Hindawi Publishing Corporation
Advances in Agriculture
Volume 2014, Article ID 250874, 6 pages
http://dx.doi.org/10.1155/2014/250874

Research Article

Effect of Irrigation Regimes and Nitrogen Levels on the Growth and Yield of Wheat

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Received 25 February 2014; Accepted 18 June 2014; Published 1 July 2014

Academic Editor: Ayman Suleiman

A field experiment was carried out to evaluate the effect of irrigation regimes and nitrogen levels on the growth and yield of wheat cv. Kanchan (*Triticum aestivum* L.). The experiment includes two factors such as four irrigation regimes and four nitrogen levels. Three farmer's fields were selected for experimentation as replication. Yield and yield contributing factors were significantly affected by irrigation regimes and different doses of nitrogen. Maximum grain yield of 2.27 t ha^{-1} by the application of 200 mm irrigation treatment. Interaction between 200 mm irrigation and 120 kg N ha^{-1} was the best combination treatment.

1. Introduction

Wheat is the second most important cereal crop and covers 0.64 million ha of land with an annual production of 1.2 million tons in Bangladesh [1]. Area under wheat is increasing because wheat requires less amount of irrigation compared to other cereal crops like rice. Wheat is grown in the driest months of the year when rainfall is scarce. Water balance analysis at Mymensingh region in Bangladesh depicts that during January to April and November to December potential evapotranspiration (PET) is higher than precipitation (Figure 1). Irrigation is necessary in order to grow crops during this period because of insufficient amount of rain water and high atmospheric evaporative demand by crops (Figure 2). Nitrogen (N) is a key element for plant nutrition. Applying N and phosphorus (P) fertilizers and other management practices increased the yield of wheat but in some cases these show adverse effects due to severely limiting irrigation [2, 3]. Nitrogen use efficiency can be increased by combining fertilizer, soil, water, and management. Two main approaches can be undertaken: increasing the use of N during crop growing season and decreasing the losses of N by applying optimum doses [4]. Proper growth and development of wheat needs favorable soil moisture in the root zone. Extractable water capacity of soil has significant influence on wheat grain yield and water productivity response to irrigation [5]. The moisture content in the soil gradually decreases with time in dry season and simultaneously soil moisture tension increases. Excessive irrigation increases evapotranspiration and decreases water use efficiency and may also reduce grain yield [6]. Limited irrigation is an important constraint for wheat production in rainfed, tropical, arid, and semi-arid regions. In scarce rainfall conditions and less irrigation, the best management option for N and irrigation levels is to maintain the maize-wheat cropping sequence [7] and limited irrigation water is combined with N fertilizer [8] to get maximum productivity of wheat. Supplemental irrigation significantly increased the yield of wheat with respect to rainfed treatment. According to Karam et al. [9], about 50% of soil water deficit as supplemental irrigation and 150 kg N ha^{-1} was the optimum combination for maximum grain yield of wheat. Level of fertilization and irrigation is very important to increase the fertilizer efficiency and decrease the loss of water. At a very high tension (about 15 bar), plants cannot absorb water from the soil through root zone and as a result it has an ultimate impact on crop yield. Proper timing and frequency

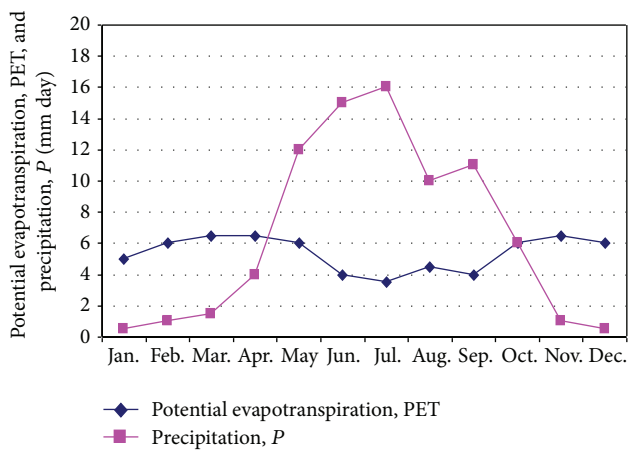


Figure 1: Hydrological balance of PET and precipitation at Mymensingh [28].

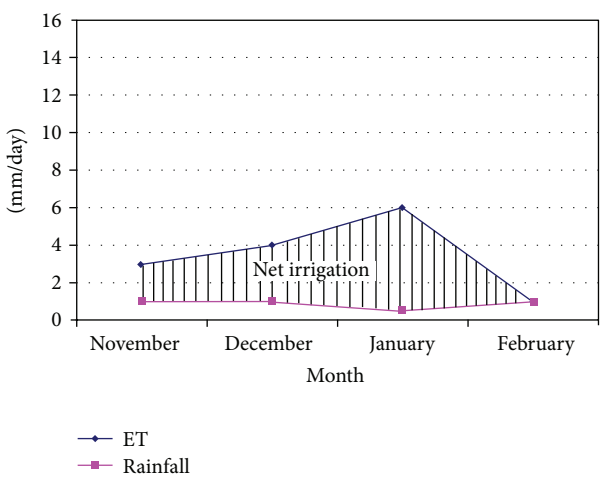


Figure 2: Net irrigation requirement of wheat [28].

of supplementary irrigation in relation to crop yield are crucial in irrigation scheduling for the most effective use of available water in optimizing wheat production [10–19]. Lack of irrigation at heading and grain formulation and during maturation significantly reduced the yield of wheat grain [20–26]. Grain yield increased with increase in the frequency of irrigation [27]. Improper scheduling of irrigation results not only in wastage of water but also in decreasing crop growth and yield [28–30]. Nitrogen for wheat production is equally important to realize the yield potential. Among the different elements of Bangladesh soil, N is the key input for achieving higher yield of wheat. Although application of nitrogenous fertilizer could increase yield to a certain level, it has adverse effect when the optimum level is exceeded [31]. Irrigation water dissolved the fertilizers and was made available to the crop for proper growth and development. Therefore, an attempt has been made to evaluate the effect of irrigation regimes and N levels and the best combination on the yield and yield contributing parameters of wheat.

2. Materials and Methods

The experiment was conducted at Mymensingh region in Bangladesh using three farmer's fields to evaluate the effect of irrigation regimes and N level on the performance of wheat cv. Kanchan. The experiment included two factors (1) four irrigation regimes ((no irrigation), 100 mm at 30 days after sowing (DAS), 200 mm (100 mm at 30 DAS + 100 mm at 45 DAS), and 300 mm (100 mm at 30 DAS + 100 mm at 45 DAS + 100 mm at 60 DAS)) and (2) four N levels (00, 80, 100, and 120 kg N ha^{-1}). The experiment was laid out in a split plot design with irrigation as main plot and N as subplot. The soil texture is loam. During land preparation the soil pH ranged from 6.02 to 7.62 and organic carbon varied from 0.51to 1.63%. The land was prepared by the farmers with country plough followed by laddering. Three farmer's fields were selected for experimentation as replication. The unit plot size was 2.5 m × 4 m (10 m^2). Triple superphosphate (TSP), muriate of potash (MP), and gypsum were applied at the rates of 80 kg P_2O_5, 60 kg K_2O, and 30 kg S ha^{-1}, respectively. One-third of the N along with the complete doze of TSP, MP, and S were applied at the time of final land preparation. The remaining two-thirds urea was top-dressed in two equal splits, namely, at 30 and 45 DAS. Data on grain and straw yield, plant height, number of ears per plant, length of ear, number of grains per ear, and 1000 grain weight were recorded. Data were analyzed following analysis of variance technique with the computer package M-stat and mean comparison was performed using Duncan's Multiple Range Test [32].

3. Results and Discussion

Effect of irrigation regimes and N levels on the yield and yield contributing characters of wheat are presented in Table 1. The yield and yield parameters were significantly affected due to application of nitrogen and irrigation water. For higher yield, it is better to apply nitrogen at the stem elongation and heading unless it is not irrigated with minimum amount of water [33]. Maximum plant height was recorded in 300 mm irrigation treatment and shortest in the control. Availability of well distributed soil moisture at different growth stages due to irrigation probably enhanced the growth of plant. Due to application of irrigation water, ears per plant were significantly increased and followed similar pattern as in number of tillers per plant. Similar trend was found in the case of ear length. Plant height and ears per plant increased with the increasing rate of N doses but were not statistically different. Maximum number of tiller per plant was produced in 200 mm irrigation treatment which was statistically similar with other irrigation treatments except for the control. The effective tillers per plant were statistically different at 5% level of significance but identical among the nitrogen treatments. The maximum number of effective tillers per plant was obtained by applying 100 kg N ha^{-1} and the lowest in control. The result revealed that the applications of 80 to 120 kg N ha^{-1} treatment were statistically identical in respect of tillers per plant. Islam [34] reported that the maximum number of tillers per plant was obtained with 120 kg N ha^{-1} and the minimum in control. Ear length showed significant

Table 1: Effect of irrigation and nitrogen on the yield and yield contributing characters of wheat.

Treatments	Plant height (cm)	Tillers plant^{-1} (no.)	Ears plant^{-1} (no.)	Ear length (cm)	Grains ear^{-1} (no.)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	1000 grain weight (g)
Irrigation								
I_0 (00 mm)	62.75^{b}	2.49^{b}	2.18^{b}	7.35^{b}	35.75^{b}	1.74^{d}	4.12^{d}	42.83^{b}
I_1 (100 mm)	65.62^{ab}	2.85^{a}	2.53^{a}	7.78^{a}	36.82^{ab}	1.99^{c}	4.38^{c}	43.50^{ab}
I_2 (200 mm)	65.87^{ab}	2.90^{a}	2.70^{a}	8.04^{a}	38.23^{a}	2.27^{a}	5.12^{a}	44.57^{a}
I_3 (300 mm)	67.80^{a}	2.81^{a}	2.59^{a}	7.95^{a}	38.10^{a}	2.14^{b}	4.71^{b}	44.50^{a}
P	<0.05*	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**
Nitrogen								
N_0 (00 kg/h)	63.92	2.63^{b}	2.40	7.02^{b}	34.15^{b}	1.84^{c}	3.96^{c}	42.58^{c}
N_1 (80 kg/ha)	65.62	2.77^{a}	2.48	7.98^{a}	37.37^{a}	1.97^{b}	4.53^{b}	43.50^{bc}
N_2 (100 kg/ha)	64.65	2.83^{a}	2.53	7.88^{a}	38.92^{a}	2.15^{a}	4.87^{a}	44.58^{ab}
N_3 (120 kg/ha)	67.75	2.82^{a}	2.59	8.25^{a}	38.47^{a}	2.18^{a}	4.97^{a}	44.83^{a}
P	ns	<0.05**	ns	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**

In a column, having common letters (s) do not differ significantly but dissimilar letter differ significantly. ns, $*$, $**$, mean non-significant, significant at $P \leq 0.05$ and $P \leq 0.01$, respectively.

difference by the use of different levels of nitrogen. The longest ear was observed from application of 120 kg N ha^{-1} and the shortest in control. S. P. Singh and H. B. Singh [35] stated that ear length increased with increasing of nitrogen levels (0 to 120 kg N ha^{-1}). Grains per ear increased with increasing rate of nitrogen up to 100 kg N ha^{-1} and then decreased. The number of grains per ear was statistically similar due to application of 80 to 120 kg N ha^{-1} and significantly superior over control. Similarly results were obtained by Patel et al. [36]. Influence of irrigation on grain yield was statistically significant at 1% level of significance. Maximum grain yield was obtained in 200 mm irrigation treatment and minimum in control. These results are in conformity with the findings of Islam [34]. He reported that grain yield of 2.10 t ha^{-1} was obtained in 120 mm irrigation and 1.70 t ha^{-1} in control. The grain yields were significantly influenced by different levels of nitrogen. The grain yield was maximum due to application of 120 kg N ha^{-1} and statistically similar to that of 100 kg N ha^{-1} and both were significantly superior to 80 kg N ha^{-1}. These results are in agreement with the findings of Patel and Upadhyay [37]. Different irrigation regimes were found to have significant effect on the straw yield. Straw yield exhibited the tendency of increasing with the influence of irrigation levels. This might be due to the luxuriant vegetative growth in terms of plant height and number of tillers per plant. The maximum straw yield was obtained with 200 mm irrigation and minimum in control. Islam [34] reported that straw yield of 2.74 t ha^{-1} was found with the application of 180 mm irrigation water. Straw yield followed similar pattern to grain yield. This might be due to the exuberant vegetative growth noted in case of higher doses of nitrogen. Higher straw yield was obtained in 120 kg N ha^{-1} treatment and statistically superior to 0 to 80 kg N ha^{-1}. A significant variation was recorded for 1000 grain weight owing to difference in irrigation levels. 1000 grain weight was statistically similar in all irrigation treatments but the control

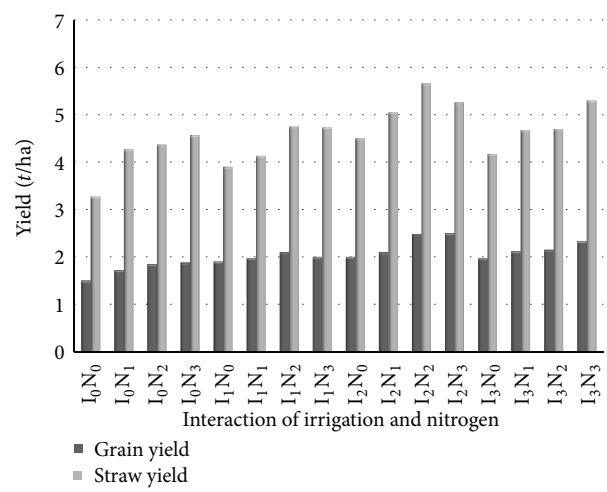
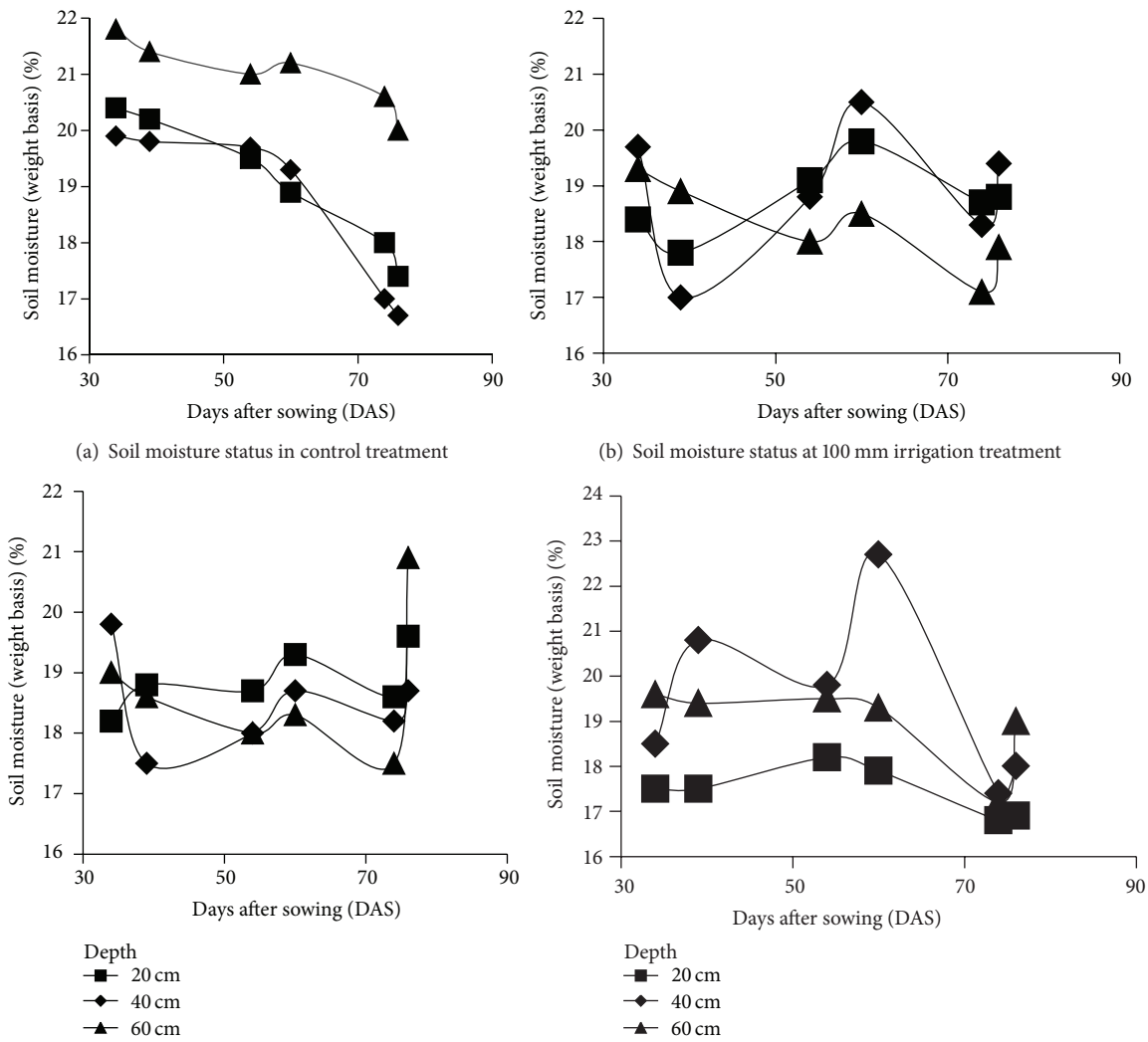


Figure 3: Combined effect of irrigation and nitrogen on the performance of wheat.

produced the lowest weight. S. P. Singh and H. B. Singh [35] reported that 1000 grain weight varied significantly with variable number of irrigation. Different N levels had significant influence on 1000 grain weight. Maximum weight of 1000 grain was found with 120 kg N ha^{-1} and minimum weight was observed with control.

Interaction between irrigation and nitrogen did not show significant effect on plant height, tillers plant^{-1}, grains ear^{-1}, and 1000 grain weight. The interaction effect of irrigation and nitrogen application on ear length was statistically significant. The longest ear was observed due to 200 mm irrigation with 80 kg N ha^{-1}. Maximum grain yield was obtained due to application of 200 mm irrigation water and 120 kg N ha^{-1} (Figure 3) which was statistically similar to the 200 mm irrigation and 100 kg N ha^{-1} treatment. Minimum grain yield was obtained in the combination of no irrigation and no



(a) Soil moisture status in control treatment

(b) Soil moisture status at 100 mm irrigation treatment

(c) Soil moisture status at 200 mm irrigation treatment

(d) Soil moisture status at 300 mm irrigation treatment

Figure 4: Soil moisture status at different depth of soil in irrigation treatments.

nitrogen treatment. These findings are corroborated with the observations by Kumar et al. [38]. Straw yields varied significantly at 1% level under different irrigation regimes and doses of nitrogen. It can be seen that straw yield increased with the increasing depth of irrigation and the highest rates of nitrogen fertilizer. Maximum straw yield was recorded by the application of 200 mm irrigation with 100 kg N ha^{-1} and the minimum straw yield was produced in control. Eventually, it may be concluded that a combination of 200 mm irrigation and 120 kg N ha^{-1} is the best in respect of yield and yield contributing characters.

The moisture status of the experimental plots during growing period of wheat is shown in Figure 4. Percentage of soil moisture gradually decreased through the soil profile in control (Figure 4(a)). Moisture status at 20 and 40 cm depths of soil decreased days after sowing and then gradually increased at every time of irrigation applied (Figures 4(b)–4(d)). It might be due to elapsed time of percolation through the soil profile. Soil moisture status at 60 cm depths followed similar trend but moisture status at 20 cm depth fluctuated at prior and following irrigation, respectively. It might be due to infiltration, evaporation, and water holding capacity of the soil.

The N contents in plots applied with 80, 100, and 120 kg N/ha treatments increased gradually up to 60 days after sowing (Figure 5). It may be due to the fact that one-third of the nitrogen was applied at sowing and the rest in two equal splits at 35 and 65 days after sowing (DAS). It can be seen that the nitrogen content decreased rapidly from 90 to 110 DAS because nitrogen was not applied at that period and also nitrogen uptake by plants may be higher due to flowering and grain formation.

4. Conclusions

The effects of combinations of irrigation regimes and nitrogen rates on yield and yield contributing parameters were studied at field level. Different doses of nitrogen significantly

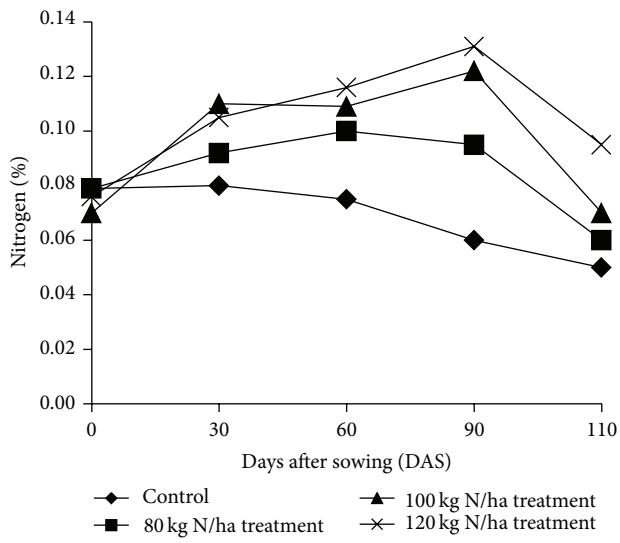


Figure 5: Nitrogen status of soil with different rates of N-application at different irrigation intervals (days).

influenced the grain yield and yield parameters. For the highest grain yield, nitrogen doses of 100 kg N ha^{-1} were the best treatment when considering nitrogen fertilizer only. Irrigation regimes also have significant effect on yield and growth parameters of wheat. The combination of 200 mm irrigation and 120 kg N ha^{-1} is the best treatment for optimal production of wheat.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgment

Financial support by the research Grant no. PY/2014/01708 of Universiti Teknologi Malaysia (UTM) is gratefully acknowledged.

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