

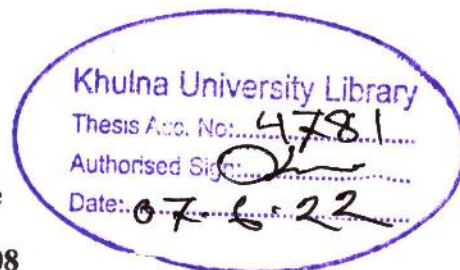
**YIELD RESPONSE OF WHEAT (*Triticum aestivum* L.) TO NITROGEN RATES UNDER
ZERO TILLAGE IN COASTAL SOIL OF SOUTHWESTERN BANGLADESH**

A Thesis

By

Shatabdi Jahan Joyee

Student ID.: MS-180808



**A Thesis (Course No. AGR-6104) Submitted to the Agrotechnology Discipline in Partial
Fulfillment of the Requirements for the Degree of Master of Science in Agronomy**

**AGROTECHNOLOGY DISCIPLINE
LIFE SCIENCE SCHOOL
KHULNA UNIVERSITY
KHULNA-9208**



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Abstract

The cropping intensity in the southwestern (SW) coastal region of Bangladesh is much lower compared to country average. Transplanted *aman* is the major crop in this area. In the recent years some *rabi* crops (wheat, sunflower, maize etc.) introduced in this region. Among the crops introduced farmers have given more preference on wheat over others. The fertility status of coastal soil is low to very low, specially in nitrogen (N). There is no fertilizer recommendation for wheat based cropping pattern in the SW coastal region. As an emerging cropping pattern, nutrient management is of prime importance as it comprises the major cost of crop cultivation. There is another problem of seed sowing and fertilizer application as the soil becomes excess wet during sowing time. To address the above mentioned issues a field experiment was conducted at Pankhali, Dacope, Khulna during *rabi* season (2018-19) with a view to examine the effect of N rates on growth and yield performance of wheat and find out the optimum rate under zero tillage condition. The experiment comprises of seven rates of N viz. 0, 60, 80, 100, 120, 140 and 160 kg ha⁻¹ with three replications. All the growth, phenological, yield and yield contributing parameters showed significant variation and gradually increased with the increasing amount of N up to 140 kg ha⁻¹ then declined. Nitrogen applied @ 140 kg ha⁻¹ produced maximum spike length (15.37 cm), number of spikelet spike⁻¹ (22.13), number of filled grain spike⁻¹ (32.80), grain spike⁻¹ (34.40), grain weight spike⁻¹ (8.11 g) and 1000 grain weight (43.37 g) and grain yield (3.82 t ha⁻¹) which were more or less similar to 120 kg N ha⁻¹. Application of N @120 kg N ha⁻¹ 140 kg N ha⁻¹ produced ~4.9 times and ~5.2 times more yield respectively over control. From the findings of the experiment it is recommended that that application of N @ 120 to 140 kg ha⁻¹ is better for wheat cultivation under zero tillage in the coastal soil of southwestern Bangladesh.

Keywords: *Triticum aestivum*, nitrogen, salinity, grain yield, zero tillage and southwestern coastal area.

*DEDICATED
TO MY
BELOVED PARENTS*

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LIST OF ACRONYMS

Abbreviation	Full meaning
AEZ	Agro-ecological zone
Ca	Calcium
Cm	Centimeter
CV	Coefficient of variation
DAS	Days after sowing
<i>et al.</i>	And others
etc.	Etcetera
FAO	Food and Agriculture Organization
G	Gram
K	Potassium
Kg	Kilogram
LSD	Least significant difference
m	Meter
m ²	Meter squares
N	Nitrogen
No.	Number
NS	Non-significant
P	Phosphorous
SRDI	Soil Resources and Development Institute
t ha ⁻¹	Ton per hectare
var.	Variety
Viz.	Namely
%	Percent
@	At the rate of
°C	Degree Celsius
&	And

CHAPTER 1

INTRODUCTION

Most of Bangladesh's coastal area lies on the southwest coastal region of the country. In Bangladesh, around 20% of coastal area covers approximately 30% of the net cultivable region (Shelley *et al.*, 2016) and continuous to support crops productivity and GDP growth. But in the recent past, the contribution of crops to GDP has decreased because of salinity (Iqbal, 2013). Out of 2.68 million ha of coastal and off-shore lands, about 1.06 million ha of arable lands are affected by varying degrees of salinity (SRDI, 2010). Due to salinity about 53% of coastal area limits crop production (Uddin, *et al.*, 2011). Farmers mostly cultivate low yielding, traditional rice varieties. Most of the land kept fallow in the summer or pre-monsoon hot season (March-early June) and autumn or post-monsoon season (October-February) because of soil salinity, lack of good quality irrigation water and late draining condition. In the recent past, with the changing degree of salinity of southwest coastal region of Bangladesh, rice production becomes very risky and crop yields, cropping intensity, production levels of rice and people's quality of livelihood are much lower than that in the other parts of the country. As limited resources with high population, farmers have no scope to keep their land fallow. So, it is crucial matter to consider high salinity tolerant crops instead of vulnerable crops to salinity, that ensures calorie intake, food security, poverty reduction, and economic growth.

Wheat (*Triticum aestivum*) is one of the leading cereals in the world. It belongs to the family Gramineae and it is the world's most widely cultivated cereal crop which ranks first followed by rice (Mondal, 2014). It is an important cereal crop in Bangladesh and ranks third in Bangladesh both in terms of production and acreage (FAO, 2014). Rice is the staple food of Bangladesh but its total production is not sufficient to feed her growing population. Bangladesh is an over

populated country. Increasing agricultural production per unit area of land is becoming most important step to cope with the present population growth in Bangladesh. Wheat can be a good supplement of rice and it can play a vital role to feed this vast population. From nutritional point of view, wheat is superior to rice for its higher protein content. Wheat grain is rich in food value containing 12% protein, 1.72% fat, 69.60% carbohydrate and 27.20% minerals. Wheat is cultivated over a wide range of environments, because of wide adaptation to diverse environmental conditions. It is a moderately salt-tolerant crop (Moud *et al.*, 2008). Wheat is mainly cultivated in the north and northwestern part of Bangladesh.

A large area of cultivable land of the coastal region remains fallow and the dominant cropping pattern is fallow-fallow-T. *aman*. Introduction of wheat into the existing cropping pattern in the southwestern coastal soil may become a costly effort to exploit these lands to meet up the food and nutritional balance of the over increasing population of Bangladesh. There is no fertilizer recommendation for wheat based cropping pattern in the southwestern coastal zone. As an emerging cropping pattern nutrient management is of prime importance as it comprises the major cost of crop cultivation.

Nitrogen (N) is an essential plant nutrient, affecting productivity, NUE and WUE in wheat (Zhou *et al.*, 2011; Grant *et al.*, 2012; Devadas *et al.*, 2014). It is largely used in the synthesis of protein, chlorophyll and other vital compounds which are attributed to all physiological and biochemical processes of plants. The response to nitrogen fertilization varies according to location, climate, crops and their varieties, characteristics of the soil, type, rate, time of fertilizer application and its placement. An efficient use of fertilizers management seems to be important under Bangladesh conditions to increase wheat yield. Nutrient deficiency and imbalance fertilization are critical factors reducing the yield of wheat (Khan *et al.*, 2010). Nitrogen is the

most important nutrient element for plants and rate of nitrogen application has a great influence on growth, development and yield of wheat (Karamanos *et al.*, 2005; Engel *et al.*, 2001; Walley *et al.*, 2001). Grain yield of wheat increases with increasing nitrogen level up to 120 kg ha⁻¹ (Singh *et al.*, 2013) to get the maximum yield of wheat, application of nitrogen in adequate amount is considered as a key to success.

Wheat productivity can also be enhanced by using better inputs, appropriate production technology and by adapting the appropriate tillage techniques. Use of severe and excessive conventional tillage practices is often injurious to soil. Conventional tillage involves intensive soil manipulation, wastage of energy resources, lacks sustainability and results environmental hazards (Wang *et al.*, 2012). Conservation tillage is a broader term that takes into account zero tillage, minimum or reduced tillage and no till. Zero tillage (ZT) is referred as zero till, no till, direct sowing of crop and direct drilling (Erenstein *et al.*, 2008). Zero-tillage technology improves wheat yield as compared to the other production techniques and facilitates minimal use of machinery and hence energy can be saved through less fuel usage. Zero till technology produce higher grain yield than other tillage techniques (Saharawat *et al.*, 2011). Zero tillage is also more economical as it has less cost of production, yields more than other techniques, sustainable and also diminishes environmental pollution (Nagarajan *et al.*, 2002).

In the soil of southwestern coastal Bangladesh, it is very difficult to sow seeds timely in winter season because of excess soil wetness. To cultivate wheat in conventional tillage practice is totally impossible because the soil comes in optimum condition for conventional tillage in late January. This is a better intervention to cultivate wheat under zero tillage timely facilitate early sowing.

In saline areas yield of wheat also decreases with increasing salinity level. Due to salinity many nutrients are unavailable for plant such as nitrogen (N), phosphorous (P), copper (Cu), zinc (Zn) and decrease potassium (K), calcium (Ca), magnesium (Mg) into plants, causing significant yield loss (Nahar *et al.*, 2016; Shelley *et al.*, 2016). Since wheat is a minor crop in saline prone area, in order to increase cropping intensity of saline area and to increase food grain production in the country. Wheat must be fitted in the cropping pattern of saline area. The fertility status of this area is low to very low especially nitrogen. As a new crop in this area it is important to find out the optimum rate and management strategy of nitrogen for wheat. With the above facts keeping in view the present investigation was done with the following objectives:

- To investigate the growth and yield response of wheat at different rates of nitrogen under zero tillage condition and
- To find out the optimum rate of nitrogen for wheat under zero tillage condition in the coastal soil of southwestern Bangladesh.

CHAPTER 2

REVIEW OF LITERATURE

Wheat is a leading cereal crop in the world. Most of the areas of the southwestern part of Bangladesh, where a vast area remains fallow for long time are affected by salt condition and farmers cannot cultivate wheat in the salt affected area due to lack of efficient salt tolerant variety or lack of proper nutrient management strategy and lack of fresh irrigation water. A good number of researchers have conducted enormous number of study on various aspects of its growth and yield at different ecological situations. Nitrogen fertilizer plays a significant role on growth and yield of wheat. On the effect of nitrogen fertilizer application a number of research works also have been carried out in home and abroad. Very limited research works have been conducted to adapt wheat in the soil of southwestern coastal Bangladesh with optimum nitrogen dose. An attempt has been made to find out the performance of wheat at different levels of nitrogen in the soil of Southwestern Bangladesh. To facilitate the research works, different literatures have been reviewed in this chapter under the following headings:

2.1 Effect of nitrogen levels on growth and yield contributing characters of wheat

Ishete and Tana (2019) recorded that maximum grain yields (5274 kg ha^{-1}) and plant height (79.59 cm) were obtained at the highest application of $200 \text{ NPS kg ha}^{-1}$ and the highest days to physiological maturity (103 days), grain filling period (46.22 days), thousand kernels weight (50.49 g), plant height (79.49 cm), grain yields (5738 kg ha^{-1}), biomass yields (11728 kg ha^{-1}) and harvest index (48.91%) were recorded at the highest N rate (92 kg N ha^{-1}).

Ali *et al.* (2018) reported that maximum number of tillers, highest plant height and biological yield was recorded from the treatment where nitrogen was applied @ 203 Kg ha^{-1} while 1000

grain yield, seeds per spike and grain yield was achieved highest from where nitrogen applied @ 145 Kg ha⁻¹.

Walsh *et al.* (2018) conducted an experiment to investigate the effect of using different rates and split application of N on the performance of spring wheat in dry land cropping systems with three at planting N fertilization application (0, 90 and 135 kg N ha⁻¹) and two topdressing N fertilization strategies as treatments. Results of that experiment showed that nitrogen had significant effect that at-planting N fertilizer application of 90 kg N ha⁻¹ has significantly increased grain yield, protein content and nitrogen uptake. On the other hand, for these site-years, increasing at-planting N fertilizer rate to 135 kg N ha⁻¹ did not further enhance wheat grain yield, protein content and nitrogen uptake values.

Litke *et al.* (2018) worked with eight nitrogen rates (N₀ or control, N₆₀, N₉₀, N₁₂₀, N₁₅₀, N₁₈₀, N₂₁₀ and N₂₄₀), crop rotation (wheat/wheat and oilseed rape (*Brassica napus ssp. oleifera*)/wheat), soil tillage (traditional soil tillage with mould-board ploughing at a depth of 22-24 cm and reduced soil tillage with disc harrowing at a depth below 10 cm) and conditions of the growing seasons (2014/2015, 2015/2016 and 2016/2017) to clarify the impact of nitrogen fertilization on winter wheat yield and yield quality under two soil tillage systems and after two forecrops. They found that winter wheat yield has been significantly affected by nitrogen fertilizer rate, soil tillage, conditions of growing year ($p < 0.001$) and forecrop ($p < 0.05$). Average yield increased significantly until the nitrogen fertilizer rate N₁₈₀.

Adnan *et al.* (2016) conducted an experiment to evaluate the impact of various nitrogen (N) and potassium (K) combinations on yield of wheat crop using three levels of nitrogen (90, 120, 150

kg N ha⁻¹). They found that nitrogen used at the rate of 150 kg ha⁻¹ significantly improved plant height, grains spike⁻¹, 1000 grain weight, biological and grain yields of wheat.

Nahar *et al.* (2015) conducted an experiment at the Agronomy Field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November 2011 to March 2012 to evaluate the performance of prilled urea and urea super granules (USG) on the growth and yield of wheat varieties. They observed that among the different nitrogenous fertilizers 84 kg N ha⁻¹ from USG (1.8 g) gave the highest grain yield (2.69 t ha⁻¹) due to the maximum number of spikes plant⁻¹, maximum number of grains spike⁻¹ and 1000-grain weight.

Mandic *et al.* (2015) carried out an experiment estimate the effects of different N fertilization levels (0, 75, and 150 kg N ha⁻¹) on some quantitative traits, rain-use efficiency (RUE), N agronomic efficiency (NAE), and N use efficiency (NUE) and they found that 75 and 150 kg N ha⁻¹ had highly significant effect on grain yield, RUE, NAE and NUE.

Akter (2015) studied an experiment to evaluate the effect of nitrogen levels on growth, yield and seed quality of wheat. He used five levels of nitrogen in their experiment and found that N₃ (25% higher nitrogen than recommended dose) gave the highest grain yield might be attributed to highest number of spikes m⁻² (194.46), spike length (15.61 cm), number of spikelets spike⁻¹ (20.91), number of grains spike⁻¹ (48.17) and 1000-grain weight (47.08 g).

Mondal (2014) conducted a field experiment to evaluate the response of wheat variety by different levels of nitrogen. The experiment included three varieties viz. BARI gom 23, BARI gom 24, and BARI gom 25 and four levels of nitrogen viz. 75, 100, 125 and 150 kg N ha⁻¹. Result demonstrated that the variety BARI gom 24 with application of 125 kg N ha⁻¹ produced the maximum grain yield (4.71 t ha⁻¹) and harvest index (49.37%).

Duan *et al.* (2014) worked with different levels of N fertilization on dry matter accumulation and remobilization, and soil water contents in a rainfed winter wheat field. They recorded that the maximum grain yields were obtained under N rate of 150 kg ha⁻¹ in all growth seasons and the accumulation of dry matter in vegetative organs significantly increased with increasing N rate up to 150 kg ha⁻¹ and then leveled off in all growth seasons.

Ullah *et al.* (2013) recorded that maximum plant height and biological yield were obtained under the highest nitrogen levels, viz., 210 kg N ha⁻¹ while highest count of number of tillers m⁻², spike length, number of spikelet spike⁻¹, number of grain spike⁻¹, 1000-grain weight, grain yield and harvest index were recorded in the treatments receiving 180 kg N ha⁻¹.

Shahzad *et al.* (2013) conducted an experiment with three Nitrogen levels viz. 0, 60, 120 and 180 kg ha⁻¹ and five wheat varieties, viz., Pir Sabak-04 (P.S), P.S-05, P.S-08, Atta Habib and Siran, at Agricultural Research Station, Baffa, Mansehra, in 2011. They concluded that among nitrogen levels, maximum tillers per m⁻², days to physiological maturity, longer spikes, number of grains spike⁻¹, thousand grains weight, biological yield and grain yield were maximum when N was applied at the rate of 120 kg ha⁻¹.

Alam (2012) conducted an experiment with two methods of sowing viz.; conventional sowing (S₁) and bed sowing (S₂) and four wheat varieties namely; Protiva (V₁), Sourav (V₂), Shatabdi (V₃) and Prodip (V₄) and four levels of nitrogen viz; 0 (N₁), 60 (N₂), 110 (N₃) and 160 (N₄) kg N ha⁻¹. He found that the highest grain yield was found with the combination of bed sowing method and 160 Kg N ha⁻¹ and the lowest one was recorded with the combination of conventional method at control treatment.



Iqbal *et al.* (2012) conducted an experiment to investigate the effect of seeding rates and different levels of nitrogen on yield and yield components of wheat at Research Area, College of Agriculture, Dera Ghazi Khan where they found that nitrogen fertilization significantly affected spikelets spike⁻¹. He reported that plant height, number of tillers m⁻², spike length, number of spikelets spike⁻¹, number of grain spike⁻¹, 1000-grain weight, grain yield, biological yield and harvest index were highest at nitrogen at 125 kg/ha and lowest at zero level of nitrogen.

Abedi *et al.* (2011) carried out an experiment to study the effect of nitrogen rate application (0, 120, 240 and 360 kg Nitrogen ha⁻¹) and nitrogen timing on grain yield, yield components, grain quality and protein banding pattern in different growth stages of wheat and they observed that yield components were significantly increased with enhancing the level of nitrogen and the highest value for grain yield was obtained at 240 kg N ha⁻¹.

Ali *et al.* (2011) conducted a field experiment to study the effects of different levels of nitrogen on growth and yield of wheat crop. The results showed that number of tillers per unit⁻¹, plant height, spike length, number of grain spike⁻¹, 1000-grain weight and grain yield were significantly increased by increasing the nitrogen levels over control. Among nitrogen levels, highest grain yield (3.848 t ha⁻¹) was obtained by an application of 180 kg N ha⁻¹.

2.2 Effect of nitrogen on seed quality of wheat

Protein content in wheat can be manipulated to some extent by the amount of fertilizer applied and the timing of application. Applying nitrogen to the soil early during crop development will generally result in high grain yield and applying nitrogen at flowering time or a little effect upon yield.

Marinaccio *et al.* (2016) studied an experiment to determine the effects of nitrogen (N) fertilization on grain yield and quality, in different pedo-climatic conditions of temperate areas). They recorded that N fertilizer rate had a more consistent effect on protein than yield; the response was affected by soil texture and rainfall during the growing season.

Abedi *et al.* (2011) found that 240 kg N ha⁻¹ application in all timing treatments resulted in maximum seed protein content (5.5 mg protein g⁻¹ grain).

Khan *et al.* (2010) works on seed quality determination tests and examined that higher electrical conductivity results poor germination.

Warraich *et al.* (2002) conducted a field experiment to evaluate the effect of different levels of N on grain quality and vigor in wheat which showed that nitrogen application improved grain protein and reduced phosphorous percentage and Seeds obtained from nitrogen fertilized plots showed increased final germination percentage, while time to 50% germination (T₅₀) and mean germination time (MGT) were significantly reduced with the nitrogen application. He also observed that seeds obtained from 120 kg N ha⁻¹ treatment showed more vigor during electrical conductivity test as compare to 0, 60 and 180 kg N ha⁻¹. He also demonstrated that the performance of seed is determined by its viability, purity, germination percentage, electrical conductivity, field emergence and seedling dry weight were with nitrogen fertilization.

2.3 Effect of zero tillage on wheat

Kaur and Kumar (2018) conducted an experiment to study about “The Effect of tillage and nitrogen scheduling on growth and yield attributes of wheat under winter season (*Triticum aestivum* L.) who concluded that application of T₁₁ - ZT + N₅ i.e. N@125 kg (4 splits) applied at

$\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{4}$ and $\frac{1}{4}$ at basal, 4, 6 and 8 WAS gave best results of respect to all the parameters of growth and yield.

Khan *et al.* (2017) conducted an experiment to investigate the influence of different conservational tillage techniques viz: Zero tillage, Minimum tillage, Conventional tillage and Deep tillage on performance of wheat cultivar during winter season 2013-2014 at Agronomic Research Area, University of Agriculture Faisalabad. They found that among four tillage techniques zero tillage remained best and enhanced the growth and yield parameters significantly Germination count, no. of fertile tillers, spikelets spike⁻¹ and no. of grains per spike were also observed more at zero tillage.

Mirja *et al.* (2015) conducted a field study to investigate the effect of three tillage methods (T₁: Conventional tillage (CT), T₂: Reduced tillage (RT) and T₃: No tillage (NT)) on the growth, development, yield and yield components of bread wheat They shown that when compared to RT (T₂) and NT (T₃) methods, the CT (T₁) method caused substantial improvement in almost all the growth, yield and yield component traits of bread wheat in both the years, particularly it improved seedling emergence percentage, plant height, root system, number of main-stem leaves per plant, number of productive tillers per plant, number of spike-lets per spike, spike length, number of grains per spike and grain and straw yields per hectare.

Arisoy *et al.* (2015) carried out an experiment to evaluate the effects of tillage on grain yield, yield components, quality and energy indices of winter wheat production. The study utilized a randomized block design with three tillage systems [moldboard plough + combined cultivator and tooth harrow + combined spring tooth harrow and rotary harrow + seeding machine (CT); rotary tiller + seeding machine (RT) and no-till (NT)] in three replications. The tillage system

had a significant effect on grain yield (GY), thousand kernel weight (TKW), plant height (PH), number of grains m⁻² (NG), number of grains per spike (NGS) and particle size index (PSI), but no significant effect on biomass yield (BY), harvest index (HI), number of spikes m⁻² (NS), hectoliter mass (HM), protein content (PC) and dry gluten (DG).

Grigoras *et al.* (2013) conducted an experiment to evaluate the impact of the conservation agriculture system compared to the conventional agriculture system on wheat yield. They found that the application of no-tillage system increased the efficiency of fertilization in terms of wheat yield compared to the classical agriculture.

Yadav *et al.* (2005) was carried out an experiment during the winter seasons of 1999-2000 and 2000-2001 to assess the performance of zero tillage in wheat (*Triticum aestivum* L. emend. Fiori & Paol.) under varying levels of nitrogen. They revealed that grain yield and number of effective tillers/m row increased significantly by 7.7 and 6.6%, respectively, with zero tillage over conventional tillage and application of 150 and 180 kg N ha⁻¹ being at par resulted in significantly higher grain yield over 120 kg N ha⁻¹.

2.4 Effects of salinity on wheat

El Hendawy *et al.* (2011) proved that salinity did not affect final germination percentage, while seeds subjected to 80 and 160 mM NaCl treatment. Salinity affected shoot growth more severely than root growth of seedlings. Height and dry weight of shoot of the genotypes ranked in the same order as their salt tolerance ranking in terms of grain yield, where as root dry weight did not. So, the measurement of shoot growth may be one of the effective criteria for screening wheat genotypes for salt tolerance at early growth stages.

Brma *et al.* (2011) reported that two lines named BARI GOM 25 and BARI GOM 26) were selected for commercial production in the southern belt. BARI GOM 25 showed a good level of tolerance to salinity.

Hameed *et al.* (2009) conducted an experiment with two wheat genotypes differing in salt tolerance and observed that the 3 days old wheat seedlings were subjected to 5, 10 and 15 dSm⁻¹ NaCl salinity for 6 days, application of low salinity (5dSm⁻¹) growth was suppressed even in tolerant genotype. The cv. Lu-26, exhibited a better protection mechanism against salinity as indicated by lower salt induced proteolysis, higher biomass accumulation and protein contents than the relatively sensitive cv. Pak-81.

Datta *et al.* (2009) undertook an experiment with five varieties of wheat viz., HOW-234, HD-2689, Raj-4101, Raj-4123, and HD-2045 varying the salinity levels to (0, 25, 50, 75, 100, 125, 150mM NaCl). They observed that different level of salinity significantly affected the growth attributes by reducing root and shoot length for salinity below 125mM. Fresh weight and dry weight of root and shoot were reduced significantly with subsequent treatment. Maximum germination was found in variety HD2689 in all the treatments and maximum inhibition was found to be in case of HOW234 variety at 150mM salinity level.

Rahman *et al.* (2008) conducted an experiment with four cultivars of wheat (*Triticum aestivum* L.) to NaCl salinity treatments measuring 0.00, -2.457, -4.914, and -14.742 bars at germination and early seeding growth stage. They observed that water uptake and germination decreased in all cultivars. Increased salt concentration also affected the early seedling growth. Among the cultivars under investigation Zarlasht cultivar appeared to be more sensitive at germination stage.

Tammam *et al.* (2008) conducted a pot experiment with salt tolerance wheat cv. Banysoif-1. Seedlings were irrigated by different saline waters (0, 60, 120, 180, 240 and 320 mM NaCl). They observed that fresh and dry weight of roots was unchanged up to the level of 120 mM NaCl then a significant reduction obtained at 240 and 320 mM NaCl. In shoots and spikes, dry matters were either unchanged or even stimulated to increase toward 180 mM NaCl then a quick reduction was observed.

Critical analysis of the literature presented above indicate that nitrogen influences on growth and yield through affecting growth at different phonological stages, yield components and yield. It was also found from the review that there are very few works on fertilization of wheat in southwestern coastal region of Bangladesh. So, research should be conducted to find out optimum rates of nitrogen fertilizer for wheat in southwestern coastal region of Bangladesh.

CHAPTER 3

MATERIALS AND METHODS

A field experiment was conducted in *rabi* season to study the yield response of wheat (*Triticum aestivum* L.) to nitrogen rates under zero tillage in coastal soil of southwestern Bangladesh. This chapter describes the materials and methods that were used in this study. This chapter presents a brief description of the experimental site, soil, climate, experimental design, treatments, cultural operations, collections and analysis of different parameters.

3.1 Experimental site and soil characteristics

The field experiment was conducted at Pankhali, Dacope, Khulna (26 km away from Khulna University) during *Rabi* 2019. The location of the experimental site is 22°24' and 22°40' north latitudes and 89°24' and 89°35' east longitudes (Appendix-II).

The experimental site was in Agro-ecological zone of 13 (Ganges Tidal Floodplain). This region (17,066 sq km) occupies an extensive area of tidal floodplain land in the southwest of the country. The greater part of this region has smooth relief having large areas of salinity. It was medium high land. The soil texture was clay type having soil pH 7.3 (almost neutral). The organic matter content of this soil was 2.4% (medium).

Table 1: Chemical properties of the experimental plot soil of Pankhali, Dacope, Khulna

	N (%)	P (µg/g soil)	K (meq/100 g soil)	Cu (µg/g soil)	Zn (µg/g soil)	B (µg/g soil)
Soil test value	0.124	31.34	0.35	107.42	1.51	1.16
Condition	Low	High	High	Very high	High	Very high

3.2 Climatic conditions

The experimental field was characterized by sub-tropical climate with moderately high temperature and heavy rainfall during the Kharif season (April to October) and low rainfall with moderately low temperature during the Rabi season (November to March).

The daily meteorological data such as daily maximum and minimum air Temperature (Figure 1), Relative humidity (Figure 2) and Rainfall (Figure 3) for the period from December, 2018 to April, 2019 recorded at the Weather Station, Khulna.

Temperature: The maximum temperature of December 2018, January 2019, February 2019, March 2019 and April 2019 was 29°C, 31.2°C, 33.5°C, 34.5°C and 37.2°C respectively and the minimum temperature was 8.0°C, 9.5°C, 11.4°C, 14.4°C and 19.8°C respectively throughout the experiment (December 2018 to April 2019).

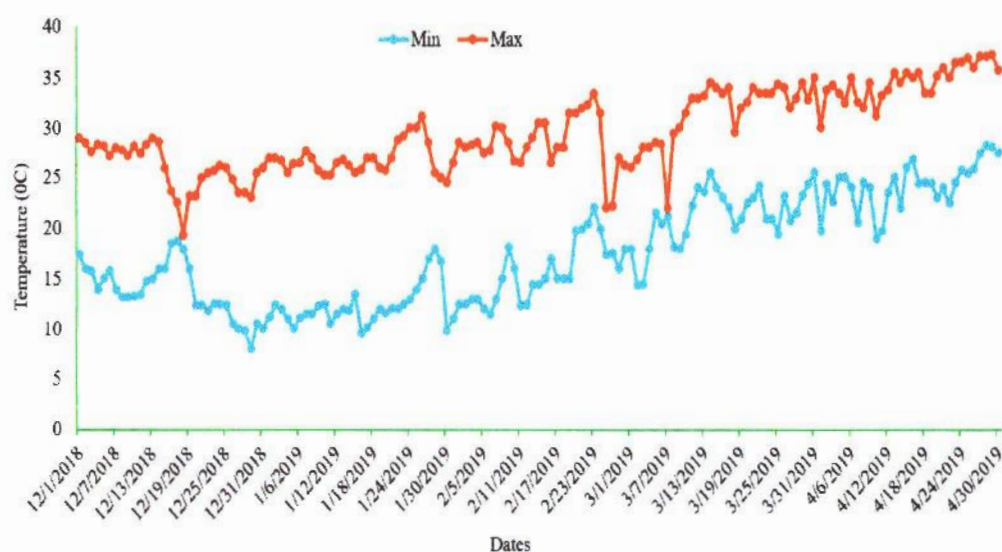


Figure 1: Maximum and minimum temperature pattern during the growing period (Dec '18-Apr '19) in the experimental area.

3.3 Water salinity

The salinity level of the water at different sources were presented in figure 4. The salinity levels of the river water was gradually increased with the progress of dry season. The water salinity in the canal, pond and river are more or less similar but after the heavy rainfall in the last week of February the salinity level was decreased and then increase but not beyond the limit. In the experimental plot canal was used as the source of irrigation. The canal was managed by disconnected it from the river during the middle of December.

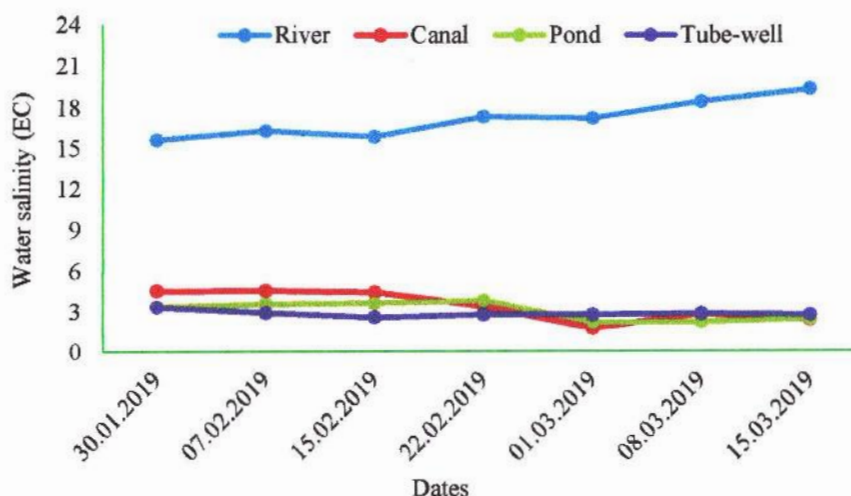


Figure 4: Salinity level of water at different sources with the progress of time

3.4 Experimental design and treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD). The entire experimental area at the farmers' field was divided into three sampling blocks representing the replications to reduce soil heterogeneity. Each block was divided into 7 unit plots with raised bunds as per the treatments. Thus, the total number of the unit plots was 21 (3×7). The size of each unit plot was 12 m² (4.0 m x 3.0 m). Plot to plot distance was 1.0 m and replication to replication distance was 1.5 m.

Basal dose of all fertilizers except and one-third portion of nitrogen were applied in the furrow made by spade in the alternate row and then covered by soil in each plot (except control) at the time of sowing. The rest of the urea was applied in two equal splits during crown root initiation stage (25 DAS) and panicle initiation stage (45 DAS).

3.7 Seed sowing and crop management

Seeds were treated with provax-200 @ 3 g kg^{-1} seed 24 hours before sowing. Seeds were sown on 10 December, 2018. Seeds were sown continuously in 20 cm apart rows opened by spade. After sowing, the seeds were covered with dry soil collected from outside and slightly pressed by hands. Seed rate was 120 kg ha^{-1} . The experimental plots were irrigated lightly after seed sowing. Before sowing no extra attempts were taken for land preparation as the cultivation process of wheat was carried out under zero tillage. The field was divided into unit plot size according to the design. All weeds, stubbles, crop residues were removed from the plots and were made ready for sowing. After sowing some cultural operations were carried out for crop management. Thinning was done at 30 DAS to maintain proper population density. Weeding was done twice during the whole growing period, the one after 20 DAS and the other after 40 DAS. There was no need of using insecticide or fungicide as the fields were fortunately free from pest or diseases attack. But the field was always under a careful observation. To maintain desired soil moisture in the plots, irrigation was given as and when necessary and the number of irrigation was 3 time in the whole cultivation period. The first irrigation was done after 25 days of sowing at crown root initiation (CR1). The second irrigation was also done after 45 days at heading stage and the third irrigation after 60 days at grain filling stage. In the last week of February there was huge rainfall occurred and the wheat field completely waterlogged. The standing water was from the field drained out by using shallow pump.

3.8 Harvesting and post-harvest operation

The crop was harvested on March 22, 2019. At maturity, when leaves, stems and pods became yellowish in colors, then the plants were harvested. 1.0 m x 1.0 m area for yield data and it was converted to t ha^{-1} . The harvested plants were tied into bundles tagged properly and carried to the threshing floor. The crops were sun dried by spreading on the threshing floor. The seeds were separated from the plants manually and thereafter cleaned, dried and weighed. The weights of the dry straw were also taken from the same demarcated area and were also converted to t ha^{-1} .

3.9 Details of collection of experimental data

3.9.1 Growth parameters

Ten plants from each plot were selected at random and tagged for the purpose of recording various observations. Observations on growth parameter and yield components were recorded at three distinct stages of crop growth *i.e.*, 30, 60, 45, 60, 75, 90 DAS and at harvesting stage.

3.9.1.1 Plant height (cm): Plant height was measured from the base of the plant to the tip of the main shoot from tagged plants. The mean plant height was worked out and expressed in centimeters per plant.

3.9.1.2 Number of tiller per plant: The total numbers of tillers produced per plant were counted from selected (tagged) plants and their average was taken as the number of tiller per plant.

3.9.1.3 Dry matter weight (gm^{-2}): Plants from 1.0 m x 1.0 m were collected and then oven dried for measurement of dry matter accumulation at maximum vegetative stage. The total dry matter production was calculated from the summation of dry matter weight of leaves and shoots and the weight was expressed in g m^{-2} .

3.9.2 Phenological parameter

3.9.2.1 First booting, first panicle initiation and first flowering: First booting, first panicle initiation and first flowering was visually observed in the field in each plot and the length was recorded.

3.9.2.2 Maximum booting and maximum panicle initiation: Maximum booting and maximum panicle initiation was visually observed and the date was recorded.

3.9.3 Data collection for yield and yield components:

For assessing yield parameters except the grain and straw yields data were collected from ten randomly selected plants from each of the plots. For yield measurement, an area of (1.0 m x 1.0 m) from center of each plot was harvested and tagged as per the replication and treatment.

3.9.3.1 Spike length (cm): The length of spike was measured by using a meter scale. The measurement was taken from the base to tip of the spike. Average length of spike was taken from ten randomly selected spikes from inner row plants of each plot. Data was recorded at harvest time. Mean data was expressed in centimeter (cm).

3.9.3.2 Number of spikelets spike⁻¹: Data on the number of spikelets spike⁻¹ was counted. Ten spike bearing plants were randomly selected and the average data were collected from inner rows of each plot except harvest area during the time of harvesting.

3.9.3.3 Number of filled grains spike⁻¹: The total numbers of filled grains from randomly selected ten spikes were counted and average of which gave the number of filled grains spike⁻¹. Presence of any food material in the grains was considered as filled grain.

3.9.3.4 Number of unfilled grains spike⁻¹: The total numbers of unfilled grains from randomly selected ten spikes were counted and average of which gave the number of unfilled grains spike⁻¹.

3.9.3.5 Weight of grains spike⁻¹ (g): The total number of cleaned dried grains spike⁻¹ were collected and sun dried properly ~12% moisture content and weight by using an electric balance.

3.9.3.6 Weight of 1000 grains (g): One thousand cleaned dried grains were randomly collected from the seed stock of each plot and were sun dried properly at ~12% moisture content and weight by using an electric balance.

3.9.3.7 Grain and straw yield (t ha⁻¹): An area of 1.0 m² harvested for yield measurement. The crop of each plot was bundled separately, tagged properly and brought to threshing floor. The bundles were dried in open sunshine, threshed and then grains were cleaned. The grain and straw weights for each plot were recorded after proper drying in sun.

3.9.3.8 Biological yield (t ha⁻¹): Biological yield was calculated by using the following formula:
Biological yield= Grain yield + straw yield.

3.9.3.9 Harvest index (%): Harvest index is the relationship between grain yield and biological yield. Harvest index (%) was determined by dividing the economic (grain) yield from the harvest area by the total biological yield (grain yield+ straw yield) of the same area.

$$\text{Harvest index} = \frac{\text{Grain yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

3.10 Nitrogen use efficiency (NUE)

Nitrogen use efficiency was calculated for each of the treatments by using the following formula.

$$\text{NUE} = \frac{\text{Yield (kg/ha) with nitrogen addition} - \text{Yield (kg/ha) without nitrogen addition}}{\text{Rate of nitrogen addition (kg/ha)}}$$

3.11 Statistical analysis

The data obtained for different characters were compiled and statistically analyzed following the analysis of variance techniques (one-way ANOVA) using Statistix 10 a statistical software. The significant differences among the treatment means were compared following all pair wise comparison by least significant different (LSD) at 5% level of probability.

CHAPTER 4

RESULT AND DISCUSSION

The present study was carried out at Pankhali, Dacope, Khulna to study the yield response of wheat (*Triticum aestivum* L.) to nitrogen rates under zero tillage in coastal soil of southwestern coastal Bangladesh. The treatments in the experiment were N₀- control (no nitrogen added), N₁ (60 kg ha⁻¹), N₂ (80 kg ha⁻¹), N₃ (100 kg ha⁻¹), N₄ (120 kg ha⁻¹), N₅ (140 kg ha⁻¹), N₆ (160 kg ha⁻¹). The results obtained from the study have been presented and discussed with tables and figures in this chapter. Interpretations were made accordingly as follows-

4.1 Effect of nitrogen variation on growth parameters of wheat grown under zero tillage

4.1.1. Plant height (cm)

Different nitrogen doses affect the plant height significantly ($p < 0.001$) at different days after sowing (DAS) and at harvest (Table 2). It was found that at 30 DAS, 140 kg N ha⁻¹ (N₅) produced the tallest plant (30.04 cm) which was statistically identical to all other treatments except no nitrogen added treatment (N₀) and 60 kg N ha⁻¹ while the shortest (16.86 cm) was found from control treatment (N₀). At 45 DAS, the tallest plants (40.92 cm) was observed from 140 kg N ha⁻¹ (N₅) which was statistically similar with 120 kg ha⁻¹ whereas the shortest plant stature (19.25 cm) were observed from the control treatments where no nitrogen (N₀) was applied. Application of nitrogen @ 140 kg ha⁻¹ (N₅) produced the tallest plants (63.00cm) whereas the shortest plant stature (29.03 cm) was produced from the control treatments where no nitrogen (N₀) was applied at 60 DAS. At 75 DAS, the tallest plant (83.83 cm) was recorded from treatment N₅ where nitrogen was applied @140 Kg ha⁻¹ which was statistically similar with 100 kg N ha⁻¹, 120 kg N ha⁻¹ and 160 kg N ha⁻¹ while the shortest plant (53.32 cm) was recorded from N₀ where nitrogen was not applied. At 90 DAS, the tallest plant (83.83cm) was

observed from plot treated with nitrogen was applied @140 Kg ha⁻¹ whereas the shortest plant (60.08 cm) was observed from control treatment (N₀). At harvest the tallest plant (87.08 cm) produced from treatment N₅ where nitrogen was applied @ 140 Kg ha⁻¹ while the shortest plant (60.83 cm) was produced from the plot where nitrogen was not added.

As the level of nitrogen increased, plant height was gradually increased up to 140 kg ha⁻¹ then declined followed by 120 kg ha⁻¹. Cell protein content increase as the application of nitrogen increase and size of plant cell increases, as a result of that leaf area and photosynthesis rate rises which ultimately make the plant taller. Wheat growth can be increased by nitrogen by increasing the process of cell division and also help to uptake other nutrients from the soil through synergistic effect which increases the shoot length of plant. Plant height was increased because nitrogen increases leaf area which results in high rate of photosynthesis, more production of assimilates and plant dry matter. Alam *et al.* (2007) reported that the highest plant height (97.07 cm) was obtained from 140 kg N ha⁻¹ under two planting methods (bed planting and conventional planting). The current study also showed similar kinds of findings. The finding of the current study is also supported by the findings of Akter (2005) who reported similar findings while worked with different levels of nitrogen.

Table 2: Effect of nitrogen variation on plant height of wheat grown under zero tillage

Nitrogen rates (kg ha ⁻¹)	Plant height (cm)					
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At harvest
0	16.86c	19.25e	29.03e	53.32d	60.08d	60.83d
60	23.48b	30.83d	48.04d	72.93c	75.83c	76.68c
80	26.60ab	35.50c	52.42c	76.33bc	79.76bc	80.80bc
100	27.59a	36.33c	55.96bc	77.46abc	81.08abc	82.92ab
120	29.01a	39.33ab	59.59ab	82.17ab	84.17ab	85.42ab
140	30.04a	40.92a	63.00a	83.83a	87.08a	88.17a
160	27.43a	37.07bc	57.04b	79.21abc	83.42ab	84.08ab
<i>Mean±SE</i>	<i>25.86±1.64</i>	<i>34.18±1.35</i>	<i>52.16±1.88</i>	<i>75.04±3.07</i>	<i>78.78±2.92</i>	<i>79.84±3.85</i>
<i>LS</i>	***	***	***	***	***	***
<i>CV (%)</i>	7.79	4.83	4.41	5.02	4.54	3.85

*** $p \leq 0.001$, *LS*= level of significance and *CV*= Co-efficient of variation, *SE*= standard error; data in each column of the table followed similar letter are not significantly different at $p \leq 0.05$ significant level according to *LSD* test.

4.1.2 Number of tillers plant⁻¹

The data pertaining to the number of tillers per plant at different stages of growth was significantly influenced (<0.001) by various treatments of nitrogen are presented in table 3. The result revealed that highest number of tillers plant⁻¹ (3.92) was recorded from 140 kg N ha⁻¹ (N₅) which was statistically similar with the result recorded from 120 and 160 kg N ha⁻¹ at 30 DAS whereas the lowest number of tillers plant⁻¹ (1.42) was recorded from control treatment. Again for 45 DAS, it was found that the highest number of tillers plant⁻¹ (4.17) which was followed by 140 kg N ha⁻¹ while the lowest number of tillers plant⁻¹ (1.50) was found in control where nitrogen was not applied. The application of 140 kg N ha⁻¹ (N₅) produced the highest number of

tillers plant⁻¹ (4.42) and the lowest number of tillers plant⁻¹ (1.50) produced from control (N₀) at 60 DAS. At 75 DAS, the highest number of tillers plant⁻¹ (4.41) was found from treatment N₅ where nitrogen was applied @140 Kg ha⁻¹ whereas the lowest number of tillers plant⁻¹ (1.92) was found from control treatment (N₀). Plot treated with nitrogen @ 140 kg ha⁻¹ produced the highest number of tillers plant⁻¹ (4.33) and the lowest number of tillers plant⁻¹ (1.83) was obtained from the plot where nitrogen was not added. At harvest the numbers of tillers plant⁻¹ the highest number of tillers plant⁻¹ (4.33) was recorded from treatment N₅ where nitrogen was applied @140 Kg ha⁻¹ while lowest number of tillers plant⁻¹ (1.67) was recorded from control plot (N₀). In maximum treatments, number of tillers increased continuously and attained a maximum value at 75 DAS, which was considered as active tillering stage. After that, number of tillers decreased towards maturity due to side tiller mortality and initiation of panicle primordia.

With the increased of nitrogen up to 140 kg ha⁻¹ was increased followed by 120 kg ha⁻¹ after that the number of tiller decreased. Nitrogen is the key nutrient elements that affect the tillering capacity of cereals. Nitrogen is a primary nutrient required by plants in large quantity for their vegetative growth. The difference in tillers plant of wheat, due to application of nitrogen, might be due to the ability of nitrogen to enhance vegetative growth. Increased levels of nitrogen resulted in reduction of mortality of tillers and produced more tillers from the main stem. Similar results were reported by Burnett *et al.* (2003), who concluded that application of nitrogen increase tillers per m². The current study are confirmatory revealed by Liaquat *et al.* (2003).

Table 3: Effect of nitrogen variation on tiller number of wheat grown under zero tillage

Nitrogen rates (kg ha ⁻¹)	Tiller number					
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At harvest
0	1.42c	1.50d	1.50c	1.92c	1.83c	1.67c
60	1.92c	2.42c	2.75d	3.25b	3.17b	3.17b
80	2.83b	3.17b	3.08bc	3.33b	3.17b	3.17b
100	3.33ab	3.33b	3.50b	3.58b	3.50b	3.41b
120	3.66a	3.58b	3.58b	3.58b	3.41b	3.41b
140	3.92a	4.17a	4.42a	4.41a	4.33a	4.33a
160	3.50ca	3.50b	3.58b	3.42b	3.25b	3.25b
<i>Mean ±SE</i>	<i>3.11±0.44</i>	<i>3.27±0.63</i>	<i>3.40±0.56</i>	<i>3.23±0.44</i>	<i>3.14±0.41</i>	<i>3.09±0.41</i>
<i>LS</i>	**	*	*	**	**	**
<i>CV (%)</i>	<i>17.31</i>	<i>23.42</i>	<i>20.15</i>	<i>16.86</i>	<i>16.05</i>	<i>16.06</i>

*** $p \leq 0.001$, LS= level of significance and CV= Co-efficient of variation, SE= standard error; data in each column of the table followed similar letter are not significantly different at $p \leq 0.05$ significant level according to LSD test.

4.1.3 Dry matter gm⁻² at maximum vegetative stage

Total dry matter in plant of wheat varied significantly ($p \leq 0.001$) due to different nitrogen levels at maximum vegetative stage (Figure 5). The application of 140 kg N ha⁻¹ (N₅) produced the maximum dry matter (56 g) which was statistically similar with 100 kg N ha⁻¹, 120 kg N ha⁻¹ and 160 kg N ha⁻¹. The minimum dry matter (13.33 g) was observed in the control treatment where no nitrogen (N₀) was applied. The dry matter of wheat at maximum vegetative stage was linearly increase with the increased of nitrogen levels up to 140 kg ha⁻¹ and the rates of increasing trend was ~77%.

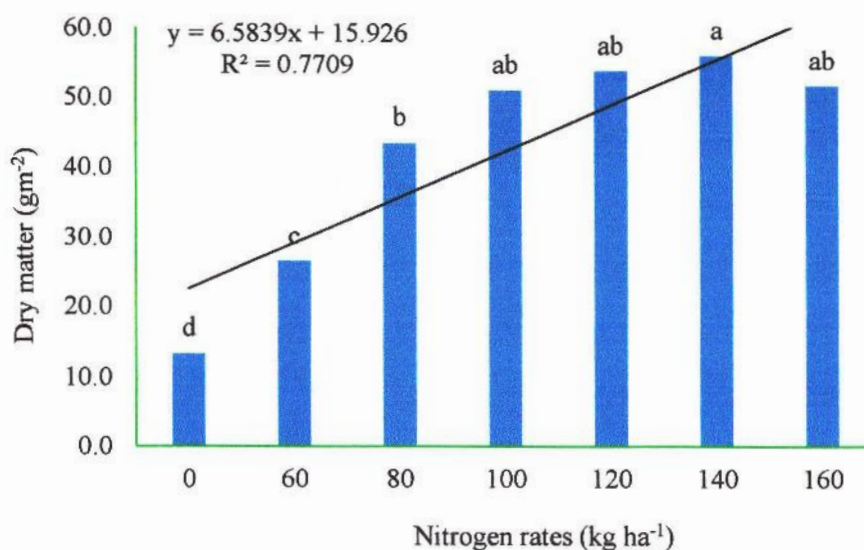


Figure 5: Effect of nitrogen rates on dry matter of wheat grown under zero tillage

The increase in plant height in response to application of N fertilizers is probably due to enhanced availability of nitrogen which enhanced more leaf area resulting in higher photo assimilates and thereby resulted in more dry matter accumulation. In general, dry matter accumulation increased at slow rate up to 30 days after transplanting and thereafter increased at faster rate up to harvest. The higher dry mass of nitrogen treated plants could be connected with the positive effect of nitrogen in some important physiological processes. The results indicated that nitrogen promotes various plant growth and contributed higher dry matter production.

4.2 Effect of nitrogen variation on phenological parameter of wheat grown under zero tillage

4.2.1 First booting and maximum booting

The days to first booting and maximum booting of wheat was significantly affected ($p < 0.001$) by different nitrogen doses (Figure 6). The maximum time reaches booting (57.67 days) was recorded from N₀ where no nitrogen applied while the lowest days to booting (43 days) was found from 140 kg N ha⁻¹.

The highest time (62 days) to reach maximum booting stage was observed from control (N_0) treatment whereas the lowest days to reach maximum booting (53.33 days) was found from application of nitrogen @ 140 kg ha^{-1} .

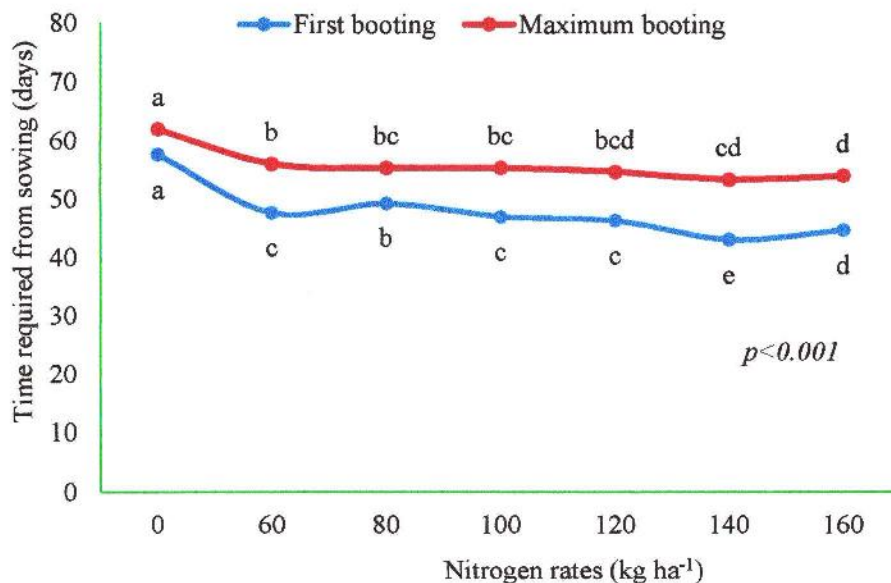


Figure 6: Effect of nitrogen rates on days to first booting and maximum booting of wheat grown under zero tillage

4.2.2 First panicle initiation and maximum panicle initiation

Significant variation ($p < 0.001$) was observed on first panicle initiation and maximum panicle initiation due to application different nitrogen doses (Figure 7). The maximum number of days (66.33) required to first panicle initiation was found in the control treatments and the minimum number of days (53.67) was found in N_5 treatments where 140 kg nitrogen was applied for one ha of land.

The maximum days (71) to reach maximum panicle initiation was obtained from N_0 where nitrogen was not incorporated while the minimum days (66.67) to reach maximum panicle initiation with the application of 140 kg N ha^{-1} .

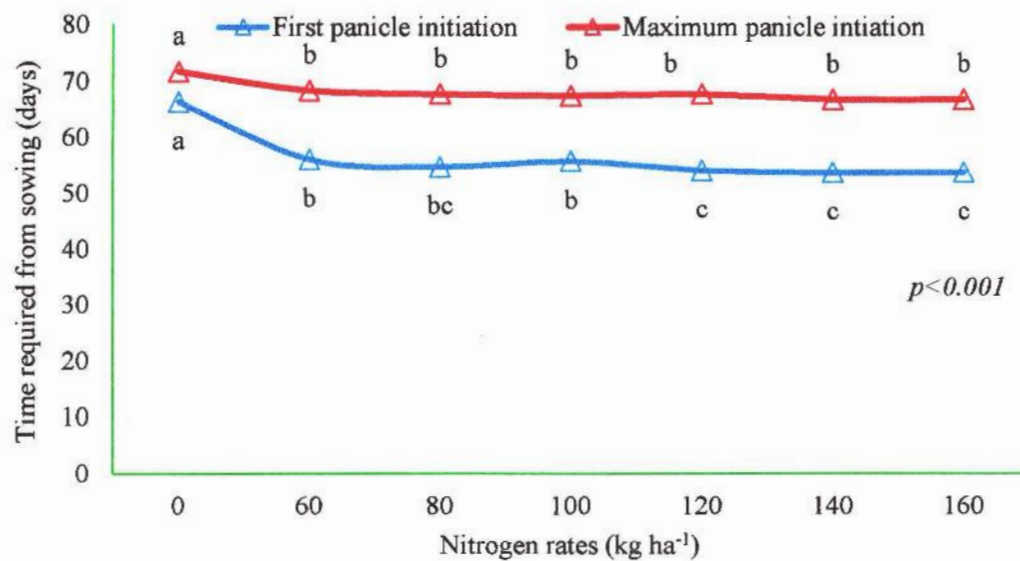


Figure 7: Effect of nitrogen rates on days to first panicle initiation and maximum panicle initiation of wheat grown under zero tillage

4.2.3 First flowering

Different nitrogen doses showed significant variation ($p < 0.001$) on days to first flowering (Figure 8). Appearance of first flower (49.7 days) was enhanced @ 140 kg N ha^{-1} while flowering delayed (66 days) due to no nitrogen fertilizer application.

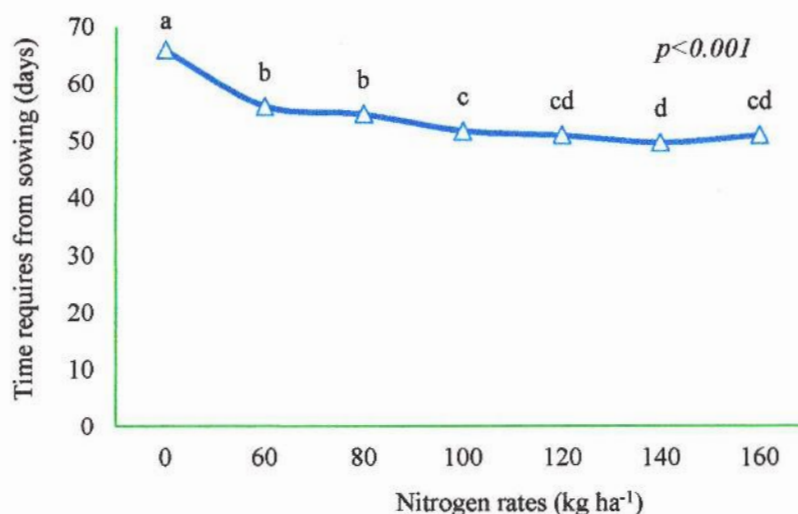


Figure 8. Effect of nitrogen rates on days to first flowering of wheat grown under zero tillage

Days to 1st flowering is a critical component of plant life history that determined by plant genotype, environment and different nitrogen dose. The effects of N fertilizer application on the flowering time of wheat were stronger than those of phosphorus and potassium fertilizer and the application of nitrogen fertilizer generally played an apparent role in the promotion of flower development and booting. Nitrogen is the main component of protein, and all types of enzymes are mainly composed of proteins. Nucleic acid, nucleotides, coenzymes, phospholipids, and cytokinins contain nitrogen. Wheat flowering as well as booting and panicle initiation was advanced with increased N nitrogen application whereas delayed without nitrogen application.

4.3 Effect of nitrogen variation on yield and yield attributes of wheat grown under zero tillage

4.3.1 Spike length (cm)

Significant variation ($p \leq 0.001$) was found regarding spike length due to different nitrogen doses. Results have been presented in the table 4. The maximum spike length (15.37 cm) was

obtained from 140 kg N ha⁻¹ (N₅) that was statistically similar with 120 kg N ha⁻¹ (N₄) while the minimum spike length (6.70 cm) was found in N₀ where nitrogen was not applied.

Spike length is indicator of number of grains and spikelets. Higher spikelets produce higher grain yield. This could be due to more assimilates transfer from flag leaf which increased number of spikelets and ultimately extended the spike. The current findings were supported by Rahman, (2005) who reported that length of spike was significantly increased with the application of nitrogen at 125 kg ha⁻¹. Hossain (2006) also observed that spike length significantly increased with N levels.

4.3.2 Number of spikelet spike⁻¹

Application of different rates of nitrogen had significant ($p \leq 0.001$) effect on production of number of spikelets spike⁻¹ (Table 4). The findings showed an increasing trend of number of spikelets spike⁻¹ with the increases in nitrogen doses and rate of increase was more rapid up to 140 kg N ha⁻¹ after that the rate of increase was decreased. However, it was recorded that 140 kg N ha⁻¹ (N₅) produced the highest number (22.12) of spikelets spike⁻¹. The lowest number (6.87) of spikelets spike⁻¹ was produced from control treatment (N₀) as expected.

Spikelet being basic flowering unit of spike directly relates to number of grains thus an important yield contributing attribute for wheat crop. Highest number of spikelets spike⁻¹ might be due to if there is more absorption of nitrogen by the plants produces more number of spikes per unit area, enhanced vegetative growth and more number of tillers per unit area. This findings were also supported by Nourmohammadi *et al.*, 2010.



4.3.3 Number of filled grain spike⁻¹

The effect of nitrogen on number of fertile grains spike⁻¹ was statistically significant ($p \leq 0.001$) (Table 4). Results showed that number of filled grains spike⁻¹ increased with increasing nitrogen levels and thereafter decreased by gradually increased the nitrogen levels. Application of 140 kg N ha⁻¹ produced the highest number of filled grains spike⁻¹ (32.80) which was statistically similar with 160 kg N ha⁻¹ whereas the lowest number of filled grains spike⁻¹ (7.87) was produced from control field (N₀). Number of filled grains spike⁻¹ increased up to 140 kg N ha⁻¹, further increase in nitrogen levels caused the decreasing of filled grains spike⁻¹.

Number of filled grain spike⁻¹ is an important yield component of wheat. Usually number of filled grain spike⁻¹ is determined at panicle primordial formation stage which depends on both genetic as well as management factors.

4.3.4 Number of unfilled grain spike⁻¹

Nitrogen had significant ($p \leq 0.01$) influence on unfilled grains per spike⁻¹ production in wheat (Table 4). The number of unfilled grains spike⁻¹ varied between 0.07 and 2.06 (Table 3) among the treatments. The highest number of unfilled grains spike⁻¹ (2.06) was recorded from 140 kg N ha⁻¹ which was statistically identical with 160 kg N ha⁻¹. In contrast, the lowest number of unfilled grain spike⁻¹ (0.07) was recorded from 60 kg N ha⁻¹.

Number of unfilled grain spike⁻¹ is the result of negative relationship of the yield component. The highest number of unfilled grains spike⁻¹ was observed from application of nitrogen @ 140 kg ha⁻¹ because this rate of nitrogen application produce higher number of spikelet per spike as well as the highest number of grain spike⁻¹. Usually with the increase of nitrogen rate number of grain spike⁻¹ increase along with the number of unfilled grain.

4.3.5 Grain spike⁻¹

Grains spike⁻¹ of wheat was significant ($p \leq 0.001$) with different levels of N application. Number of grains spike⁻¹ varied from 8.40 to 34.40 (Table 4). The maximum number of grains spike⁻¹ (34.40) was produced @ 140 kg N ha⁻¹ (N₅) which was statistically similar with 120 kg N ha⁻¹ (N₄). The minimum number of grains spike⁻¹ (8.40) was produced from control plot.

The number of grain spike⁻¹ due to increased vegetative growth was observed in case of plant height as well as optimum crop stand with better nutrition. Better nutrition enhanced the source capacity to better fill the sink. These results are quite in line with Gundapur and Bhatti (1993). Nitrogen fertilizer applied in optimum dose decrease the chance of seeds to deteriorate in the spikes otherwise in case of seed deterioration grain yield reduced (Seiling *et al.*, 2005). These results are supported by Bakht *et al.* (2010), who reported that addition of different levels of nitrogen to different varieties enhances the number of grains per spike.

4.3.6 Grain weight spike⁻¹ (g)

The weight of grain was significantly ($p \leq 0.001$) influenced by different nitrogen doses (Table 4). The maximum weight of grains spike⁻¹ (8.11 g) was obtained from 140 kg N ha⁻¹ (N₅) while the minimum weight of grains spike⁻¹ was (1.64 g) from control field.

Grain weight is an important character. The increase in weight of grains per spike might be due to high availability of nitrogen and the crop's efficient use of nitrogen and it appears that the application of nitrogen increased the protein percentage, which in turn increased the grain weight. As the number of grain and filled grain spike⁻¹ was highest in 140 kg N ha⁻¹ which leads to the maximum gain weight spike⁻¹

4.3.7 1000 grain weight (g)

1000-grain weight of wheat was significantly ($p \leq 0.001$) influenced by different levels of N (Table 4). When application of nitrogen was 140 kg ha^{-1} , the weight of 1000 seed was 43.37 g (maximum). Again, when nitrogen was not applied at all (control), the weight of 1000 seed was 26.33 g (minimum).

These results indicate that nitrogen has a key role in the growth and development of grain due to more dry matter accumulation in seed because of nitrogen. Similar results are reported by Ling and Silberbush (2002), who reported that application of nitrogen produced heavier grains. When application of nitrogen above 160 kg ha^{-1} the weight of 1000 grain was 41.31 g which indicates that application of over doses nitrogen fertilizer the grain weight drastically decreased. Mazurkiewicz and Bojarezyk (2004) found that differentiation of the level of nitrogen fertilization did not significantly influence the mass of 1000-grain.

4.3.8 Grain yield (t ha^{-1})

Nitrogen had significant ($p \leq 0.001$) effects on grain yield. Grain yield was varied from 3.8 t ha^{-1} to 0.7 t ha^{-1} (Figure 9). The highest grain yield (3.8 t ha^{-1}) was obtained from 140 kg N ha^{-1} which was statistically similar with 120 kg N ha^{-1} and the lowest grain yield (0.7 t ha^{-1}) was recorded from control field (N_0). There is positive polynomial relationship between the rates of nitrogen and grain yield of wheat up to 140 kg ha^{-1} and the rates of increasing trend was ~94% after that declined with the increased of nitrogen rates.

4.3.9 Straw yield (t ha^{-1})

The straw yield of wheat at different rates of nitrogen showed significant variation ($p < 0.001$). The straw yield at different levels of nitrogen application ranged from 1.29 t ha^{-1} to 4.84 t ha^{-1} (Table 4). The maximum straw yield (4.84 t ha^{-1}) was obtained from application of 140 kg N ha^{-1} (N_5) and as expected the lowest straw yield (1.29 t ha^{-1}) was obtained from N_0 where no nitrogen was added. The application of $\text{N @ } 160 \text{ kg ha}^{-1}$ decreased the straw yield.

Nitrogen is an important nutrient required by plants in large quantity for their vegetative growth. The application of large amount of nitrogen increased the straw yield might be due to the ability of nitrogen to enhance vegetative growth. Das (2003) showed that the straw yield increased gradually with the increase of nitrogen dose. Rahman (2005) reported that most of the yield components of wheat including straw yield was significantly higher at 125 kg N ha^{-1} . Pandey *et al.* (2004) observed that grain and straw yield differed significantly under varying fertilizer levels.

4.3.10 Biological yield (t ha^{-1})

Application of different doses of nitrogen showed significant differences ($p < 0.001$) for on biological yield (Figure 10). It was found that the maximum biological yield (8.65 t ha^{-1}) was produced from 140 kg N ha^{-1} (N_5) which was statistically identical to the result found from application of nitrogen @ 120 kg ha^{-1} . On the other hand, the minimum biological yield (2.02 t ha^{-1}) was produced from the treatment control field.

More application of nitrogen gave tall plants, more grain yield, and highest number of tillers per plant and total dry matter which collectively resulted in higher biological yield. As a result of more biological yield a plant with its large canopy is able to intercepts more sun radiation and produce more assimilates. There are many studies which revealed that with increasing the

nitrogen rate biological yield increased (Ghobadi *et al.*, 2010). During pollination high levels of nitrogen increased the total dry matter that help to get more grain yield McDonald (2002). Many other scientists reported that high levels of nitrogen yield in more straw and grain weight (Bulman and Smith, 1993).

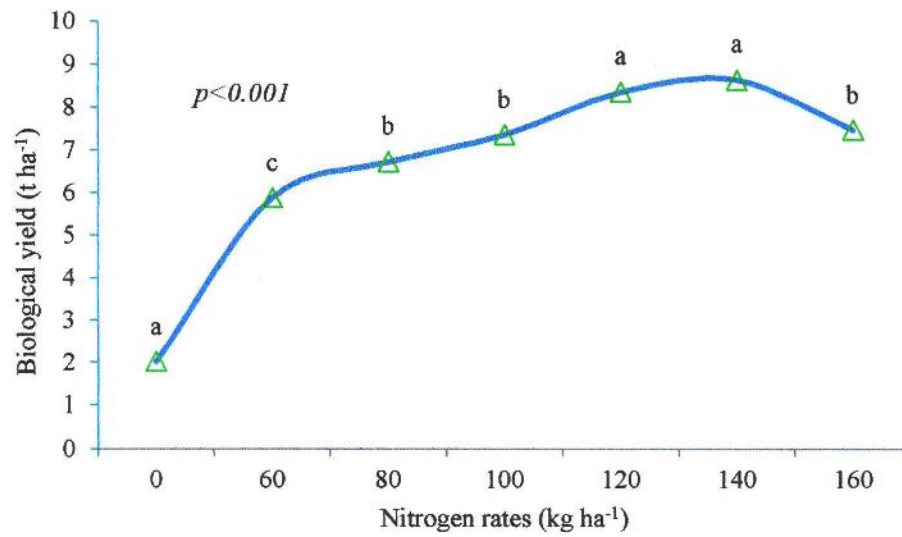


Figure 10: Effect of nitrogen rates on biological yield of wheat grown under zero tillage

4.3.11 Harvest index (%)

The influence of nitrogen doses on harvest index was significant ($p < 0.001$). The harvest index ranged from (36.25%) to (44.09%). The highest value (44.09%) was obtained from 140 kg N ha⁻¹ (N₅) and the lowest value (36.25%) was obtained from control treatment (N₀) (Table 3).

When harvest index is low it means that there is less translocation of assimilates from the source to sink which results in less development of seeds and make them shrivled size. When harvest index is high it means that more assimilates were translocated from source to the grains which result in improved development and filling. Harvest index is directly associated with the plant dry matter and grain weight which ultimately depends upon the availability and uptake of

nutrient specially nitrogen. The more will be the nitrogen amount the more will be growth and development but upto to a certain limit beyond that limit it can cause toxicity to the plant and reduce it. The current study was supported by Pandey *et al.* (2004) who calculated that harvest index increased significantly up to 120 kg N ha⁻¹ but decreased thereafter. According to Alam *et al.* (2007), the harvest index was significantly highest at 140 kg N ha⁻¹.

Table 4: Effect of nitrogen variation on yield and yield attributes of wheat grown under zero tillage

Nitrogen rate (kg/ha)	Spike length (cm)	Spikelet/ spike	Filled grain/spike	Unfilled grain/spike	Grain/ spike	Grain weight/spike (g)	1000 grain weight (g)	Straw yield (t ha ⁻¹)	Harvest index (%)
0	6.70e	6.87d	7.87d	0.60bc	8.40e	1.64d	26.43c	1.29d	36.25f
60	11.98d	13.67c	19.00c	0.07c	18.43d	3.84c	40.46b	3.63c	38.36e
80	12.17cd	13.73c	20.07c	0.80bc	21.40c	4.14c	40.78ab	4.07bc	39.52de
100	13.43bcd	17.87b	22.13bc	0.13c	27.47b	5.23b	41.14ab	4.33ab	41.25cd
120	14.11ab	17.90b	26.40b	0.27bc	32.33a	7.26a	42.41ab	4.73a	43.54ab
140	15.37a	22.13a	32.80a	2.06a	34.40a	8.11a	43.37a	4.84a	44.10a
160	13.64bc	18.37b	31.93a	1.33ab	29.27b	7.59a	41.31ab	4.37ab	41.65bc
Mean±SE	12.48±0.73	15.79±0.78	22.89±2.12	0.75±0.51	24.57±1.11	5.40±0.44	39.46±1.28	3892.1±261.31	40.67±0.93
LS	***	***	***	**	***	***	***	***	***
CV (%)	7.15	6.05	11.36	83.39	5.51	10.07	3.98	8.22	2.87

*** $p \leq 0.001$, ** $p \leq 0.01$, LS= level of significance and CV= Co-efficient of variation, SE= standard error; data in each column of the table followed similar letter are not significantly different at $p \leq 0.05$ significant level according to LSD test.

4.4.12 Nitrogen use efficiency

The range of nitrogen use efficiency varied significantly ($p \leq 0.001$) from 14.88 % to 25.33% (Figure 11). The maximum (25.33%) nitrogen use efficiency was recorded from application of nitrogen @ 60 kg ha⁻¹ which was identical to all other treatments except application of nitrogen @ 160 kg ha⁻¹ which was the minimum nitrogen (14.88%) use efficiency. Initially there was a decreasing pattern of nitrogen use efficiency with the increase of nitrogen rates and the decreasing rate was ~65% from 60 -160 kg ha⁻¹

Nitrogen use efficiency in terms of agronomic efficiency i.e., kg grain yield increased per kg nitrogen applied. A high nitrogen use efficiency indicate that more N is being removed than is being applied and the plants are accessing N from the organic pool or residual N from fertilizer applications to a preceding crop. A lower nitrogen use efficiency indicate that less N is being removed than that has been applied; applied N is left in the soil and may be lost if not used by the next crop.

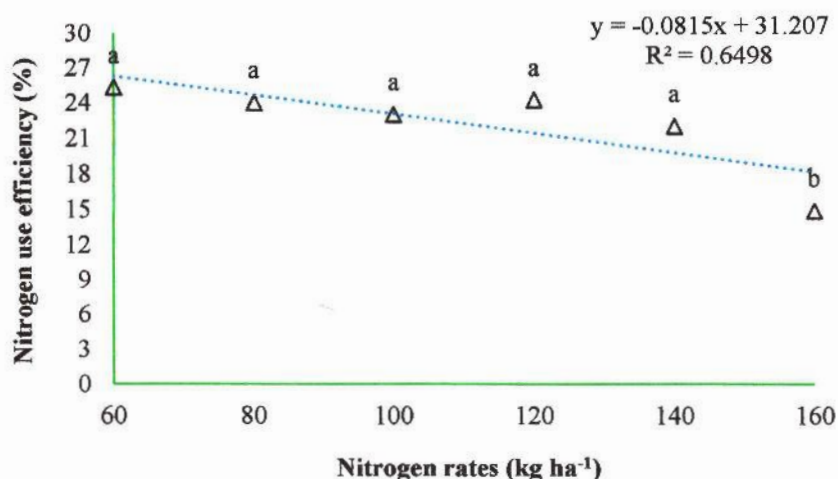


Figure 11. Nitrogen use efficiency of wheat at different rates of nitrogen under zero tillage in the coastal soil of southwestern Bangladesh.

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary

An experiment was carried out at Pankhali, Dacope, Khulna during the period from December, 2018 to March, 2019 to find out the yield response of wheat (*Triticum aestivum* L.) to nitrogen rates under zero tillage in coastal soil of southwestern Bangladesh. The treatments of N @ 0, 60, 80, 100, 120, 140 and 160 kg ha⁻¹ were applied from urea.

All management practices and intercultural operations such as weeding, irrigation and pest management were done as and when necessary. Data were collected for plant height (cm), number of total tillers per plant, dry matter content (g), first booting (days), maximum booting (days), first panicle initiation (days), maximum panicle initiation (days) and first flowering (days), spike length (cm), number of spikelet spike⁻¹, grain spike⁻¹, number of filled grain spike⁻¹, number of unfilled grain spike⁻¹, 1000-grain weight, grain yield (t ha⁻¹), straw yield (t ha⁻¹), biological yield (t ha⁻¹) and harvest index (%).

The data obtained from different characters were statistically analyzed following the analysis of variance techniques by using Statistics-10 a statistical software. The significant differences among the treatment means were compared following all pair wise comparison by least significant different (LSD) at 5% level of probability.

Nitrogen had significant effect on growth and yield parameters. Nitrogen applied @ 140 kg ha⁻¹ produced the highest plant height (30, 45, 60, 75, 90 DAS and at harvest) and number of tillers (30, 45, 60, 75, 90 DAS and at harvest) whereas lowest plant height and number of tillers were found from the control plot.

Dry matter accumulation increased significantly with the increasing rate of N up to 140 kg ha^{-1} and then decreased due to over dose. Nitrogen at the rate of 140 kg ha^{-1} produced highest amount of dry matter.

Plot treated with 140 kg N ha^{-1} took minimum days for first booting (43 days), first panicle initiation (53.67 days) and first flowering and plot treated with no nitrogen took maximum days for first booting (57.67 days), first panicle initiation (66.33 days) and first flowering.

Length of spike increased with the increasing nitrogen levels. Application of 120 kg and 140 kg N ha^{-1} produced statistically similar spike length.

The effect of different levels of nitrogen on the number of spikelets spike^{-1} was found significant. Application of 140 kg N ha^{-1} produced highest number (22.13) of spikelets spike^{-1} . Significant variation was observed due to different nitrogen doses on number of filled grain spike^{-1} . Statistically similar number of filled grain spike^{-1} was recorded from the treatments 140 and 160 kg N ha^{-1} . Maximum grains spike^{-1} (34.40) was obtained from N_5 treatment where 140 kg N ha^{-1} was applied.

In nitrogen treatments grains weight and 1000 grains weight were influenced significantly. The maximum 1000-grains weight (43.37 g) was found from the field treated with 140 kg N ha^{-1} which was statistically similar with other treatments except control and application of nitrogen @ 140 kg ha^{-1} produced maximum grain weight.

In respect of grain yield, nitrogen had significant variation at different levels. The highest grain yield (3.8 t ha^{-1}) was obtained from 140 kg N ha^{-1} . Like grain yield, higher straw yield (4.84 t ha^{-1}) and biological yield (8.65 t ha^{-1}) were obtained from the treatment of 140 kg N ha^{-1} than other N treatments. Harvest index was significantly influenced by nitrogen levels on wheat

where 120 kg N ha⁻¹ and 140 kg N ha⁻¹ produced statistically similar harvest index value which were 44.09 % and 43.54% respectively.

Conclusion

From the findings of the experiment and supported discussion, it can be concluded that application of nitrogen @ 140 kg ha⁻¹ performed better which was very closer to that of 120 kg N ha⁻¹. So, 120-140 kg N ha⁻¹ might be optimum dose for wheat cultivation under zero tillage condition in the coastal zone soil of southwestern Bangladesh,

Recommendations

However, better understanding and conformity of the results it would be recommended that-

- ✓ The same experiment with similar treatment should be repeated at least one more year and
- ✓ The experiment should be trialed in the farmer's field at different location of southwestern coastal region of Bangladesh.

CHAPTER 6

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APPENDICES

Appendix-I: Nutrient rate and plot wise fertilizers calculation

N level	Nutrient (kg ha ⁻¹)	Fertilizer (kg ha ⁻¹) (Urea-TSP-MoP-Gypsum-ZnSO ₄ -Borax)	Fertilizer (g plot ⁻¹) (12 m ²) (Urea-TSP-MoP-Gypsum-ZnSO ₄ -Borax)
N ₀	N ₀ -P ₃₀ -K ₇₅ -S ₂₀ -Zn ₂ -B ₁	0-150-150-100-6-6	0-180-180-120-7.2-7.2
N ₁	N ₆₀ -P ₃₀ -K ₇₅ -S ₂₀ -Zn ₂ -B ₁	130-150-150-100-6-6	156-180-180-120-7.2-7.2
N ₂	N ₈₀ -P ₃₀ -K ₇₅ -S ₂₀ -Zn ₂ -B ₁	174-150-150-100-6-6	209-180-180-120-7.2-7.2
N ₃	N ₁₀₀ -P ₃₀ -K ₇₅ -S ₂₀ -Zn ₂ -B ₁	217-150-150-100-6-6	260-180-180-120-7.2-7.2
N ₄	N ₁₂₀ -P ₃₀ -K ₇₅ -S ₂₀ -Zn ₂ -B ₁	260-150-150-100-6-6	312-180-180-120-7.2-7.2
N ₅	N ₁₄₀ -P ₃₀ -K ₇₅ -S ₂₀ -Zn ₂ -B ₁	304-150-150-100-6-6	365-180-180-120-7.2-7.2
N ₆	N ₁₆₀ -P ₃₀ -K ₇₅ -S ₂₀ -Zn ₂ -B ₁	348-150-150-100-6-6	418-180-180-120-7.2-7.2

Appendix-II: Google map of the experimental location

