. Rahman (2004); Khaleque (2005) noticed similar findings in wheat. Higher grain dry weight (g) was in the fertilizer treated plants than in the control. Increased grain dry weight (g) was produced by increasing fertilizer levels. F_3 treatment had the highest grain dry weight (1.347g). Haque (2000); Rahman (2004); khaleque (2005) reported similar findings in wheat. The highest spike RGR was obtained in the F_3 treatment (0.077 gg^{-1} day^{-1}) at 7 DAA and the lowest was in F_1 treatment (0.017 gg^{-1} day^{-1}). The lowest grain RGR was in the non-fertilized plants at all the DAA. Fertilizer treated plants had higher grain RGR than the control. The highest grain RGR (0.049 gg^{-1} day^{-1}) was in the F_3 treatment. Rahman (2004) and Khaleque (2005) found similar findings in wheat.

Table 3. Influence of fertilizer on mean values of spikelet number, spike dry weight (g), grain number, grain dry weight (g), spike RGR (gg^{-1} day^{-1}) and grain RGR (gg^{-1} day^{-1}) at different days after anthesis

	Days after anthesis (DAA)					Days after anthesis (DAA)				
	07	14	21	28	35	07	14	21	28	35
	Spikelet number					Spike dry weight (g)				
F_0 (00 00 00)	23.667	25.375	25.375	25.375	25.375	0.273	0.430	0.554	0.803	1.143
F_1 (40 25 15)	31.501	37.125	37.125	37.125	37.125	0.516	0.937	1.055	1.370	1.542
F_2 (80 50 30)	41.583	44.750	44.750	44.750	44.750	0.705	1.127	1.295	1.738	1.986
F_3(120 75 45)	46.875	49.875	49.875	49.875	49.875	0.827	1.427	1.852	2.173	2.446
LSD (5%)	1.840	2.044	2.129	2.044	2.044	0.011	0.034	0.062	0.075	0.130
	Grain number					Grain dry weight (g)				
F_0 (00 00 00)	20.125	18.333	16.958	15.875	15.625	0.123	0.231	0.287	0.334	0.387
F_1 (40 25 15)	26.208	24.417	22.792	21.583	21.583	0.322	0.426	0.526	0.614	0.742
F_2 (80 50 30)	35.042	33.000	31.833	30.917	30.917	0.449	0.621	0.740	0.932	1.149
F_3(120 75 45)	41.625	38.458	36.992	34.083	33.417	0.530	0.750	0.898	1.131	1.347
LSD (5%)	2.485	2.654	3.413	3.652	3.862	0.016	0.012	0.038	0.083	0.153
	Spike RGR (gg^{-1} day^{-1})					Grain RGR (gg^{-1} day^{-1})				
F_0 (00 00 00)	0.065	0.036	0.053	0.048		0.038	0.023	0.020	0.019	
F_1 (40 25 15)	0.066	0.017	0.037	0.017		0.038	0.024	0.022	0.026	
F_2 (80 50 30)	0.067	0.020	0.040	0.021		0.046	0.025	0.032	0.028	
F_3(120 75 45)	0.077	0.036	0.023	0.018		0.049	0.025	0.031	0.029	
LSD (5%)	0.007	0.006	0.005	0.006		0.029	0.003	0.006	0.007	

Effect of varieties

BHL-3 had the highest number of spikelet spike^{-1} among the varieties (41.250). BL-1 had the highest spike dry weight (1.813 g) as well as grain dry weight (1.058 g) at the last harvest. Again the highest grain number (28.333) was found in BL-1 at the first harvest. At first harvest interval, BL-1 had the highest spike RGR, whereas, the highest grain RGR was observed in BHL-3 (Table 4).

Table 4. Mean values of spikelet number, spike dry weight (g), grain number, grain dry weight (g), spike RGR (gg^{-1} day^{-1}) and grain RGR (gg^{-1} day^{-1}) at different days after anthesis as influenced by varieties

	Days after anthesis (DAA)					Days after anthesis (DAA)				
	07	14	21	28	35	07	14	21	28	35
	Spikelet number					Spike dry weight (g)				
BARI Barley-1	34.125	41.000	41.000	41.000	41.000	0.563	0.953	1.179	1.502	1.745
BARI Barley-2	34.625	38.000	38.000	38.000	38.000	0.588	0.992	1.171	1.510	1.807
BHL-3	39.500	41.250	41.250	41.250	41.250	0.577	0.976	1.198	1.512	1.752
BL-1	35.375	36.175	36.875	36.875	36.875	0.592	1.008	1.208	1.559	1.813
LSD (5%)	0.750	1.041	0.987	0.987	0.987	0.017	0.044	0.061	0.083	0.055
	Grain number					Grain dry weight (g)				
BARI Barley-1	29.625	27.250	25.333	23.833	23.583	0.337	0.498	0.593	0.712	0.814
BARI Barley-2	30.125	27.875	26.417	25.292	25.208	0.373	0.506	0.606	0.736	0.902
BHL-3	30.833	28.176	26.500	24.792	24.417	0.346	0.506	0.609	0.730	0.851
BL-1	32.417	30.917	29.625	28.542	28.333	0.368	0.519	0.642	0.832	1.058
LSD (5%)	0.763	0.948	0.865	0.625	0.567	0.012	0.014	0.012	0.049	0.052
	Spike RGR (gg^{-1} day^{-1})					Grain RGR (gg^{-1} day^{-1})				
BARI Barley-1	0.072	0.031	0.037	0.025		0.060	0.027	0.025	0.020	
BARI Barley-2	0.072	0.023	0.040	0.030		0.049	0.028	0.026	0.028	
BHL-3	0.073	0.030	0.035	0.025		0.057	0.029	0.022	0.020	
BL-1	0.075	0.026	0.040	0.024		0.055	0.030	0.032	0.031	
LSD (5%)	0.006	0.006	0.007	0.009		0.007	0.000	0.004	0.004	

From the present study, it is revealed that-

i) Increasing levels of soil moisture and NPK fertilizers influenced to increase the different characters of grain. BHL-3 produced the highest spikelet number (SN) and grain RGR and BL-1 produced the highest spike dry weight (g), grain number, grain dry weight (g) and spike RGR.

ii) Among the four varieties of barley, BL-1 was highest in grain growth at the highest level of irrigation and fertilizer than that of control (Mollah, 2007).

iii) If the soil moisture and fertilizer levels are maintained properly, better grain growth and higher grain yield can be achieved from the variety BL-1.

REFERENCES

Alam, M. Z. 2003. *Influence of planting dates and nitrogen levels on growth, grain yield and nitrogen utilization of barely (Hordeum vulgare* L). Ph. D. Thesis, Crop Physiology Laboratory, Department of Botany, Rajshahi University, Rajshahi. pp. 61-292.

BARI (Bangladesh Agricultural Research Institute). 2003-2004. Barley Improvement. Annual Research Report. Plant Breeding Division. Joydebpur, Gazipur. p. 1.

FAO, 2002. FAOSTAT: Statistics database (online.) (Subset production within Agriculture database) Available at http:11apps.fao.org

Gomez, K. A. and Gomez, A. A. 1984. Statistical procedure for agricultural research. John wiley and sons. New York.

Haider, S. A. 2002. *Effect of water stress on the physiology and grain yield of four bread wheat* (*Triticum aestivum* L.) *cultivars*. Ph.D. Thesis, Crop Physiology Laboratory, Department of Botany, Rajshahi University. Rajshahi. pp. 71-342.

Ikegami, S., Tsuchihashi, F., Nakamura, K. and Innami, S. 1991. Effects of barley on development of diabetes in rats. *J. Jap. Soc. Nut. Food Sci*. 44 (6): 447-454.

Khaleque, M. A. 2005. *Study on growth and yield of modern wheat varieties in different agronomic management practices*. Ph. D. Thesis, Institute of Biological Sciences, Rajshahi University. Rajshahi. pp. 53-243.

Labuschange, M. T. and Van- Deventer, C. S. 1992. The effect of moisture stress on the yield and yield components of several wheat cultivars and their F_1 hybrids. *J. Agron. Crop Sci*. 168(3): 153-158.

Machado, S. and Paulsen, G. M. 2001. Combined effects of drought and high temperature on water relations of wheat and sorghum. *Plant and Soil*. 233(2): 179-187.

Mollah, M. S. I. 2007. *Studies on the physiological attributes and there relationship to yield of barley* (*Hordeum vulgare* L) *under different soil moisture regime and NPN fertilizers*. Ph.D. Thesis, Crop Physiology Laboratory, Department of Botany, Rajshahi University, Rajshahi. pp. 115-156, 168-194.

Okuyama, L. A. and Igarashi, S. 1990. Grain yield and yield components of wheat as a function of water stress at tillering stage. Informa-Da-Pesquisa-Instituto-Agronomic Da-Parana. 94: 49-52.

Patel, N. M., Sadarja, S. G., B. B and Khanpara, V. D. 1995. Effect of nitrogen, potassium and Zinc on growth and yield of wheat (*Triticum aestivum*). *Indian J. Agron*. 40 (2): 290-292.

Radford, P. J. 1967. Growth analysis formulae-their use and abuse, *Crop Sci*. 7: 171-175.

Rahman, M. A. 2004. Effect of irrigation on nitrogen uptake, yield attributes of wheat varieties. Ph.D. Thesis, Crop physiology Laboratory, Department of Botany, Rajshahi University. pp. 45-257.

Rahman, M. S. and Paul, N. K. 1998. Effect of soil regimes on physiological characters and yield of wheat cultivars. *J. Bio. Sci*. 6: 5-10.

Rahman, M. S., Sarker, A. M. Islam, M. S. and Paul, N. K. 2001. Effect of Soul mosture on grain yield of wheat (*Triticum aestivum* L.) cultivars. *Environment & Ecol*. 19 (2): 304-308.

Singh, R. V., Dubey, V. K. and Vyas, M. D. 1992. Effect of Seed rate, nitrogen level and method of fertilizer placement on wheat (*Triticum aestivum*) under the sown condition. *Indian J. Agron*. 37(1): 43-46.

Tarique, M. H. 2003. *Growth and yield of wheat* (*Triticum aestivum* L.) *in relation to NPK fertilizers and competition*. Ph.D. Thesis, Crop Physiology Laboratory, Department of Botany, Rajshahi University, Rajshahi. pp. 51-145, 149-258.