BIOMASS QUALITY AND YIELD RESPONSE OF FODDER MAIZE (*Zea mays*) TO PLANT POPULATION AND NITROGEN RATES IN THE SALINE SOILS OF SOUTHWESTERN COASTAL BANGLADESH

A Thesis

By

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This thesis (Course No. 081108 AN-6118) is submitted to the Agrotechnology Discipline of Khulna University for the partial fulfillment of the requirements for the degree of Master of Science in Animal Nutrition

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Khulna University
Khulna-9208

December, 2024

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Dedicated to

My

Beloved Parents

Biomass Quality and Yield Response of Fodder Maize (*Zea mays*) to Plant Population and Nitrogen Rates in the Saline Soils of Southwestern Coastal Bangladesh

Abstract

Green fodder is considered as an economic source of nutrients over concentrated feeds and plays a significant role in the improvement of livestock productivity, especially for milch animals. Poor health and productivity of livestock in this southwestern coastal region of Bangladesh are mainly constrained by the acute scarcity of forage. Fodder yield and quality are largely influenced by nutrition, plant population, and cutting age. Thus, an experiment was conducted at the farmer's field in the saline soil of southwestern Bangladesh to evaluate the yield and quality response of biomass to nitrogen and the cutting age of maize fodder. The experimental treatment consisted of five nitrogen rates (0, 155, 195, 235 and 275 kg ha^{-1}) and four levels of plant population $unit^{-1}$ area (124220, 173910, 204970 and 239130 ha^{-1}). Growth parameters and biomass yield were higher with the application of 235 kg N ha^{-1} and the use of 204970 plant population ha^{-1} separately. The highest ash content was attained at 275 kg N ha^{-1} and 124220 plant population ha^{-1} and the highest ether extract content was obtained at 195 kg N ha^{-1} and 124220 plant population ha^{-1}. The highest crude protein (CP) and crude fibre (CF) content was achieved from the interaction of 275 kg N ha^{-1} with 124220 plant population ha^{-1}. The higher the N rates, the higher the biomass accumulation, which improved the biomass quality and net income. Biomass accumulation and net income were higher with higher plant population $unit^{-1}$ areas, but quality declined. The biomass accumulation, CF, and EE were increased in the later cut (80 days) but the CP and ash content were higher in the early cut (50 days). The findings of this study may be concluded that the application of N @ 235-275 kg ha^{-1} and 204970-239130 plant population ha^{-1} with a 65 days cut is suitable for maize fodder in the saline soil of southwestern coastal Bangladesh.

Keywords: *Maize, Fodder, Biomass productivity, Quality, Saline soil, Profitability*

ACKNOWLEDGEMENT

All praises to "Almighty Allah" who is the creator and ruler of the universe, whose mercy kept alive and empower to complete the research work and to prepare this manuscript successfully.

The author is delighted to express his special appreciation, proudly heartiest gratefulness, the deepest sense of respect, and preeminent regard to his honorable research Supervisor, Dr. Bidhan Chandro Sarker, Professor, Agrotechnology Discipline, Khulna University, Khulna for his constant and educational guidance, valuable suggestions, continuous inspiration and immense help throughout the tenure of this research work and also in preparing the thesis.

The author wishes to express his gratefulness, sincere appreciation, deep sense, and immense admiration to his respected research Co-supervisor Dr. Md. Shafiqul Islam, Professor, Agrotechnology Discipline, Khulna University, Khulna for his generous guidance, precious advice, and helpful suggestions during the course of the study for successful completion of the research work and preparation of the manuscript.

The author would like to express his heartfelt appreciation and gratitude to all the respected teachers of the Agrotechnology Discipline for their valuable teaching, sympathetic co-operation, helpful suggestions, constant inspiration, and encouragement during the course of this study.

The author is grateful to Mr. Bidhan Tarafder, a field worker at Pankhali, Dacope, Khulna for his continuous assistance with field layout, land preparation, fertilizing, fencing, intercultural operations, cutting, and help in data collection. The author passes on his sincere thanks to Mr. Biplab Kumar Das, Lab Attendant, Agronomy Laboratory of Agrotechnology Discipline, Khulna University, Khulna for his continuous assistance all the time during the research period. I would like to express my thanks to my batch mate Shahriar Kabir Shuvo who assisted the author with data collection and soil analysis.

The author would like to thank all his friends who supported and believed in him. They all had helped him to focus on what he had to do. Finally, the author would like to give thanks to his family and relatives for their blessings and constant inspiration.

December, 2024 **The Author**

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CHAPTER I

INTRODUCTION

Maize (*Zea mays* L.), a significant cereal crop globally, is now effectively integrated into diverse cropping systems in the Indo-Gangetic plains (Gathala et al., 2015). Its popularity is rising steadily due to its versatile uses such as in various food products, as fodder for livestock; feed for poultry and as a source of fuel and raw materials for industry (Shiferaw et al., 2011; Valbuena et al., 2012). Maize production, along with other cereals, has doubled in the last four decades due to higher yields achieved through the adoption of improved crop varieties and increased use of fertilizer, water and pesticides (Evenson and Gollin, 2003). Maize, along with rice and wheat, is essential in global agriculture, supplying a minimum of 30% of the dietary calories for over 4.5 billion people in 94 developing nations (FAO, 2016). Maize is valued for its nutritional composition, containing approximately 66.7% starch, 10% protein, 4.8% oil, 8.5% fiber, 3% sugar, and 7% ash (Noor et al., 2010). As a cash crop for farmers, maize is extensively cultivated for sale as green fodder. There are notable differences in the nutritional quality characteristics between maize stover and the entire plant used as forage. Additionally, maize stover and dry leaves are valued as efficient cooking fuels worldwide (Shiferaw et al., 2011). Besides that, both the green parts of the plant and the grains are utilized as feed for livestock and poultry. It also serves as a raw material for numerous agro-based industries (Abuzar et al., 2011; Memon et al., 2011; Maqsood et al., 2012). Due to its rich composition of carbohydrates, fats, proteins, essential vitamins and minerals, maize has gained recognition as a valuable nutritional resource for economically disadvantaged populations (Prasanna et al., 2001). Therefore, maize fodder can play a significant role in livestock food security and nutritional programs in Bangladesh, owing to its superior productivity and nutritional benefits. The market demand for maize in South Asia, including Bangladesh, has seen substantial growth over the past decade. This increase is driven by expanding industries in poultry and fish feed, as well as the use of maize in processed foods (Ali et al., 2008; Timsina, 2011).

Green fodder is a crucial component of the diet for milking animals, supplying essential nutrients needed for milk production and maintaining their overall health. Fresh green grasses can be chopped into small pieces and converted into silage, which can be preserved for years and used as feed during dry or drought periods. Green forages offer a cooling effect on the animal bodies, are more palatable, contain easily digestible nutrients and provide fresh, naturally usable nutrients while also having a mild laxative effect. Green fodders are nutrient-rich and serve as a primary source of Vitamin A and enhance the immune system of livestock. It also plays a vital role in preserving and supporting the function of mucous membranes. Additionally, Vitamin A is essential for reproductive health, aiding in conception, sustaining pregnancy, and ensuring proper placental expulsion. Prusti et al. (2014) observed a 5-12% reduction in enteric methane emissions when river buffaloes were fed a diet based on green fodder. Dairy animals producing 5-7 liters of milk per day can be sustained entirely on green fodder. Incorporating green fodder into the diet of dairy animals reduces the need for concentrate feed, thereby improving profitability. Consequently, year-round fodder production is crucial for achieving economically and environmentally sustainable dairy farming.

The significance of fodder crops in agriculture is indisputable, as they provide essential and nutritious feed that is crucial for livestock production, ensuring the supply of milk, butter and other by-products for human consumption. Approximately two-thirds of the global maize production is utilized for livestock feed, as well as for commercial starch and oil production. In Bangladesh, livestock sector is the country's second-largest, after fisheries, in meeting the nation's protein needs (BARC, 2011). The livestock industry in Bangladesh is vital to the nation's economic growth, playing a key role in ensuring food and nutrition security, creating self-employment opportunities, and most importantly, alleviating poverty (Bangladesh Economic Review, 2023). In Bangladesh, the livestock sector is expanding rapidly, contributing approximately 2% to the GDP and over 16% to the agricultural sector in the fiscal year 2021-22. With a livestock population exceeding 430 million, Bangladesh has achieved self-sufficiency in meat production, meeting the per capita demand of 830 grams and supporting a substantial portion of the population, with 20% directly and 50% indirectly dependent on it (Hossan, 2023).

Fodder feed encompasses a variety of items such as fodder maize, hay, straw, silage, compressed and pelleted feeds, oils, mixed rations, sprouted grains, and legumes. Fodder maize intended for silage is harvested when the plant is green and the cob is immature (Boller et al., 2010; Meehan and Gilliland, 2013). However, there was a noticeable decrease in global production of fodder maize from 9,494,800 metric tonnes in 2000 to 9,188,130 metric tonnes in 2010 (GeoHive, 2013). Currently, the majority of fodder maize is produced in the United States, China, and Brazil. As a result, fodder maize has become a crucial crop, second only to grass in importance as forage. It is either fed directly to farm animals as fresh feed or ensiled to produce high-energy silage, which supplements grass silage for winter livestock feeding (Rasheed and Mehmood, 2004). Fodder maize is known for its ease of cultivation and resilience to drought conditions, reliably yielding high outputs with minimal input from farmers. Maize stands out as a leading forage crop globally due to its rapid growth rate, high yield, wide adaptability, excellent digestibility, palatability and absence of any significant anti-nutritional factors (Hedayetullah and Zaman, 2018). On a dry weight basis, typical nutritional values in fodder maize include 20.5-24.7% dry matter (DM), 5.5-8.7% crude protein (CP), 23.1-30.2% crude fiber (CF), 64.1-72.8% neutral detergent fiber (NDF), 38.3-46.8% acid detergent fiber (ADF) and 6.0-8.0% ash (Chaudhary et al., 2011). However, achieving the best quantity and quality of maize fodder production relies on several factors, with timely sowing, sufficient moisture availability and adequate supply of essential macro- and micro-nutrients to the plant being paramount (Fales and Fritz, 2007).

Plant population is another crucial factor that significantly impacts the growth, development, and yield of maize. The ideal plant population allows plants to efficiently utilize solar radiation and nutrients. Increased penetration of sunlight can reach the soil surface, potentially leading to excessive evaporation of soil moisture. Narrower spacing disrupts intercultural operations and increases competition among plants for nutrients, air, and light. This can result in maize plants becoming shorter, weaker, and thinner, ultimately leading to reduced yield. Properly adjusting plant spacing in maize fields is crucial to maximize the crop's use of solar energy and minimize soil moisture evaporation (FAO, 2012). Therefore, maintaining an optimal population ensures the efficient utilization of natural resources such as nutrients, sunlight, and soil moisture, promoting satisfactory growth and yield. Narrower row spacing and higher plant density delay the onset of competition among plants (Duncan, 1984), leading to enhanced early crop growth (Bullock et al., 1988). Therefore, it is essential to ensure the optimal nitrogen application rate and appropriate plant spacing to maximize maize yield.

Nitrogen functions as a growth promoter for plants, constituting approximately one to four percent of their dry matter (Anonymous, 2000). Nitrogen is essential for the formation of cell membranes, chlorophyll, amino acids, nucleic acids, enzymes and proteins (Seilsepour and Rashidi, 2011). A lack of nitrogen decreases plant growth and yield (Haque et al., 2001; Shah et al., 2003; Maqsood et al., 2014), whereas adding nitrogen enhances crop production (Ahmad, 2000). There is a direct correlation between nitrogen fertilizer levels and the number of days until tasseling occurs (Gungula et al., 2003). It also enhances the dry matter content of maize (Abbas et al., 2003). Therefore, it is essential to apply nitrogen optimally to enhance the quality of maize (Li et al., 2010). Nitrogen fertilization led to an increase in the number of leaves per plant and leaf area (El Noeman et al., 1990; Gasim, 2001). John and Warren (1967) observed that nitrogen supplementation enlarged stem diameter. Koul (1997) documented that applying nitrogen led to increased plant height, leaf area, number of leaves and stem diameter in fodder maize, resulting in higher yields of fresh and dry forage. Nitrogen application also increased the leaf-to-stem ratio (Duncan, 1980). These results align with Gasim's (2001) findings, which suggest that the increase in leaf-to-stem ratio due to nitrogen application is likely attributed to higher leaf numbers and increased leaf area, resulting in larger and more robust leaves. Salem and Ali (1979) observed that nitrogen application enhanced the number of ears per plant, ear height, days to mid-silking and protein content while reducing the number of barren stalks. Nitrogen was found to increase grain protein content (Warren et al., 1975; Gangwar and Kalra, 1988). Higher protein content in maize straw was achieved with increased nitrogen doses (Rai, 1965). Tripathi et al. (1979) observed that nitrogen application significantly increased crude protein content in forage oats.

Fodder cultivation in Bangladesh in terms of area and production is very limited according to the demand for livestock. The area coverage and total production of fodder in Bangladesh are 20263 ha and 424178 metric tons with an average yield of green fodder is 20.93 t ha^{-1} (BBS, 2023). The productivity of livestock in the coastal zone of southwestern Bangladesh is inferior due to the critical shortage of fodder. This area is a single-crop (monsoon rice) area and most of the land remains fallow during winter and following the dry season due to the constraints of excessive soil wetness and later on lack of fresh irrigation water and soil salinity (Sarker et al., 2023). After the harvest of monsoon rice maize can be cultivated as it can fit in wet soil, and can tolerate salinity and moisture stress moderately. Additionally, this study holds significance for sustainable agriculture and environmental stewardship. Farmers can minimize environmental impacts associated with excessive fertilizer use while maximizing crop productivity by identifying the appropriate seed and nitrogen rates. With the above view, an experiment was carried out to study biomass quality and yield response of fodder maize to plant population and nitrogen rates in the saline soil of southwestern coastal Bangladesh. This research can contribute to the development of best management practices for maize cultivation as a fodder crop, promoting resource efficiency and minimizing the potential for nutrient runoff and environmental degradation. Thus, the present research aimed to evaluate the effect of nitrogen and plant population on biomass yield and quality of maize fodder grown under zero tillage conditions in the coastal soils of southwestern Bangladesh.

CHAPTER II

REVIEW OF LITERATURE

2.1 Maize fodder

For ruminant animals, maize (*Zea mays* L.) green forage—especially when it includes the stalks, leaves, and ears—is an energy-dense diet. While maize feed is often ensiled in colder climates, year-round maize cultivation in tropical climates may allow for continuous green forage gathering, negating the need for ensiling (Brewbaker, 2003). In times of shortage (dry, hot summers and winters) grazing whole maize plants also gives cattle access to green forage (Potter, 2012; Newport, 2006). Corn green forage is an important source of nutrition for smallholder-owned livestock in severe environments with little forage (Methu et al., 2006). Compared to most other tropical fodder crops, where the digestible matter (DM) is frequently less than 40%, maize is a higher calorie source. In tropical regions, maize feed matures in three months, requires just one harvest, requires less labor, and requires less expensive machinery than grass forage, which needs to be collected virtually every month (Brewbaker, 2003).

2.2 Maize forage production in Bangladesh

Maize is the third most cultivated grain in Bangladesh, suitable for cultivation throughout the year in all three seasons. Notably, winter maize dominates, covering 84% of the country's total maize-growing areas. Planting occurs between October and February, spanning five months, depending on land suitability and agricultural practices.

From an agricultural and soil perspective, maize can thrive across Bangladesh due to its adaptability. It is known for its rapid growth rate. Maize flourishes in temperatures ranging from a minimum of 10°C to a maximum of 30°C. The plant pollinates effectively and matures quickly within the temperature range of 20°C to 30°C. Bangladesh's average temperatures, with a minimum of 12°C and a maximum of 29°C, create an ideal environment for successful maize cultivation (BARC, 2013). As a short-day crop, maize can be cultivated year-round throughout the country. In Bangladesh, maize is cultivated across 4.96 lakh hectares of land, yielding 45.92 lakh metric tons annually with an average yield of 9.25 tons per hectare (BBS, 2023). It is grown for multiple purposes including fodder, sweet corn, baby corn, boiled and roasted cobs, popcorn and both field corn for animal feed and human consumption, as well as for various industrial processed products.

Recently, Bangladesh has approximately 567.34 lakh ruminants (DLS, 2021). Among livestock, cattle play a crucial role in the country, contributing significantly to milk (98.0%), meat (60.0%), and hides (60.0%) production (Sarker et al., 2021). Despite agriculture occupying 77.35% of the total cultivated land, only a minimal 0.04% is allocated to fodder production in Bangladesh (BBS, 2021).

Livestock can also be fed various fodder trees and weeds (Ehsanul, 2016; Khan et al., 2009). While there is an increasing trend in fodder crop production in Bangladesh (Sarker et al., 2021), there still exists a deficit of approximately 45% in fodder supply (Huque & Sarker, 2014). This is partly because there is limited land available for fodder production compared to the cultivation of other economically valuable food crops.

Enhancing forage and fodder production at the farm level is a key priority alongside implementing breeding policies, strengthening veterinary services, enforcing hygiene regulations and legal frameworks, introducing good manufacturing practices for traditional dairy products, and developing human resources to accelerate livestock development in the country. Fodder production appears to be gaining famous in various regions of our country, particularly for livestock farming, especially in dairy production (Sarker et al., 2021). Increased fodder production resulted in a rise in crossbred cows, contributing to higher milk production (Islam et al., 2016).

Kaveri-54 maize was sown for this experiment, which is normally used for grain production. There is no specific variety of maize for fodder production. So, Kaveri-54 was selected for fodder production.

2.3 Effect of nitrogen rates on the growth parameters of maize fodder

Various factors influence the growth of crops such as forage maize, including parameters like leaf count, plant height, stem thickness, and leaf surface area, which are notably impacted by nitrogen fertilizer application (Boltro et al., 2022). Various growth assessments such as leaf area index, leaf length, leaf width, and growth rate are enhanced through nitrogen application (Namakka et al., 2012). The application of nitrogen enhances photosynthetic pigments in maize crops, although it results in a decrease in the chlorophyll a:b ratio (Akram 2014).

Paul et al. (2019) conducted a field experiment on fodder maize and found that varying nitrogen levels significantly influence growth parameters. They observed that applying 200 kg N ha-1 resulted in the tallest plant height (204.9 cm) and the highest number of leaves per plant unit (12.22), whereas applying 100 kg N ha-1 led to shorter plant height (155.4 cm) and fewer leaves per plant unit (10.56). Ahmed et al. (2017) observed that higher concentrations of urea had adverse effects on plant growth. In contrast, Khanna et al. (2019) found that applying azotobacter yielded the best results, and even a combination of FYM application showed favorable improvements in crop growth and yield.

Khan et al. (2014) reported a significant increase in the number of plant leaves through the application of nitrogen at optimal levels. Valdabadi and Farahani (2012) from Iran found that nitrogen application significantly influenced various growth parameters of maize, including total dry weight (TDW), relative growth rate (RGR), leaf area index (LAI), and crop growth rate (CGR). The application of 520 kg urea ha^{-1} resulted in the highest values of LAI (4.2), TDW (1910 g m^{-2}), CGR (31.2 g. g^{-1}. M^{-2} day^{-1}), and RGR (0.08 g.g. day^{-1}). Jena et al. (2015) suggested that applying 240 kg N ha^{-1} resulted in taller plants (212.75 cm) and a higher leaf area index (3.89) compared to untreated control treatments.

Nitrogen is found in protoplasm, proteins, nucleic acids, and chlorophyll, contributing significantly to the vegetative and reproductive stages of crop growth. Elevated nitrogen levels have been linked to enhanced plant height, stem diameter, leaf size, leaf area index, dry matter accumulation, net assimilation rate, and yield per hectare (Cheema et al., 2010). In the same vein, fodder maize cultivar Akbar achieved maximum stem diameter, leaf area index, green fodder yield, and total dry matter production when supplied with elevated nitrogen through fertigation (Hassan et al., 2010; Iqbal et al., 2006).

According to Reddy and Bhanumurty (2010), the application of 240 kg N ha^{-1} resulted in significantly higher yields of green fodder, dry matter, and crude protein. Similar results were observed by Almodares et al. (2009), who noted increased biomass and crude protein in fodder maize with higher nitrogen levels. In a comparable investigation, Nadeem et al. (2009) found that varying nitrogen levels significantly influenced the growth parameters (such as plant height, number of leaves per plant, stem diameter, and leaf area) and crude protein content of the maize cultivar Afgooi.

Ayub et al. (2002) conducted an experiment regarding nitrogen (0, 120, 160 and 200 kg ha^{-1}) and Phosphorous (0, 40, 60 and 80 kg ha^{-1}) levels on maize fodder and reported that 200 kg N ha^{-1} resulted in the highest plant height (198.8 cm), stem diameter (1.58), and leaf area $plant^{-1}$ (4218 cm^2). Considering the significance of nitrogen for achieving economic returns, an experiment was conducted to investigate the impact of varying nitrogen levels on fodder maize.

2.4 Effect of nitrogen on biomass yield of maize fodder

Nitrogen fertilization significantly influences the yield of forage crops. For instance, applying 200 kg of nitrogen per hectare resulted in the highest forage yield (70.38 tons ha^{-1}) for fodder maize compared to 150 kg N ha^{-1}, whereas applying 100 kg N ha^{-1} yielded the lowest forage yield (46.72 tons ha^{-1}) (Paul et al., 2019). Similarly, Khan et al. (2014) found that optimal yield was achieved when nitrogen was applied correctly at the appropriate dosage. Jena et al. (2015), in their study conducted in Andhra Pradesh on maize crops, demonstrated that the application of 240 kg N ha^{-1} resulted in the highest dry matter production (13432 kg ha^{-1}), whereas the lowest dry matter production (4022 kg ha^{-1}) was observed in the control environment. Kar et al. (2016) found that applying the appropriate recommended fertilizer dose led to increased dry matter content (21.66%) and higher dry matter yield (83.77 q ha^{-1}).

Kalra and Sharma (2015) conducted an experiment on fodder maize in Punjab, focusing on agro-climatic factors. They found that higher heat use efficiency (6.46 kg/ha °C days) and photo-thermal index (22.76 °C days/day) was observed with the application of 120 kg N ha^{-1} compared to the control. This increase was attributed to enhanced photosynthesis rates, resulting in greater accumulation of dry matter. Additionally, they observed lower accumulated photo-thermal units (19531 °C days) and growing degree days (1427 °C days) with higher nitrogen application compared to the control condition. Consequently, this enhances the vegetative growth of the fodder maize crop and boosts the yield of green fodder.

Meena et al. (2019) experimented and found that applying a higher nitrogen dose of 120 kg ha^{-1} led to an increase in both crude fiber content and crude fiber yield by 9.5% and 48.4%, respectively, compared to the control. These findings are consistent with studies conducted by Bilal et al. (2005), Budakli et al. (2010), Emine et al. (2010), Aslam et al. (2011), Dar et al. (2014), and Ali and Muhammad (2017). Fodder maize treated with 120 kg N ha^{-1} significantly increased nitrogen content (1.17%) and nitrogen uptake (145.3 kg ha^{-1}). The application of nitrogen likely enhanced the nutritional conditions in the rhizosphere and within the plant system, facilitating nutrient absorption, uptake, and translocation to reproductive structures, thereby increasing both nitrogen content and uptake. Increased green and dry fodder yields resulting from nutrient supplementation likely led to higher nitrogen content in the fodder, which in turn reflected increased nitrogen uptake by fodder maize. Similar observations were documented by Reddy and Bhanumurthy (2010), Patil (2013), Dar et al. (2014), Khan et al. (2014), and Vyas et al. (2015).

From the findings of Ayub et al. (2002) reported that the highest green fodder yield and dry matter percentages was produced from the application of 200 kg N ha^{-1} than other doses (0, 120 and 160 kg ha^{-1}). The production of dry fodder yield depends on the photosynthetic efficiency of a plant, converting photosynthates into dry matter, influenced by both genetic characteristics of cultivars and growing conditions. Fodder maize plants receiving nitrogen doses of 200 (9.99 t ha^{-1}), 280 (9.59 t ha^{-1}), 240 (9.46 t ha^{-1}), and 160 kg ha-1 (9.44 t ha^{-1}) achieved the highest and statistically comparable dry fodder yields. A similar pattern was observed in green fodder yield, highlighting nitrogen's significant role in assimilate production. Increased nitrogen likely stimulated vigorous plant growth, leading to greater partitioning of dry matter. Cerny et al. (2012) noted a linear increase in dry matter yield of fodder maize (up to 14.8 t ha^{-1} with fertilizer N up to 120 kg ha^{-1}), consistent with findings reported by Ayub et al. (2002).

2.5 Effect of nitrogen on quality attributes of fodder maize

The efficiencies and quality attributes are crucial factors for fodder maize crops. Providing high-quality feed to animals typically results in increased output. Therefore, it is essential to cultivate high-quality fodder crops. According to Kar et al. (2016), the highest carbohydrate content (83.30%) was observed in fodder maize crops when applying the recommended dose of nitrogen, compared to sugarcane (78.55%) and sorghum (73.18%). This high carbohydrate content in maize indicates its significant energy value as a green fodder crop. Iqbal et al. (2014) suggested that the application of nitrogen, whether in organic or inorganic forms, enhanced the characteristics and quality attributes of fodder maize. For instance, protein content increased to 8.43%, which was higher compared to control treatments. Similarly, Htet et al. (2016) conducted trials on forage maize and found a higher percentage of crude protein and nitrogen-free extract at 70 days after sowing compared to 90 days after sowing. Baghdadi et al. (2017) conducted a study to examine the effects of nitrogen and pre-sowing treatments on fodder attributes of maize. They found that applying 360 kg nitrogen ha^{-1} resulted in higher percentages of crude protein (7.04%), acid detergent fiber (27.64%), total ash (6.02%), and dry matter digestibility (58.41%) compared to lower nitrogen application rates (120 kg ha^{-1}). Meena et al. (2019) experimented and found significant effects on yield and crude fiber content based on varying nitrogen levels. They also observed that the highest percentages of crude protein content (7.04%), crude fiber content (25.21%), crude protein yield (866 kg ha^{-1}), crude fiber yield (3143 kg ha^{-1}), and nitrogen content (1.17%) were achieved with the application of 120 kg nitrogen per hectare compared to the control condition.

Young, growing, and lactating animals often need additional supplementation of crude protein. Ensuring sufficient crude protein in animal diets is crucial for their health, productivity, and overall profitability of ranching operations (Firdous et al., 1996; Kebede et al., 2012). The observed linear increase in crude protein percentage with higher nitrogen concentrations is likely attributable to nitrogen being a fundamental component of protein molecules and essential for amino acid synthesis. Aslam et al. (2011) also noted a similar trend with the highest nitrogen application (150 kg ha^{-1}).

Crude fiber is essential for proper rumen function and metabolism, and it serves as a beneficial dietary component. The physical attributes of fiber, particularly its particle size, play a significant role in controlling the rate of digestion, rumination, saliva production, and the pH balance in the rumen (Johnston et al., 2003; Kebede et al., 2012). The increase in crude fiber content with higher nitrogen levels can be explained by the greater stem diameter and taller plant height. Aslam et al. (2011) also observed similar findings. Increased protein synthesis and reduced levels of pectin, cellulose, and hemicellulose, which are key components of crude fiber (Tiwana et al., 2003), have been similarly noted by Ibrahim et al. (2006) and Reza et al. (2012). Chaudhary et al. (2011) reported that on a dry weight basis, fodder maize typically contains 20.5-24.7% dry matter (DM), 5.5-8.7% crude protein (CP), 23.1-30.2% crude fibre (CF), 64.1-72.8% neutral detergent fibre (NDF), 38.3-46.8% acid detergent fibre (ADF), and 6.0-8.0% ash.

2.6 Effect of plant population quality and nitrogen uptake

Proper spacing of maize plants in the field is crucial for maximizing solar energy absorption by the crop and minimizing soil moisture evaporation (FAO, 2012). The amount of radiation intercepted by the leaves and their efficiency in converting to biomass are key factors influencing total dry matter production. It is advisable to maintain optimal population levels to fully utilize natural resources such as nutrients, sunlight, and soil moisture, ensuring a satisfactory yield (Mariscal et al., 2000). Excessively dense planting is undesirable as it promotes competition among plants for these resources. The production of biomass in a crop primarily hinges on the development of leaf area and subsequent photosynthetic activity (Abuzar et al., 2011; Sangoi, 2001; Natr, 1992). Widdicombe and Thelen (2002) noted that the levels of crude protein, ether extract, and ash content in forage maize rose as the plant density increased. Seeding densities play a crucial role in affecting the growth, yield, and quality aspects of crops (Mahmood, 1998). Higher seeding densities have the potential to enhance the yield of various types of fodder crops. Significant differences in planting densities have been noted to achieve increased maize fodder yields. Graybil et al. (1991) found that the highest silage yield was achieved with either 26,000 or 32,000 plants per acre, depending on the hybrid used. Cox (1997) indicated that the average plant densities for corn silage were above 36,000 plants per acre in 1992 and 32,523 in 1993.

Meena et al. (2019) conducted an experiment of three spacing (S1:20cm, S2:30cm, S3:40cm) and four levels of nitrogen (N1:00 kg N ha^{-1}, N2:80 kg N ha^{-1}, N3: 100 kg N ha^{-1} and N4: 120 kg N ha^{-1}) on fodder maize and reported that wider row spacing of 40 cm resulted in significantly higher levels of crude protein (6.98%) and crude fiber content (25.11%), comparable to those observed with 30 cm row spacing. The increased crude protein content in wider row spacing could be attributed to lower plant density, allowing more nitrogen availability per plant. Maximum yields for crude protein and crude fiber were notably achieved with a row spacing of 30 cm (800 and 2905 kg ha^{-1}, respectively). These findings align with those reported by Emine et al. (2010) and Dar et al. (2014).

From the finding of Aslam et al. (2011) reported that the highest protein content achieved with a seed rate of 75 kg ha^{-1} exceeded that of 125 kg ha^{-1} by 10.27% and 100 kg ha^{-1} by 6.71%. This indicates a decrease in protein content with higher seed rates. Importantly, the protein contents at seed rates of 100 kg ha^{-1} and 125 kg ha^{-1} are statistically similar. These findings are consistent with those reported by Mahmood (1980) and Ayub et al. (1999). The highest crude fiber content (30.803%) was observed with a seed rate of 125 kg ha^{-1}, whereas the lowest (29.653%) was observed with a seed rate of 75 kg ha^{-1}.

Shivkumar et al. (2022) conducted field experiments in 2019 -2021 at Field No.36 of Eastern block farm, Department of Agronomy, Tamil Nadu Agricultural University, Effect of Spacing and Fertilizer Levels on Growth, Yield and Economics of Fodder Maize Pre-Release Culture TNFM 131-9. The results revealed that wider spacing of 40 cm x 15cm recorded higher stem girth (2.21 cm), green fodder yield (44.80 t/ha), dry matter yield (12.10 t/ha) and crude protein yield (1.54 t/ha) which was on par with 30cm x 15cm.

2.7 Effect of salinity on fodder

Nowadays, salinity poses a significant challenge for the country. Over 30% of Bangladesh's arable land is situated in its coastal regions. According to Hussain et al. (2019), around 1.056 million hectares of the 2.86 million hectares of coastal and offshore lands are experiencing varying levels of salinity. Katerji et al. (1994) carried out an experiment to observe the effect of salinity on the emergence and early seedling growth of sunflower and maize. Experiments were conducted in pots filled with sandy clay and sandy loam. The experiments consisted of a control and four different degrees of saline water qualifies with chloride concentrations of 15, 30, 45, and 60 meq/l. The emergence of sunflower and maize were affected by salinity. Soil texture did not affect the emergence. The higher the salinity level the lower the leaf area and the dry matter production. Leaf, stem, and root showed an almost similar growth reduction due to salinity. Maize has the capacity to tolerate salinity to some extent. To fit the fodder production in optimum time just after harvesting of T. aman rice using different spacing and N rate a new intervention for the maximization of fodder intensity in the coastal soil of southwestern Bangladesh.

CHAPTER III

MATERIALS AND METHODS

The study was conducted at the farmer's field in the village of Pankhali, Dacope, Khulna which was located at 26 km southwest of the Khulna university campus. The main objective of this study was to evaluate the effect of nitrogen rate and plant population per unit area on growth and biomass yield and quality of maize fodder under zero tillage conditions in the coastal soil of southwestern Bangladesh. A brief description of the experimental procedures is given below:

3.1 Details of the experiment site

The experiment was conducted in the farmer's field (22°24' N 89°24' E and the elevation was 3 m above the mean sea level) of Pankhali, Dacope, Khulna situated in the Agro-ecological Zone of Ganges Tidal Flood Plain (AEZ-13). The experimental site was characterized by a sub-tropical climate with moderately low rainfall with moderately low temperature during the Rabi season (November to March). Temperature in the study area during the growing period was ranging from 9.4-35.2 °C (Fig. 1A). The average monthly maximum temperature of January 2024, February 2024 and March 2024 was 27.4 °C, 33.0 °C and 35.2 °C respectively while the minimum monthly average temperature was 9.4 °C, 12.8 °C and 15.6 °C respectively (Fig. 1A). Both the maximum and minimum temperature steadily increased with the progress of time (Fig. 1A). The cumulative rainfall during the growing period was 87 mm (Fig. 1B). The texture of the experimental field soil was silty-loam type. The physicochemical properties of the experimental filed soil are presented in Table 1.

Table 1: Physical and chemical properties of the soil (experimental plot soil) of Pankhali, Dacope, Khulna

	Salinity	OM	N	K	P	Cu	Zn	B
	(dS m^{-1})	(%)		meq/100g soil)	(µg/g soil)			
Soil test value	4.2	2.54	0.147	0.53	32.83	115.72	2.29	0.88
Status	Light	Medium	Low	High	Very high	Very high	Very high	Very high

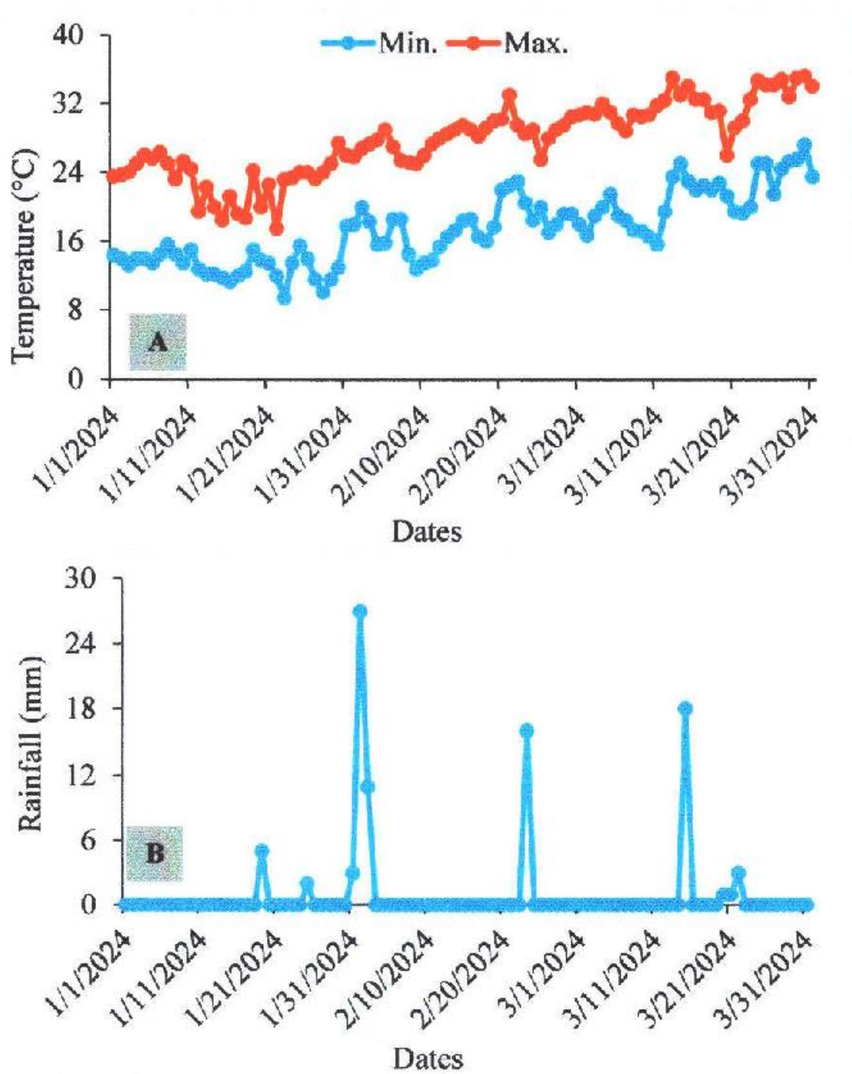

Figure 1. Daily temperature (A) and rainfall (B) pattern in the study area during the cultivation period.

3.2 Experimental design and treatment

The experiment was carried out in factorial randomized complete block design (RCBD) with three replications. The experimental treatment comprised four plant population (124220 ha^{-1}, 173910 ha^{-1}, 204970 ha^{-1} and 239130 ha^{-1}) and five nitrogen rates (0, 155, 195, 235 and 275 kg ha^{-1}). Maize hybrid variety Kaveri-54 (drought tolerant) was used as the planting materials in this study.

3.3 Collection of seeds

Seed (Kaveri 54 hybrid maize) of maize was collected from the local market of Khulna city. Hybrid maize Caberi 54 is the best in yield. Drought and storm-tolerant varieties. Yields satisfactorily on grassland and sandy soils. Attractive orange color. Life span: 145-150 days. Sowing time: September - December.

Sowing distance: 22 inches from row to row, 9-10 inches from plant to plant.

Seed rate: 6-7 kg/acre.

Grain Nature: Attractive orange color.

Plant height: Medium and relatively hardy.

Yield: Bumper yield with good management.

The moisture content of the grain at maturity is very low.

3.4 Seed sown and nutrient management

Seeds were sowing on 4th January, 2024. The spacing was 30 cm × 30 cm, 30 cm × 20 cm, 40 cm × 10 cm, and 20 cm × 20 cm and several seeds were sowing in every spacing like 80, 112, 132, and 154. Fertilizers were applied Urea, TSP, MOP, Gypsum, Zn and B acid by making holes on both sides (~7-8 cm away) of the seedlings ~7-10 cm depth of the soil after sowing of seeds and then the holes were refilled by soil and pressed mildly. The source of N, P, K, S, Zn and B were urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid. A little water was also given to the fertilizer hole. 1 month later only use urea and 45 days later use the last dose of urea. Urea was used as basal following treatment variable to investigate the effect of nitrogen doses and spacing of maize. Five nitrogen doses are N_0 (0 kg urea ha^{-1}), N_1 (155 kg urea ha^{-1}), N_2 (195 kg urea ha^{-1}), N_3 (235 kg urea ha^{-1}) and N_4 (275 kg urea ha^{-1}).

Nitrogen fertilizer was applied as per the experimental treatments and other fertilizers were applied in each unit plot according to the fertilizer recommendation guide (BARC, 2018). The variables were assessed including biomass production, nutritional composition (protein, fiber, and carbohydrates), and other quality parameters (e.g., digestibility, energy content).

3.5 Field and crop management

Sixty (60) plots having the same dimension of 2.8m×2.3m= 6.44m^2 spaces for each plot were arranged for this experiment. Replication to replication distance was 1.5 m and plot to plot distance was maintained 1.0 m.

3.5.1 Weeding

The crop was plagued with a few weeds in the early stages of crop establishment. The first weeding was done by hand 15 days after the seeds were sown, and the second was done 15 days later.

3.5.2 Irrigation management

Irrigation plays a crucial role in fodder agriculture, significantly influencing crop growth. The first irrigation was applied when the fodder was 30 days old, preceded by the application of urea fertilizer to enrich the soil with nutrients and support balanced crop development. The second irrigation followed at 45 days, using the same approach. A plastic pipe drainage system was utilized to manage and control water flow efficiently. The water was sourced from a nearby canal, ensuring adequate moisture levels were maintained. This irrigation method, combined with fertilizer application, provided sufficient water for the crops, boosting growth and improving their overall quality.

3.5.3 Pest control

Flies, moles, worms and insects were found during the trial. Theovit and carbofuran pesticides were used to suppress them. Thiophanate-methyl was used to treat fungal infections.

3.6 Harvesting and processing

Depending on the sowing date, the fodder was harvested (50 days, 65 days, and 80 days) by scissors when the plant had fully matured. Each plot's harvested product was packaged separately and properly marked. The bundles were placed on the open threshing floor after being dried in the sun for ten to twelve days and next went to the agronomy lab at Khulna University for oven drying. After the oven-dried, the fodder's dry weight was recorded and finally grind the fodder for proximate analysis. Finally, fodder yields of each treatment were determined on a dry weight basis and converted to t ha^{-1}.

3.7 Sampling, data collection, measurement and calculation

After harvesting and drying, 180 fodder samples were taken to the laboratory for nutrient analysis.

3.7.1 Plant height (cm)

The height of the plant was recorded in centimeters (cm) at the time of 30, 40, 50, 60, 65 and 80 days after transplanting (DAT). Five plants were selected randomly from each plot avoiding the sideline for data collection. Data were carefully recorded from the five individual plants of each plot. The plants were tagged in blue rope to detect them for future data collection. A large scale was used to measure the height of the plant. The height was measured from the ground level to the tip of the plant leaf. Finally, the average plant height was calculated from the collected data.

3.7.2 Number of leaves

The number of leaves was counted and recorded from five randomly selected plants at the time of 30, 40, 50, 60, 65 and 80 DAT. Data were recorded carefully by counting all leaf numbers from the five plants of each plot and then calculating the mean value for analysis.

3.7.3 Stem diameter (cm)

The stem diameter was measured by measuring tape from five plants at the time of 30, 40, 50, 60, 65 and 80 DAT. Data were recorded carefully from the five plants of each plot and finally measured the average value of stem diameter.

3.7.4 Chlorophyll content of leaves

Using a SPAD meter, the chlorophyll content of leaves was measured. Representative samples of 5 plants were selected randomly from each plot and the chlorophyll content was estimated from the upper most leaf which covered 2 × 3 mm leaf area and the average was calculated.

3.7.5 Biomass

Randomly five plants were harvested from each plot and their mean shoot weight was recorded.

3.8 Proximate analysis

The chemical composition of dried fodder samples was determined as per the standard method of the Association of Official Analytical Chemists (AOAC, 1990).

3.8.1 Crude protein (CP) analysis

Test procedures

Digestion

Digestion was carried out using the DK 8 Heating Digester from VELP SCIENTIFICA. A sample weighing 1g with an accuracy of ±0.1mg was prepared. For each sample, 2 catalysts and 12 ml of H_2SO_4 were added, and the mixture was placed into the digestion block. The temperature of the digestion block was maintained at 420 °C, and the sample was heated for 60 minutes until the fumes ceased and clean blue color appeared. Subsequently, the sample was allowed to cool to a temperature between 50-60 °C.

Distillation

The distillation was performed using the UDK 129 Distillation Unit from VELP SCIENTIFICA. After the sample was cooled, it was combined with 50 ml of distilled water. Subsequently, 50 ml of NaOH was introduced with an inclined position of tube into the solution. The digestion flask was then placed in the distillation chamber. In a conical flask, 30 ml of boric acid solution was prepared, and 3 drops of indicator were added to it. The water flow had been adjusted beforehand. Distillation continued until the indicator solution no longer turned green in color.

Titration

The sample from the flask was used for titration. 0.1% H_2SO_4 solution was dispensed from the burette, drop by drop. This process continued until the solution in the conical flask changed color from green to blue. Once the solution's color had changed, the titration process was concluded, and the strength of the titrant was recorded.

Calculation

$$\text{CP (\%)} = \frac{(ml\ HCL\ required\ for\ sample - ml\ HCL) \times 14.007 \times 100}{Weight\ of\ sample \times 1000}$$

3.8.2 Crude fibre (CF) analysis

Test procedures

Crude fiber analysis was performed using the Fiber Extractor (VELP SCIENTIFICA FIWE) Raw Fiber Extractor. 1g sample was placed into crucibles fixed within the channels of the extractor. In the flask of the analyzer, 150 ml of 1.25% H_2SO_4 was added, along with 3-5 drops of n-octanol as an anti-foam agent. The fiber analyzer was activated, and the mixture was boiled precisely for 30 minutes. After this time, the remaining solution was filtered. The residue in the crucible was washed three times with 30 ml of hot boiled water (filling the crucible to the top each time) while using compressed air to stir the contents. After draining the final wash, 150 ml of 1.25% KOH and 3-5 drops of the anti-foam agent were added. The mixture was boiled for another 30 minutes and washed three times again. A final wash with cold deionized water cooled the crucible, followed by three washes with 25 ml of acetone while stirring with compressed air. The crucibles with the acetone-washed content were dried at 105°C for one hour in an oven and then cooled in a desiccator to determine the dry weight (W_1). Subsequently, the crucibles were placed in a muffle furnace and heated to 550°C for three hours. After cooling in a desiccator, the crucibles were reweighed to obtain the final weight (W_2).

Calculation

$$\text{CF (\%)} = \frac{Weight\ of\ oven\ dried\ sample\ (g) - weight\ of\ ash\ containing\ crucible\ (g)}{Weight\ of\ sample\ (g)} \times 100$$

3.8.3 Ether extract (EE) analysis

Test procedure:

Ether extract analysis was performed using the VELP SCIENTIFICASER 148 Solvent Extractor.

Sample: 3g (W_1) of grounded and homogenized material was weighed in an extraction thimble with 1 mg proximation. Total weight- thimble weight = wet sample weight.

Chemicals: petroleum ether with a boiling range of 40-60°C, ensuring residue evaporation did not exceed 10 mg/L. The sample drying process involved drying the thimble for one hour in a 125°C oven.

Immersion: The sample, either the thimble or the glass crucible containing the dry hydrolyzed sample, was placed into the extraction apparatus. After weighing the extract collecting vessel (W_2), 40 ml of petroleum ether was added. The thimble with the sample, connected to the extraction unit via a thimble connector, was assembled and the extraction unit was closed. Cooling water flow was initiated, followed by heating. Once the solvent began to boil, the thimble or glass crucibles were immersed for 30 minutes.

Washing: After 30 minutes of extraction, the thimble or glass crucible was moved into the "Washing" position for 60 minutes.

Recovery: After washing, the stopcock positioned below the water was shut, and the condenser was cooled to evaporate the solvent completely from the extraction vessel.

Weighing: the extract-containing cups were placed in an oven at 125°C for 30 minutes to dry and then weighed (W_3) after cooling a desiccator.

Calculation:

$$\text{EE (\%)} = \frac{\text{Weight of vessel and ether extract } (g) - \text{weight of empty vessel } (g)}{\text{Weight of sample } (g)} \times 100$$

3.8.4 Dry matter (DM)

Test procedure

Envelopes were weighted (W_1) and weight was recorded to 0.001g. After harvesting, fresh shoot weight (W_2) of forage was taken and the envelope was filled with sample and dried in oven for 24 hours at 105°C. Thereafter the dried sample containing envelope (W_3) is weighted.

Calculation:

$$\text{DM (\%)} = \frac{\text{Weight of envelope and dried sample } (g) - \text{Weight of envelope } (g)}{\text{Weight of fresh sample } (g) - \text{Weight of envelope } (g)} \times 100$$

3.8.5 Ash analysis

Test procedure

Crucibles were placed in a muffle furnace and allowed to reach 600°C, which took approximately 30 minutes. The weight of the crucible was recorded to 0.0001 grams (W_1). Approximately 3 grams of the sample was weighed into a pre-tared crucible, and the weight of the sample was recorded to 0.0001 grams (W_2). The crucibles containing the samples were ashed in the muffle furnace at 600°C for 6 hours after the furnace reached the desired temperature. After ashing, the crucibles were allowed to cool in the furnace to below 20°C and then transferred to a desiccator with a vented top. The crucibles were cooled to room temperature in the desiccator and weighed immediately. The weight was recorded to 0.0001 grams (W_3). The ash percentage was calculated and reported to one decimal place.

Calculation

$$\text{Ash (\%)} = \frac{\textit{Weight of crucible with ash (g)} - \textit{weight of empty crucible (g)}}{\textit{Weight of plant sample (g)}} \times 100$$

3.9 Statistical analysis

The collected, calculated and recorded data on different parameters were compiled and statistically analyzed following the analysis of variance techniques (two-way ANOVA) using the statistics computer package 'Statistix 10'. The comparison among the treatment means was tested following all pairwise comparisons by Tukey's HSD test at 95% level of confidence.

CHAPTER IV

RESULTS

4.1. Effect of plant population, nitrogen rates and their interaction on growth parameters of maize fodder

4.1.1. Plant height (cm)

Plant height varied significantly with the individual effect of plant population and nitrogen rates yet their interaction was not significant (Table 2 and Table 3).

At 30 DAS, the highest plant height (23.8 cm) was found with the plant population of 124220 ha^{-1} while plant population @ 239130 ha^{-1} resulted in the shortest plant (19.2 cm). At 40 DAS, the highest plant height (44.5 cm) was found with the plant population of 124220 ha^{-1} whereas, the plant population @ 239130 ha^{-1} resulted in the shortest plant (35.9 cm). At 50 DAS, the tallest plants were again found with the plant population of 124220 ha^{-1} (72.3 cm) which was statistically similar to the plant population of 173910 ha^{-1} (68.9 cm) while the shortest plants were again found with the plant population of 239130 ha^{-1} (62.1 cm). At 60 DAS, the highest plant height was again found with the plant population of 124220 ha^{-1} (118.5 cm) which was statistically similar to the plant population of 173910 ha^{-1} (114.2 cm) whereas, the shortest plants were again found with the plant population of 239130 ha^{-1} (102.4 cm). At 65 DAS, the highest plant height was found with the plant population of 124220 ha^{-1} (146.3 cm) which was statistically similar to the plant population of 173910 ha^{-1} (141.2 cm) while the shortest was found with the plant population of 239130 ha^{-1} (132.4 cm). At 80 DAS, the highest plant height was again found with the plant population of 124220 ha^{-1} (182.8 cm) which was statistically identical to the plant population of 173910 ha^{-1} (175.4 cm) whereas, the shortest was again found with the plant population of 239130 ha^{-1} (159.7 cm).

Table 2. Effect of plant population ha^{-1} on growth parameters of maize as fodder grown in the coastal soil of southwestern Bangladesh

Plant population ha^{-1}	Plant height (cm)					
	30 DAS	40 DAS	50 DAS	60 DAS	65 DAS	80 DAS
124220	23.8 a	44.5 a	72.3 a	118.5 a	146.3 a	182.8 a
173910	21.4 b	40.7 b	68.9 ab	114.2 ab	141.2 ab	175.4 ab
204970	20.6 bc	38.1 bc	65.7 bc	109.2 bc	137.2 bc	167.5 bc
239130	19.2 c	35.9 c	62.1 c	102.4 c	132.4 c	159.7 c
SE (±)	*0.62*	*1.32*	*1.72*	*2.65*	*2.82*	*4.04*
P value	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
CV (%)	*8.01*	*9.09*	*6.98*	*6.53*	*5.55*	*6.46*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

Plant height showed a significant difference ($p \leq 0.01$) among the nitrogen rates at different days after sowing (DAS) (Table 3). At 30 DAS, the highest plant height (24.4 cm) was found in the 275 kg N ha^{-1} treatment which was statistically similar at par to 235 kg N ha^{-1} treatment (23.5 cm), and 195 kg N ha^{-1} treatment (22.5 cm) whereas, the shortest (15.3 cm) was found in no N added treatment. At 40 DAS, the plant height varied from 19.9 cm to 48.7 cm. The maximum plant height (48.7 cm) was recorded from the 275 kg N ha^{-1} treatment which was statistically similar to the 235 kg N ha^{-1} treatment (46.9 cm) and the minimum (19.9 cm) was found from no N added treatment. At 50 DAS, 275 kg N ha^{-1} produced the tallest plant (85.6 cm), statistically similar to the 235 kg N ha^{-1} treatment (82.5 cm) and the shortest (27.2 cm) was found in no N added treatment. At 60 DAS, the highest plant height (143.9 cm) was found in the 275 kg N ha^{-1} treatment which was statistically similar to the 235 kg N ha^{-1} treatment (136.4 cm), and the shortest (37.3 cm) was found in no N added treatment. At 65 DAS, the tallest plants were observed under 275 kg N ha^{-1} treatment (177.8 cm) which was statistically to the 235 kg N ha^{-1} treatment (169.7 cm), and the control plot showed a significantly lower height of 38.9 cm. At 80 DAS, plant height peaked at 213.3 cm with the application of 275 kg N ha^{-1} treatment which was statistically similar at par to 235 kg N ha^{-1} treatment (208.3 cm), and 195 kg N ha^{-1} treatment (201.8 cm), while the control plot recorded the shortest plants at 41.0 cm.

Table 3. Effect of nitrogen rates on growth parameters of maize as fodder grown in the coastal soil of southwestern Bangladesh

Nitrogen rates	Plant height (cm)					
(kg ha^{-1})	30 DAS	40 DAS	50 DAS	60 DAS	65 DAS	80 DAS
no N added	15.3 c	19.9 d	27.2 d	37.3 d	38.9 d	41.0 c
155	20.7 b	38.8 c	62.6 c	110.7 c	150.1 c	192.4 b
195	22.5 ab	44.5 b	78.5 b	127.2 b	160.2 b	201.8 ab
235	23.5 a	46.9 ab	82.5 ab	136.4 a	169.7 a	208.3 a
275	24.4a	48.7 a	85.6 a	143.9 a	177.8 a	213.3 a
SE (±)	*0.70*	*1.48*	*1.92*	*2.96*	*3.15*	*4.52*
P value	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
CV (%)	*8.01*	*9.09*	*6.98*	*6.53*	*5.55*	*6.46*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

4.1.2. Leaf numbers

Plant population and nitrogen rates significantly influenced the number of leaf $plant^{-1}$ separately but their interaction had no significant influence (Table 4 and Table 5).

At 30 DAS, the highest leaf number (4.9) was found with the plant population of 124220 ha^{-1} which was statistically similar to the plant population of 173910 ha^{-1} (4.7) while the lowest leaf number (4.2) was found with the plant population of 239130 ha^{-1}. At 40 DAS, the highest leaf number (6.5) was found with the plant population of 124220 ha^{-1} which was statistically similar to the plant population of 173910 ha^{-1} (6.2) whereas, the lowest leaf number (5.9) was found with the plant population of 239130 ha^{-1}. At 50 DAS, the highest leaf number (7.2) was found with the plant population of 124220 ha^{-1} which was statistically similar to the plant population of 173910 ha^{-1} (7.1) while the plant population @ 239130 ha^{-1} resulted in the lowest leaf number (6.6). At 60 DAS, the highest leaf number (8.2) was found with the plant population of 124220 ha^{-1} which was statistically similar to the plant population of 173910 ha^{-1} (8.0) while the lowest leaf number (7.4) was found with the plant population of 239130 ha^{-1}. At 65 DAS, the highest leaf number (8.8) was found with the plant population of 124220 ha^{-1} which was statistically similar to the plant population of 173910 ha^{-1} (8.5) while the plant population @ 239130 ha^{-1} resulted in the lowest leaf number (8.2). At 80 DAS, the highest leaf number (9.4) was found with the plant population of 124220 ha^{-1} which was statistically similar to the plant population of 173910 ha^{-1} (9.2) while the plant population @ 239130 ha^{-1} resulted in the lowest leaf number (8.7).

Table 4. Effect of plant population ha^{-1} on leaf numbers of maize as fodder grown in the coastal soil of southwestern Bangladesh

Plant population ha^{-1}	Leaf numbers					
	30 DAS	40 DAS	50 DAS	60 DAS	65 DAS	80 DAS
124220	4.9 a	6.5 a	7.2 a	8.2 a	8.8 a	9.4 a
173910	4.7 ab	6.2 ab	7.1 ab	8.0 a	8.5 ab	9.2 ab
204970	4.4 bc	6.0 bc	6.9 b	7.7 b	8.4 bc	9.0 bc
239130	4.2 c	5.9 c	6.6 c	7.4 b	8.2 c	8.7 c
SE (±)	*0.11*	*0.10*	*0.09*	*0.10*	*0.11*	*0.11*
P value	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
CV (%)	*7.15*	*4.80*	*3.73*	*3.69*	*3.74*	*3.46*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

At 30 DAS, the maximum leaf number (4.9) was recorded in the 235 kg N ha^{-1} treatment, statistically similar at par to 155 kg N ha^{-1}, 195 kg N ha^{-1}, and 275 kg N ha^{-1} treatment (4.8, 4.7, and 4.8). At the same time, the lowest (3.7) was found in no N-added treatment. At 40 DAS, 275 kg N ha^{-1} treatment produced the highest leaf number (7.0) which was statistically similar to 235 kg N ha^{-1} treatment (6.9) whereas, the lowest (4.3) was found in no N added treatment. At 50 DAS, the highest leaf number (7.9) was recorded in the 275 kg N ha^{-1} treatment which was statistically similar at par to 235 kg N ha^{-1} and 195 kg N ha^{-1} treatment (7.8 and 7.7), and the lowest (4.5) was found in no N added treatment. At 60 DAS, the highest leaf number (9.4) was recorded in the 275 kg N ha^{-1} treatment which was statistically similar to the 235 kg N ha^{-1} treatment (9.1) while the lowest (4.4) was found in no N added treatment. At 65 DAS, the highest leaf number (9.9) was recorded in the 275 kg N ha^{-1} treatment which was statistically identical at par to 235 kg N ha^{-1} and 195 kg N ha^{-1} treatment (9.8 and 9.6) whereas, the lowest (4.6) was found in no N added treatment. At 80 DAS, the highest leaf number (10.9) was recorded in the 275 kg N ha^{-1} treatment which was statistically similar at par with 235 kg N ha^{-1} treatment (10.6) while the lowest (4.9) was found in the no N added treatment.

Table 5. Effect of nitrogen rates on leaf numbers of maize as fodder grown in the coastal soil of southwestern Bangladesh

Nitrogen rates	Leaf numbers					
(kg ha^{-1})	30 DAS	40 DAS	50 DAS	60 DAS	65 DAS	80 DAS
No N added	3.7 b	4.3 d	4.5 c	4.4 d	4.6 c	4.9 d
155	4.8 a	6.0 c	7.1 b	7.9 c	8.7 b	9.2 c
195	4.7 a	6.7 b	7.7 a	8.4 b	9.6 a	9.9 b
235	4.9 a	6.9 ab	7.8 a	9.1 a	9.8 a	10.6 a
275	4.8 a	7.0 a	7.9 a	9.4 a	9.9 a	10.9 a
SE (±)	*0.13*	*0.12*	*0.10*	*0.11*	*0.13*	*0.12*
P value	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
CV (%)	*7.15*	*4.80*	*3.73*	*3.69*	*3.74*	*3.46*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

4.1.3. Stem diameter (cm)

Individually, plant population and N rates had a significant effect on stem diameter while their interaction was not significant (Table 6 and Table 7).

In the case of plant population, at 40 DAS, the highest stem diameter (3.1 cm) was recorded with the plant population of 124220 ha^{-1} which was statistically similar to the plant population of 173910 ha^{-1} (2.9 cm) while the lowest stem diameter (2.6 cm) was found with the plant population of 239130 ha^{-1}. At 50 DAS, the highest stem diameter (4.8 cm) was found with the plant population of 124220 ha^{-1} while the lowest stem diameter (4.1 cm) was found with the plant population of 239130 ha^{-1}. At 60 DAS, the highest stem diameter (5.5 cm) was recorded with the plant population of 124220 ha^{-1} while the plant population @ 239130 ha^{-1} resulted in the lowest stem diameter (4.7 cm). At 65 DAS, the highest stem diameter (5.7 cm) was found with the plant population of 124220 ha^{-1} which was statistically similar to the plant population of 173910 ha^{-1} (5.5 cm) whereas, the lowest stem diameter (5.2 cm) was found with the plant population of 239130 ha^{-1}. At 80 DAS, the highest stem diameter (5.7 cm) was found with the plant population of 124220 ha^{-1} which was statistically similar to the plant population of 173910 ha^{-1} (5.5 cm) while the lowest stem diameter (5.1 cm) was found with the plant population of 239130 ha^{-1}.

Table 6. Effect of plant population ha^{-1} on stem diameter of maize as fodder grown in the coastal soil of southwestern Bangladesh

Plant population ha^{-1}	Stem diameter (cm)				
	40 DAS	50 DAS	60 DAS	65 DAS	80 DAS
124220	3.1 a	4.8 a	5.5 a	5.7 a	5.7 a
173910	2.9 ab	4.6 b	5.2 b	5.5 ab	5.5 a
204970	2.7 bc	4.3 c	5.1 b	5.4 b	5.2 b
239130	2.6 c	4.1 c	4.7 c	5.2 c	5.1 b
SE (±)	*0.08*	*0.07*	*0.06*	*0.06*	*0.08*
P value	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
CV (%)	*7.73*	*4.78*	*3.63*	*3.47*	*4.41*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

Stem diameter had significant effect ($p \leq 0.01$) in response to different nitrogen rates of the maize fodder (Table 7). At 40 DAS, the maximum stem diameter (3.4 cm) was recorded from the 275 kg N ha^{-1} treatment which was statistically similar to the 235 kg N ha^{-1} treatment (3.3 cm) whereas, the minimum (1.6 cm) was found in no N added treatment. At 50 DAS, the maximum stem diameter (5.5 cm) was recorded from the 275 kg N ha^{-1} treatment which was statistically identical to the 235 kg N ha^{-1} treatment (5.3 cm) while the minimum (2.1) was found in no N added treatment. At 60 DAS, the maximum stem diameter (6.3 cm) was recorded from the 275 kg N ha^{-1} treatment which was statistically uniform to 235 kg N ha^{-1} treatment (6.1) while the minimum (2.3 cm) was found in no N added treatment. At 65 DAS, the highest stem diameter (6.6 cm) was recorded from the 275 kg N ha^{-1} treatment which was statistically similar to the 235 kg N ha^{-1} treatment (6.5 cm) whereas, the minimum (2.4 cm) was found in no N added treatment. At 80 DAS, the highest stem diameter (6.4 cm) was recorded in the 275 kg N ha^{-1} treatment which was statistically similar at par to 235 kg N ha^{-1} and 195 kg N ha^{-1} treatment (6.3 cm and 6.2 cm) while the lowest (2.6 cm) was found in no N added treatment.

Table 7. Effect of nitrogen rates on stem diameter of maize as fodder grown in the coastal soil of southwestern Bangladesh

Nitrogen rates (kg ha^{-1})	Stem diameter (cm)				
	40 DAS	50 DAS	60 DAS	65 DAS	80 DAS
No N added	1.6 d	2.1 d	2.3 d	2.4 d	2.6 c
155	2.7 c	4.2 c	5.3 c	5.6 c	5.5 b
195	3.1 b	5.0 b	5.9 b	6.3 b	6.2 a
235	3.3 ab	5.3 a	6.1 a	6.5 ab	6.3 a
275	3.4 a	5.5 a	6.3 a	6.6 a	6.4 a
SE (±)	*0.09*	*0.08*	*0.07*	*0.07*	*0.09*
P value	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
CV (%)	*7.73*	*4.78*	*3.63*	*3.47*	*4.41*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

4.2. Effect of plant population, nitrogen rates and their interaction on leaf chlorophyll content index (SPAD value) of maize fodder

Leaf chlorophyll content index has differed substantially with the effect of plant population ha^{-1} and nitrogen rates yet their interaction was not significant (Table 8 and Table 9).

At 30 DAS, the highest leaf chlorophyll content index (32.3) was found with the plant population of 124220 ha^{-1} which was statistically similar at par to the plant population of 173910 ha^{-1} and plant population of 204970 ha^{-1} whereas, the lowest (29.1) was found with the plant population of 239130 ha^{-1}. At 40 DAS, the highest leaf chlorophyll content index (37.3) was found with the plant population of 124220 ha^{-1} which was statistically similar to the plant population of 173910 ha^{-1} while the lowest (32.4) was found with the plant population of 239130 ha^{-1}. At 50 DAS, the highest leaf chlorophyll content index (41.3) was found with the plant population of 124220 ha^{-1} which was statistically similar to the plant population of 173910 ha^{-1} while the plant population @ 239130 ha^{-1} resulting in the lowest leaf chlorophyll content index (36.8). At 60 DAS, the highest leaf chlorophyll content index (39.4) was recorded with the plant population of 124220 ha^{-1} while the lowest (35.9) was measured from the plant population of 239130 ha^{-1}. At 65 DAS, the highest leaf chlorophyll content index (37.2) was recorded with the plant population of 124220 ha^{-1} while the plant population @ 239130 ha^{-1} resulted in the lowest leaf chlorophyll content index (33.5). At 80 DAS, the highest leaf chlorophyll content $plant^{-1}$ (34.3) was found with the plant population of 124220 ha^{-1} which was statistically similar at par to the plant population of 173910 ha^{-1} and plant population of 204970 ha^{-1} whereas, the lowest leaf chlorophyll content index (31.2) was found with the plant population of 239130 ha^{-1}.

Table 8. Effect of plant population ha^{-1} on leaf chlorophyll content index of maize as fodder grown in the coastal soil of southwestern Bangladesh

Plant population ha^{-1}	Leaf chlorophyll content index (SPAD value)					
	30 DAS	40 DAS	50 DAS	60 DAS	65 DAS	80 DAS
124220	32.3 a	37.3 a	41.3 a	39.4 a	37.2 a	34.3 a
173910	31.2 a	36.2 ab	39.8 ab	37.9 b	35.8 b	33.5 a
204970	30.5 ab	35.0 b	38.4 bc	36.9 bc	34.9 b	32.4 ab
239130	29.1 b	32.4 c	36.8 c	35.9 c	33.5 c	31.2 b
SE (±)	*0.75*	*0.75*	*0.63*	*0.46*	*0.48*	*0.71*
P value	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
CV (%)	*6.74*	*5.85*	*4.47*	*3.40*	*3.76*	*5.94*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

At 30 DAS, the highest leaf chlorophyll content index (35.5) was recorded in the 275 kg N ha^{-1} treatment which was statistically similar at par to 235 kg N ha^{-1} and 195 kg N ha^{-1} treatment (34.7 and 33.9) and the lowest (18.5) was recorded in no N added treatment. At 40 DAS, the maximum leaf chlorophyll content index (42.7) was recorded in the 275 kg N ha^{-1} treatment which was statistically identical to the 235 kg N ha^{-1} treatment (42.3) whereas, the minimum (18.4) was recorded in no N added treatment. At 50 DAS, the highest leaf chlorophyll content index (47.0) was recorded in the 275 kg N ha^{-1} treatment which was statistically similar to 235 kg N ha^{-1} treatment (46.5) whereas, the minimum (19.5) was recorded in the no N added treatment. At 60 DAS, the highest leaf chlorophyll content index (43.9) was observed in the 275 kg N ha^{-1} treatment which was statistically similar to the 235 kg N ha^{-1} treatment (43.0) while the minimum (18.7) was observed in no N added treatment. At 65 DAS, the highest leaf chlorophyll content index (41.5) was found in the 275 kg N ha^{-1} treatment which was statistically similar to the 235 kg N ha^{-1} treatment (40.4) while the minimum (17.8) was found in no N added treatment. At 80 DAS, the highest leaf chlorophyll content index (38.8) was found in the 275 kg N ha^{-1} treatment which was statistically similar at par to 235 kg N ha^{-1} and 195 kg N ha^{-1} treatment (37.6 and 36.5) whereas, the minimum (16.1) was found in no N added treatment.

Table 9. Effect of nitrogen rates on leaf chlorophyll content index of maize as fodder grown in the coastal soil of southwestern Bangladesh

Nitrogen rates (kg ha^{-1})	Leaf chlorophyll content index (SPAD value)					
	30 DAS	40 DAS	50 DAS	60 DAS	65 DAS	80 DAS
no N added	18.5 c	18.4 d	19.5 d	18.7 d	17.8 d	16.1 c
155	31.3 b	33.5 c	37.6 c	39.8 c	37.5 c	35.2 b
195	33.9 a	39.2 b	44.8 b	42.2 b	39.5 b	36.5 ab
235	34.7 a	42.3 a	46.5 ab	43.0 ab	40.4 ab	37.6 a
275	35.5 a	42.7 a	47.0 a	43.9 a	41.5 a	38.8 a
SE (±)	*0.84*	*0.84*	*0.71*	*0.52*	*0.54*	*0.79*
P value	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
CV (%)	*6.74*	*5.85*	*4.47*	*3.40*	*3.76*	*5.94*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

4.3. Effect of plant population, nitrogen rates and their interaction on Biomass accumulation (fresh weight basis & dry weight basis) of maize fodder

4.3.1. Fresh biomass (t ha^{-1})

Biomass accumulation (fresh weight basis & dry weight basis) of maize fodder at different cutting (50, 65, and 80 DAS) varied significantly with the effect of plant population ha^{-1} and nitrogen rates (Fig. 2 and Fig. 3).

At 50 DAS, the highest biomass accumulation (13.9 t ha^{-1}) on fresh weight was found with the plant population of 239130 ha^{-1} which was statistically similar to 204970 ha^{-1} while the lowest (10.0 t ha^{-1}) was found with the plant population of 124220 ha^{-1}. At 65 DAS, the highest biomass accumulation (17.9 t ha^{-1}) on a fresh weight basis was recorded with the plant population of 239130 ha^{-1} whereas, the lowest (14.1 t ha^{-1}) was recorded with the plant population of 124220 ha^{-1}. At 80 DAS, the highest biomass accumulation (21.9 t ha^{-1}) on a fresh weight basis was recorded with the plant population of 239130 ha^{-1} which was statistically at par with 204970 ha^{-1} and 173910 ha^{-1} whereas, the lowest (17.7 t ha^{-1}) was recorded with the plant population of 124220 ha^{-1}.

At 50 DAS, the highest biomass accumulation (16.5 t ha^{-1}) on a fresh weight basis was recorded from the 275 kg N ha^{-1} which was statistically identical to 235 kg N ha^{-1} whereas, the minimum (3.6 t ha^{-1}) was recorded in no N added treatment. At 65 DAS, the highest biomass accumulation (22.7 t ha^{-1}) on a fresh weight basis was recorded from the 275 kg N ha^{-1} treatment while the minimum (4.3 t ha^{-1}) was recorded in no N added treatment. At 80 DAS, the highest biomass accumulation (27.6 t ha^{-1}) on a fresh weight basis was recorded from the 275 kg N ha^{-1} treatment which was statistically identical to 235 kg N ha^{-1} whereas, the minimum (4.7 t ha^{-1}) was recorded in no N added treatment.

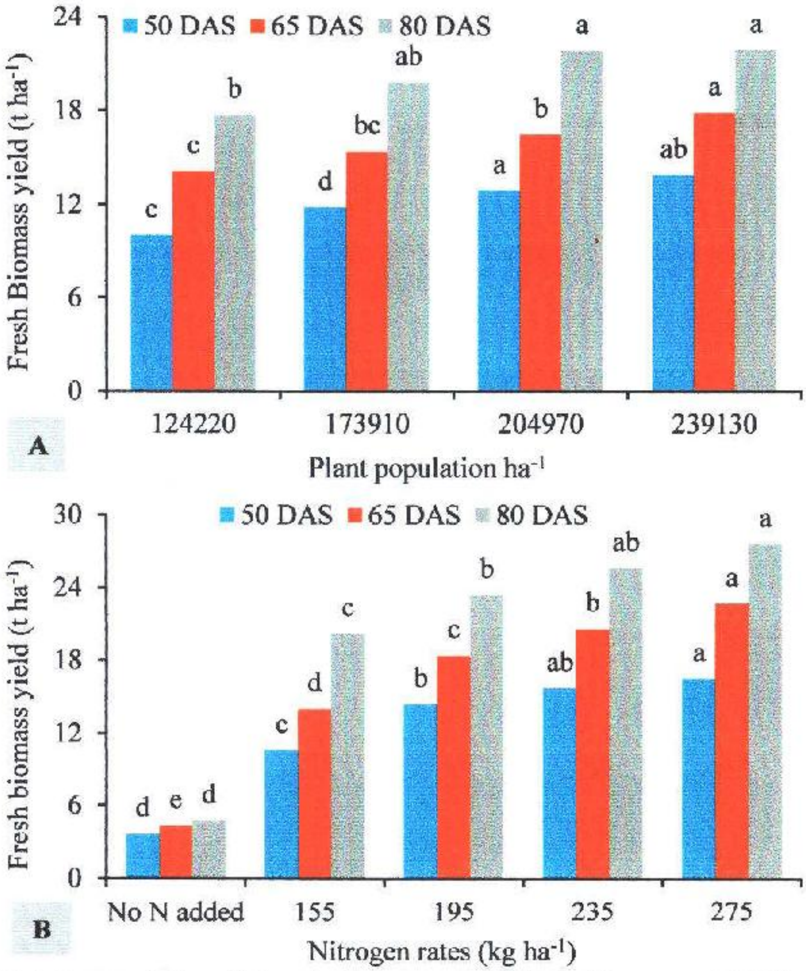

Fig. 2. Effect of plant population (A) and nitrogen rates (B) on biomass yield (fresh weight basis) of maize fodder grown in the coastal saline soil of southwestern Bangladesh.

4.3.2. Dry biomass (t ha^{-1})

At 50 DAS, the highest biomass accumulation (2.2 t ha^{-1}) on a dry weight basis was calculated from the plant population of 239130 ha^{-1} which was statistically similar to 204970 ha^{-1} while the lowest (1.7 t ha^{-1}) was found with the plant population of 124220 ha^{-1}. At 65 DAS, the highest biomass accumulation (2.4 t ha^{-1}) on a dry weight basis was recorded with the plant population of 239130 ha^{-1} which was statistically uniform to 204970 ha^{-1} while the lowest (1.9 t ha^{-1}) was recorded with the plant population of 124220 ha^{-1}. At 80 DAS, the highest biomass accumulation (4.4 t ha^{-1}) on a dry weight basis was recorded with the plant population of 239130 ha^{-1} which was statistically similar to 204970 ha^{-1} while the lowest (3.7 t ha^{-1}) was found with the plant population of 124220 ha^{-1}.

At 50 DAS, the highest biomass accumulation (2.6 t ha^{-1}) on a dry weight basis was recorded from the 275 kg N ha^{-1} treatment while the minimum (0.7 t ha^{-1}) was recorded in no N added treatment. At 65 DAS, the highest biomass accumulation (2.9 t ha^{-1}) on dry weight basis was recorded from the 275 kg N ha^{-1} treatment which was statistically at par with 235 kg N ha^{-1} while the minimum (0.9 kg) was recorded in no N added treatment. At 80 DAS, the highest biomass accumulation (5.7 t ha^{-1}) on a dry weight basis was recorded from the 275 kg N ha^{-1} treatment while the minimum (1.3 t ha^{-1}) was found in no N added treatment.

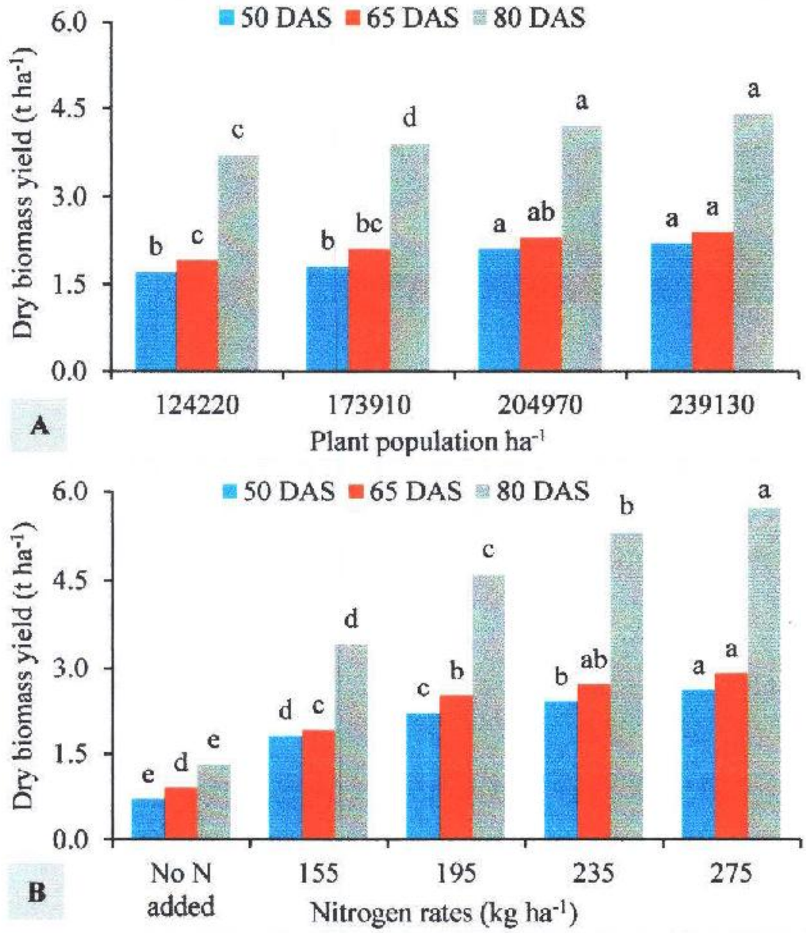

Fig. 3. Effect of plant population (A) and nitrogen rates (B) on biomass yield (dry weight basis) of maize fodder grown in the coastal saline soil of southwestern Bangladesh

4.4. Effect of plant population, nitrogen rates and their interaction on quality attributes of maize fodder

4.4.1. Crude fibre (%)

Crude fibre concentration of maize fodder at different cutting (50, 65 and 80 DAS) varied significantly with the effect of plant population ha^{-1}, nitrogen rates and their interaction (Table 10, Table 11 and Table 12).

At 50 DAS, the highest crude fibre concentration (26.13%) was recorded with the plant population of 124220 ha^{-1} while the lowest (22.11%) was recorded with the plant population of 239130 ha^{-1}. At 65 DAS, the plant population of 124220 ha^{-1} resulted from the highest crude fibre concentration (29.16%) but the lowest (24.40%) was recorded with the plant population of 239130 ha^{-1}. At 80 DAS, crude fibre concentration was highest (31.35%) with the plant population of 124220 ha^{-1} while the lowest (25.97%) was recorded with the plant population of 239130 ha^{-1}. Among the different cuts, crude fibre concentration was highest in the delayed cut than that of early cut.

There was a significant increase in crude fibre with higher rates of nitrogen application. Among the different N rates, at 50 DAS, application @ 275 kg N ha^{-1} treatment resulted in the highest crude fibre concentration (26.71%) while the lowest (20.51%) resulted in control treatment (no N added). At 65 DAS, the highest crude fiber concentration (29.75%) was measured from 275 kg N ha^{-1} whereas the lowest (23.17%) was obtained from no N-added treatment. Similarly, at 80 DAS, application of N @ 275 kg ha^{-1} provided the higher crude fibre concentration (32.55%) but no N-added treatment provided the lower (24.85%) crude fibre concentration. From the results, it was noticed that crude fibre concentration was higher in the delayed cut (80 DAS) and then gradually declined with the early cut at all the levels of nitrogen rate.

At 50 DAS, among the different interactions of N rates and plant population ha^{-1} the higher crude fibre concentration (29.54%) was measured from the interaction of 275 kg N ha^{-1} with the plant population of 124220 ha^{-1} while the lower (19.38%) was found in no N added treatment with the plant population of 239130 ha^{-1}. At 65 DAS, 275 kg N ha^{-1} with the plant population of 124220 ha^{-1} interaction resulted in the highest crude fibre concentration (32.51%) and the lowest (21.23%) was found in no N added with the plant population of 239130 ha^{-1}. At 80 DAS, higher N rate (275 kg ha^{-1}) with the plant population of 124220 ha^{-1} resulted in the maximum crude fibre concentration (35.84%) whereas the minimum (22.64%) was recorded from no N added treatment with the plant population of 239130 ha^{-1}.

4.4.2. Crude protein (%)

Crude protein of maize fodder at different cutting (50, 65 and 80 DAS) varied significantly with the effect of plant population ha^{-1}, nitrogen rates and their interaction (Table 10, Table 11 and Table 12).

At 50 DAS, crude protein was highest (8.10%) found with the plant population of 124220 ha^{-1} while the lowest (5.67%) was measured from the plant population of 239130 ha^{-1}. At 65 DAS, the plant population of 124220 ha^{-1} resulted in the highest crude protein concentration (7.46%) while the plant population of 239130 ha^{-1} resulted in the lowest crude protein (5.03%). At 80 DAS, the highest crude protein (6.31%) was found with the plant population of 124220 ha^{-1}

which was statistically similar to 173910 ha^{-1} while the plant population @ 239130 ha^{-1} resulted in the lowest crude protein (4.40%). Among the different cuts, crude protein concentration was highest in the early cut and afterwards decreased with the delayed cut.

There was a significant increase in crude protein with higher nitrogen rates. Among the different N rates, at 50 DAS, application of N @ 275 kg ha^{-1} provided the highest crude protein (10.74%) but no N-added treatment provided the lower (3.20%) crude protein. At 65 DAS, the highest crude protein (10.23%) was measured from 275 kg N ha^{-1} whereas the lowest (2.25%) was obtained from no N added treatment. Similarly, at 80 DAS, application @ 275 kg N ha^{-1} resulted in the highest crude protein (9.36%) while the lowest (1.36%) was found in the control treatment (no N added). From the results, it was noticed that crude protein was highest in the early cut (50 DAS) and then gradually decreased with the delayed cut at all the levels of nitrogen rate.

At 50 DAS, the higher N rate (275 kg ha^{-1}) with the plant population of 124220 ha^{-1} resulted in the maximum crude protein (12.69%) which was statistically similar to 275 kg N ha^{-1} with the plant population of 173910 ha^{-1} whereas, the minimum (2.64%) was recorded from no N added treatment with the plant population of 239130 ha^{-1}. At 65 DAS, 275 kg N ha^{-1} with the plant population of 124220 ha^{-1} interaction resulted in the highest crude protein (12.46%) and the lowest (2.02%) was found in no N added with the plant population of 239130 ha^{-1}. At 80 DAS, the highest crude protein (10.91%) was measured from the interaction of 275 kg N ha-1 with the plant population of 124220 ha-1 which was statistically similar to 275 kg N ha-1 with the plant population of 173910 ha-1 while the lowest (1.19%) was found in no N added treatment with the plant population of 239130 ha-1.

Table 10. Effect of plant population ha^{-1} on crude fibre and crude protein of maize fodder grown in the coastal soil of southwestern Bangladesh

Plant population ha^{-1}	Crude fibre (%)			Crude protein (%)		
	50 DAS	65 DAS	80 DAS	50 DAS	65 DAS	80 DAS
124220	26.13 a	29.16 a	31.35 a	8.10 a	7.46 a	6.31 a
173910	24.76 b	27.64 b	29.50 b	7.46 b	6.89 b	5.96 a
204970	23.28 c	26.06 c	27.73 c	6.70 c	6.06 c	5.40 b
239130	22.11 d	24.40 d	25.97 d	5.67 d	5.03 d	4.40 c
SE (±)	*0.63*	*0.08*	*0.07*	*0.18*	0.14	*0.14*
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CV (%)	*0.73*	*0.80*	*0.63*	*6.99*	*6.01*	*6.82*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

Table 11. Effect of nitrogen rates on crude fibre and crude protein of maize fodder grown in the coastal soil of southwestern Bangladesh

Nitrogen rates ($kg\ ha^{-1}$)	Crude fibre (%)			Crude protein (%)		
	50 DAS	65 DAS	80 DAS	50 DAS	65 DAS	80 DAS
No N added	20.51 e	23.17 e	24.85 e	3.20 e	2.25 e	1.36 e
155	22.84 d	25.88 d	27.03 d	4.53 d	3.96 d	2.67 d
195	23.90 c	26.77 c	28.59 c	7.21 c	6.35 c	6.47 c
235	26.40 b	28.49 b	30.17 b	9.24 b	8.99 b	7.71 b
275	26.71 a	29.75 a	32.55 a	10.74 a	10.23 a	9.36 a
SE (±)	*0.07*	*0.09*	*0.07*	*0.20*	*0.15*	*0.15*
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CV (%)	*0.73*	*0.80*	*0.63*	*6.99*	*6.01*	*6.82*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

Table 12. Integration between nitrogen rates and plant population ha^{-1} on crude fibre and crude protein of maize fodder grown in the coastal saline soil of southwestern Bangladesh

Nitrogen rates ($kg\ ha^{-1}$)	Plant population ha^{-1}	Crude fibre (%)			Crude protein (%)		
		50 DAS	65 DAS	80 DAS	50 DAS	65 DAS	80 DAS
No N added	124220	21.68 ij	24.69 ij	26.75 g	3.81 i-l	2.54 j-l	1.50 j
	173910	20.99 k	23.98 k	25.60 h	3.29 kl	2.31 kl	1.39 j
	204970	20.01 l	22.78 l	24.40 i	3.07 kl	2.12 kl	1.33 j
	239130	19.38 m	21.23 m	22.64 j	2.64 l	2.02 l	1.19 j
155	124220	24.44 ef	27.74 e	29.96 d	5.23 hi	4.56 h	3.46 h
	173910	23.41 g	26.44 g	27.55 f	4.97 h-j	4.39 hi	2.90 hi
	204970	22.11 i	25.36 hi	26.04 h	4.25 i-k	3.63 h-j	2.25 ij
	239130	21.37 jk	23.97 k	24.56 i	3.69 j-l	3.25 i-k	2.08 ij
195	124220	26.06 d	29.73 c	31.16 c	8.28 ef	7.54 f	7.12 d-f
	173910	24.61 e	27.49 ef	29.89 d	7.54 ef	7.00 fg	6.89 ef
	204970	22.86 h	25.72 h	27.67 f	7.00 fg	6.06 g	6.62 ef
	239130	22.01 i	24.14 jk	25.65 h	6.00 gh	4.79 h	5.23 g
235	124220	28.90 b	31.14 b	33.02 b	10.50 bc	10.16 bc	8.52 bc
	173910	27.14 c	29.58 c	31.13 c	9.91 cd	9.67 cd	8.10 b-d
	204970	25.63 d	27.53 ef	29.10 e	9.00 c-e	8.78 de	7.71 c-e
	239130	23.92 fg	25.73 h	27.42 f	7.52 ef	7.33 f	6.48 f
275	124220	29.54 a	32.51 a	35.84 a	12.69 a	12.46 a	10.91 a
	173910	27.65 c	30.70 b	33.32 b	11.57 ab	11.04 b	10.44 a
	204970	25.79 d	28.89 d	31.46 c	10.19 bc	9.69 cd	9.09 b
	239130	23.89 g	26.90 fg	29.59 de	8.50 d-f	7.73 ef	7.00 d-f
SE (±)		*0.14*	*0.17*	*0.15*	*0.40*	*0.31*	*0.30*
P value		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CV (%)		*0.73*	*0.80*	*0.63*	*6.99*	*6.01*	*6.82*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different. CF, CP and DAS represent as crude fibre, crude protein and days after sowing, respectively.

4.4.3. Ether extract (%)

Ether extract of maize fodder at different cutting (50, 65 and 80 DAS) varied significantly with the effect of plant population ha^{-1}, nitrogen rates and their interaction (Table 13, Table 14 and Table 15).

At 50 DAS, the highest ether extract (4.27%) was recorded with the plant population of 124220 ha^{-1} which was statistically identical to the plant population of 173910 ha^{-1} while the plant population @ 239130 ha^{-1} resulted in the lowest ether extract (3.80%). At 65 DAS, the plant population of 124220 ha^{-1} resulted from the highest ether extract (4.54%) which was statistically identical to the plant population of 173910 ha^{-1} whereas, the lowest (4.14%) was measured from the plant population of 239130 ha^{-1}. At 80 DAS, ether extract was highest (5.07%) with the plant population of 124220 ha^{-1} while the lowest (4.50%) was measured from the plant population of 239130 ha^{-1}. Among the different cuts, ether extract was lowest in the early cut and afterwards increased with the delayed cut.

Among the different N rates, at 50 DAS, application @ 195 kg N ha^{-1} resulted in the highest ether extract (4.70%) while the lowest (3.27%) was found in the control treatment (no N added). At 65 DAS, the highest ether extract (4.97%) was measured from 195 kg N ha^{-1} whereas the lowest (3.56%) was obtained from no N-added treatment. Similarly, at 80 DAS, application of N @ 195 kg ha^{-1} provided the higher ether extract (5.34%) which was statistically similar to 235 kg N ha^{-1} (5.30%) while no N added treatment provided the lower (3.50%) ether extract. From the results, it was noticed that ether extract concentration was lowest in the early cut (50 DAS) and then gradually increased with the delayed cut at all the levels of nitrogen rate.

At 50 DAS, application of N @ 195 kg N ha^{-1} with the plant population of 124220 ha^{-1} resulted in the highest ether extract (5.02%) which was statistically at par to 195 kg N ha^{-1} with the plant population of 173910 ha^{-1}, 195 kg N ha^{-1} with the plant population of 204970 ha^{-1} and 235 kg N ha^{-1} with the plant population of 124220 ha^{-1} while the lowest was found in no N added with the plant population of 239130 ha^{-1}. At 65 DAS, 195 kg N ha^{-1} with the plant population of 124220 ha^{-1} interaction resulted in the highest ether extract (5.24%) which was statistically similar to 195 kg N ha^{-1} with the plant population of 173910 ha^{-1} while the lowest (3.42%) was found in no N added treatment with the plant population of 239130 ha^{-1}. At 80 DAS, application of N rate (235 kg ha^{-1}) with the plant population of 124220 ha^{-1} resulted in the maximum ether extract (5.68%) which was statistically similar at par to 195 kg N ha^{-1} with the plant population of 173910 ha^{-1}, 195 kg N ha^{-1} with the plant population of 204970 ha^{-1}, 235 kg N ha^{-1} with the plant population of 124220 ha^{-1}, 235 kg N ha^{-1} with the plant population of 173910 ha^{-1}, and 275 kg

N ha^{-1} with the plant population of 124220 ha^{-1} whereas, th
from no N added treatment with the plant population of 2ſ

4.4.4. Ash (%)

Ash content of maize fodder at different cutting
significantly with the effect of plant population ha^{-1}, nitrog
13, Table 14 and Table 15).

At 50 DAS, the highest ash content (10.20%) was recorded with the plant p
ha^{-1} while the lowest (9.07%) was found with the plant population of 239130 ha
the plant population of 124220 ha^{-1} resulted from the highest ash content (8.90%) w
lowest (7.94%) was recorded from the plant population of 239130 ha^{-1}. At 80 DAS, ash conte
was highest (6.54%) with the plant population of 124220 ha^{-1} while the lowest (5.90%) was measured from the plant population of 239130 ha^{-1}. Among the different cuts, ash content was highest in the early cut and afterward reduced with the delayed cut.

There was a significant increase in ash with the higher rates of nitrogen application. At 50 DAS, application @ 275 kg N ha^{-1} resulted in the highest ash content (11.17%) while the lowest (7.30%) was found in the control treatment (no N added). At 65 DAS, the highest ash content (9.35%) was measured from 275 kg N ha^{-1} whereas the lowest (7.08%) was obtained from no N added treatment. Similarly, at 80 DAS, application of N @ 275 kg ha^{-1} provided the higher ash content (6.80%) which was statistically identical to 235 kg N ha^{-1} but no N added treatment provided the lower ash content (5.6%). From the results, it was noticed that ash content was higher in the early cut (50 DAS) and then gradually declined with the delayed cut at all the levels of nitrogen rate.

At 50 DAS, application of N @ 275 kg ha^{-1} with the plant population of 124220 ha^{-1} resulted in the highest ash content (11.52%) which was statistically at par to 275 kg N ha^{-1} with the plant population of 173910 ha^{-1}, 275 kg N ha^{-1} with the plant population of 204970 ha^{-1}, 275 kg N ha^{-1} with the plant population of 239130 ha^{-1}, 235 kg N ha^{-1} with the plant population of 124220 ha^{-1} and 195 kg N ha^{-1} with the plant population of 124220 ha^{-1} whereas, the lowest (6.73%) was found in no N added treatment with the plant population of 239130 ha^{-1}. At 65 DAS, 275 kg N ha^{-1} with the plant population of 124220 ha^{-1} interaction resulted in the highest ash content (10.12%) which was statistically similar to 235 kg N ha^{-1} with the plant population of 124220 ha^{-1} and the lowest (6.56%) was found in no N added treatment with the plant population of 239130 ha^{-1}. At 80 DAS, the application of N rate (275 kg ha^{-1}) with the plant population of

124220 ha^{-1} resulted in the maximum ash content (7.14%) which was statistically kg N ha^{-1} with the plant population of 173910 ha^{-1}, 275 kg N ha^{-1} with the plant po, 204970 ha^{-1}, 235 kg N ha^{-1} with the plant population of 124220 ha^{-1}, 235 kg N ha^{-1} with . population of 173910 ha^{-1}, and 195 kg N ha^{-1} with the plant population of 124220 ha^{-1} wh the minimum (5.41%) was recorded from no N added treatment with the plant population 239130 ha^{-1}.

Table 13. Effect of plant population ha^{-1} on ether extract and ash of maize fodder grown in the coastal saline soil of southwestern Bangladesh

Plant population ha^{-1}	Ether extract (%)			Ash (%)		
	50 DAS	65 DAS	80 DAS	50 DAS	65 DAS	80 DAS
124220	4.27 a	4.54 a	5.07 a	10.20 a	8.90 a	6.54 a
173910	4.20 a	4.50 ab	4.91 b	9.71 b	8.56 b	6.30 b
204970	4.00 b	4.40 b	4.70 c	9.34 c	8.32 c	6.11 c
239130	3.80 c	4.14 c	4.50 d	9.07 d	7.94 d	5.90 d
SE (±)	*0.06*	*0.03*	*0.04*	*0.08*	*0.75*	*0.06*
P value	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
CV (%)	*4.25*	*2.19*	*2.68*	*2.45*	*2.45*	*2.96*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

Table 14. Effect of nitrogen rates on ether extract and ash of maize fodder grown in the coastal saline soil of southwestern Bangladesh

Nitrogen rates (kg ha^{-1})	Ether extract (%)			Ash (%)		
	50 DAS	65 DAS	80 DAS	50 DAS	65 DAS	80 DAS
No N added	3.27 d	3.56 e	3.50 d	7.30 e	7.08 e	5.64 c
155	3.91 c	4.30 d	4.70 c	8.98 d	8.20 d	5.84 c
195	4.70 a	4.97 a	5.34 a	9.80 c	8.60 c	6.24 b
235	4.30 b	4.70 b	5.30 a	10.61 b	8.92 b	6.57 a
275	4.12 b	4.45 c	5.08 b	11.17 a	9.35 a	6.80 a
SE (±)	*0.07*	*0.04*	*0.05*	*0.09*	*0.08*	*0.07*
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CV (%)	*4.25*	*2.19*	*2.68*	*2.45*	*2.45*	*2.96*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

Table 15. Integration between nitrogen rates and plant population ha^{-1} on ether extract and ash of maize fodder grown in the coastal saline soil of southwestern Bangladesh

Nitrogen rates (kg ha^{-1})	Plant population ha^{-1}	Ether extract (%)			Ash (%)		
		50 DAS	65 DAS	80 DAS	50 DAS	65 DAS	80 DAS
No N added	124220	3.44 g-i	3.67 i	3.81 i	7.86 jk	7.51 h-j	5.88 f-j
	173910	3.36 g-i	3.57 i	3.67 ij	7.57 kl	7.31 ij	5.70 g-j
	204970	3.19 hi	3.58 i	3.32 jk	7.06 lm	6.95 jk	5.59 h-j
	239130	3.09 i	3.42 i	3.18 k	6.73 m	6.56 k	5.41 j
155	124220	4.11 c-f	4.38 f-h	4.92 e-g	9.45 f-h	8.38 d-g	6.12 d-h
	173910	4.04 d-f	4.39 f-h	4.89 fg	9.13 g-i	8.33 d-g	6.01 e-i
	204970	3.85 e-g	4.22 gh	4.62 gh	8.80 hi	8.16 e-g	5.71 g-j
	239130	3.65 f-h	4.16 h	4.37 h	8.56 ij	7.90 g-i	5.51 ij
195	124220	5.02 a	5.24 a	5.61 a	10.89 a-c	8.96 b-d	6.63 a-d
	173910	4.83 ab	5.08 ab	5.34 a-c	9.85 e-g	8.76 c-e	6.32 c-f
	204970	4.60 a-c	4.90 bc	5.30 a-e	9.36 gh	8.54 c-f	6.17 d-g
	239130	4.29 b-e	4.67 c-f	5.09 b-f	9.05 hi	8.11 f-h	5.84 f-j
235	124220	4.56 a-d	4.82 b-d	5.68 a	11.20 ab	9.50 ab	6.92 ab
	173910	4.40 b-d	4.76 c-e	5.47 ab	10.71 b-d	8.96 b-d	6.62 a-d
	204970	4.16 c-f	4.78 c-e	5.15 b-f	10.45 c-e	8.80 c-e	6.48 b-e
	239130	4.06 d-f	4.37 f-h	4.93 d-g	10.11 d-f	8.44 d-g	6.26 d-g
275	124220	4.22 c-e	4.58 d-f	5.32 a-d	11.52 a	10.12 a	7.14 a
	173910	4.33 b-e	4.63 c-f	5.20 b-f	11.28 ab	9.45 b	6.89 a-c
	204970	4.10 c-f	4.48 e-g	4.97 c-g	11.02 a-c	9.17 bc	6.64 a-d
	239130	3.84 e-g	4.13 h	4.85 fg	10.89 a-c	8.69 c-f	6.46 b-e
SE (±)		*0.14*	*0.08*	*0.10*	*0.19*	*0.17*	*0.15*
P value		*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
CV (%)		*4.25*	*2.19*	*2.68*	*2.45*	*2.45*	*2.96*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different. EE, Ash and DAS represent as ether extract, ash and days after sowing, respectively.

4.4.5. Nitrogen concentration (%)

Nitrogen concentration of maize fodder at different cutting (50, 65 and 80 DAS) varied significantly with the effect of plant population ha^{-1}, nitrogen rates and their interaction (Table 16, Table 17 and Table 18).

At 50 DAS, the highest nitrogen concentration (1.00%) was recorded with the plant population of 124220 ha^{-1} which was statistically similar to the plant population of 173910 ha^{-1} (0.95%). In contrast, the lowest (0.70%) was found with the plant population of 239130 ha^{-1}. At 65 DAS, the plant population of 124220 ha^{-1} resulted in the highest nitrogen concentration (1.20%) but the lowest (0.80%) was recorded from the plant population of 239130 ha^{-1}. At 80 DAS, nitrogen concentration was highest (1.30%) with the plant population of 124220 ha^{-1} while the lowest (0.90%) was measured from the plant population of 239130 ha^{-1}. Among the different cuts, nitrogen concentration was lowest in the early cut and afterward increased with the delayed cut.

There was a significant increase in nitrogen concentration with the higher rates of nitrogen application. At 50 DAS, application @ 275 kg N ha^{-1} resulted in the highest nitrogen concentration (1.50%) while the lowest (0.21%) was found in the control treatment (no N added). At 65 DAS, the highest nitrogen concentration (1.63%) was measured from 275 kg N ha^{-1} whereas the lowest (0.36%) was obtained from no N added treatment. Similarly, at 80 DAS, the application of N @ 275 kg ha^{-1} provided the higher nitrogen concentration (1.71%) but no N-added treatment provided the lower nitrogen concentration (0.51%). From the results, it was noticed that nitrogen concentration was lowest in the early cut (50 DAS) and then gradually increased with the delayed cut at all the levels of nitrogen rate.

At 50 DAS, the highest nitrogen concentration (1.74%) was measured from the interaction of 275 kg N ha^{-1} with the plant population of 124220 ha^{-1} which was statistically similar to 275 kg N ha^{-1} with the plant population of 173910 ha^{-1} while the lowest (0.19%) was found in no N added treatment with the plant population of 239130 ha^{-1}. At 65 DAS, 275 kg N ha^{-1} and the plant population of 124220 ha^{-1} interaction resulted in the highest nitrogen concentration (1.99%) and the lowest (0.32%) was found in no N added treatment with the plant population of 239130 ha^{-1}. At 80 DAS, higher N rate (275 kg ha^{-1}) with the plant population of 124220 ha^{-1} resulted in the maximum nitrogen concentration (2.03%) which was statistically similar to 275 kg N ha^{-1} with the plant population of 173910 ha^{-1} while the minimum (0.42%) was recorded from no N added treatment with the plant population of 239130 ha^{-1}.

4.4.6. Total nitrogen uptake (kg ha^{-1})

Plant population ha^{-1}, nitrogen rates and their interaction had a significant influence on the total nitrogen uptake of maize fodder at different cutting (Table 16, Table 17 and Table 18).

Among the plant population, at 50 DAS, the highest total nitrogen uptake (21.19 kg ha^{-1}) was recorded with the plant population of 204970 ha^{-1} which was statistically similar at par to the plant population of 173910 ha^{-1}, and plant population of 124220 ha^{-1} while the lowest (18.32 kg ha^{-1}) was found with the plant population of 239130 ha^{-1}. At 65 DAS, the plant population of 173910 ha^{-1} resulted in the highest total nitrogen uptake (26.77 kg ha^{-1}) which was statistically similar at par to the plant population of 124220 ha^{-1}, and plant population of 204970 ha^{-1} while the lowest (22.21 kg ha^{-1}) was recorded with the plant population of 239130 ha^{-1}. At 80 DAS, total nitrogen uptake was highest (55.23 kg ha^{-1}) with the plant population of 124220 ha^{-1} which was statistically similar at par to the plant population of 173910 ha^{-1}, and plant population of 204970 ha^{-1} whereas, the lowest (45.34 kg ha^{-1}) was measured from the plant population of

239130 ha^{-1}. Among the different cuts, total nitrogen uptake was lowest in the early cut and afterward increased with the delayed cut.

There was a significant increase in total nitrogen uptake with the higher rates of nitrogen application. Total nitrogen uptake was highest (39.30 kg ha^{-1}) with the application of N @ 275 kg ha^{-1} while the lowest (1.52 kg ha^{-1}) was found in the control treatment (no N added). At 65 DAS, the highest total nitrogen uptake (46.90 kg ha^{-1}) was measured from the 275 kg N ha^{-1} whereas, the lowest (3.38 kg ha^{-1}) was obtained from no N-added treatment. Similarly, at 80 DAS, the application of N @ 275 kg ha^{-1} provided the higher total nitrogen uptake (96.93 kg ha^{-1}) but no N-added treatment provided the lower nitrogen concentration (6.43 kg ha^{-1}). From the results, it was noticed that total nitrogen uptake was lowest in the early cut (50 DAS) and then gradually increased with the delayed cut at all the levels of nitrogen rate.

Table 16. Effect of plant population ha^{-1} on nitrogen concentration and total nitrogen uptake of maize fodder grown in the coastal saline soil of southwestern Bangladesh

Plant population ha^{-1}	Nitrogen concentration (%)			Total nitrogen uptake (kg ha^{-1})		
	50 DAS	65 DAS	80 DAS	50 DAS	65 DAS	80 DAS
124220	1.00 a	1.20 a	1.30 a	20.40 a	26.73 a	55.23 a
173910	0.95 a	1.10 b	1.20 b	21.06 a	26.77 a	54.34 a
204970	0.86 b	0.97 c	1.07 c	21.19 a	25.22 a	51.90 a
239130	0.70 c	0.80 d	0.90 d	18.32 b	22.21 b	45.34 b
SE (±)	*0.02*	*0.02*	*0.03*	*0.72*	*0.98*	*1.70*
P value	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
CV (%)	*6.82*	*6.01*	*6.98*	*9.78*	*10.65*	*9.05*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

Table 17. Effect of nitrogen rates on nitrogen concentration and total nitrogen uptake of maize fodder grown in the coastal saline soil of southwestern Bangladesh

Nitrogen rates (kg ha^{-1})	Nitrogen concentration (%)			Total nitrogen uptake (kg ha^{-1})		
	50 DAS	65 DAS	80 DAS	50 DAS	65 DAS	80 DAS
No N added	0.21 e	0.36 e	0.51 e	1.52 e	3.38 e	6.43 e
155	0.43 d	0.63 d	0.72 d	7.42 d	12.40 d	24.23 d
195	1.03 c	1.01 c	1.15 c	23.08 c	25.21 c	52.80 c
235	1.23 b	1.43 b	1.48 b	29.90 b	38.31 b	78.09 b
275	1.50 a	1.63 a	1.71 a	39.30 a	46.90 a	96.93 a
SE (±)	*0.02*	*0.02*	*0.03*	*0.80*	*1.09*	*1.91*
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CV (%)	*6.82*	*6.01*	*6.98*	*9.78*	*10.65*	*9.05*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

At 50 DAS, among the different interactions of N rates and plant population ha^{-1}, the highest total nitrogen uptake (40.84 kg ha^{-1}) was measured from the interaction of 275 kg N ha^{-1} with the plant population of 124220 ha^{-1} which was statistically similar at par to 275 kg N ha^{-1} with the plant population of 173910 ha^{-1}, and 275 kg N ha^{-1} with the plant population of 204970 ha^{-1}, while the lowest (1.42 kg ha^{-1}) was found in no N added treatment with the plant population of 124220 ha^{-1}. At 65 DAS, 275 kg N ha^{-1} and the plant population of 124220 ha^{-1} interaction resulted in the highest total nitrogen uptake (52.27 kg ha^{-1}) which was statistically similar at par to 275 kg N ha^{-1} with the plant population of 173910 ha^{-1}, and 275 kg N ha^{-1} with the plant population of 204970 ha^{-1} and the lowest (3.07 kg ha^{-1}) was found in no N added treatment with the plant population of 124220 ha^{-1}. At 80 DAS, higher N rate (275 kg ha^{-1}) with the plant population of 124220 ha^{-1} resulted in the maximum total nitrogen uptake (107.52 kg ha^{-1}) which was statistically similar to the 275 kg N ha^{-1} with the plant population of 173910 ha^{-1}, and 275 kg N ha^{-1} with the plant population of 204970 ha^{-1} whereas, the minimum (5.99 kg ha^{-1}) was recorded from no N added treatment with the plant population of 173910 ha^{-1}.

Table 18. Integration between nitrogen rates and plant population ha^{-1} on nitrogen concentration and total nitrogen uptake of maize fodder grown in the coastal saline soil of southwestern Bangladesh

Nitrogen rates (kg ha^{-1})	Plant population ha^{-1}	N concentration (%)			Total N uptake (kg ha^{-1})		
		50 DAS	65 DAS	80 DAS	50 DAS	65 DAS	80 DAS
No N added	124220	0.24 j	0.40 j-l	0.61 i-l	1.42 h	3.07 i	6.31 g
	173910	0.22 j	0.37 kl	0.52 kl	1.42 h	3.43 i	5.99 g
	204970	0.21 j	0.34 kl	0.49 kl	1.70 gh	3.50 hi	6.75 g
	239130	0.19 j	0.32 l	0.42 l	1.55 h	3.50 hi	6.69 g
155	124220	0.55 h	0.73 h	0.83 hi	8.67 f	13.22 g	24.49 f
	173910	0.46 hi	0.70 hi	0.79 h-j	7.69 fg	13.46 fg	25.18 f
	204970	0.36 ij	0.58 h-j	0.68 i-k	6.89 f-h	11.79 gh	24.28 f
	239130	0.33 ij	0.52 i-k	0.59 j-l	6.46 f-h	11.09 g-i	22.96 f
195	124220	1.14 d-f	1.20 f	1.32 ef	21.56 e	25.88 e	55.68 de
	173910	1.10 ef	1.12 fg	1.20 ef	22.75 de	27.51 de	54.44 de
	204970	1.06 ef	0.97 g	1.12 fg	25.72 c-e	25.66 e	53.45 e
	239130	0.83 g	0.76 h	0.96 gh	22.32 e	21.78 ef	47.64 e
235	124220	1.36 bc	1.62 bc	1.68 bc	29.53 bc	39.23 bc	82.15 bc
	173910	1.29 b-d	1.54 cd	1.58 cd	29.59 bc	40.33 bc	82.79 bc
	204970	1.23 c-e	1.40 de	1.44 c-e	31.91 b	39.25 bc	79.04 c
	239130	1.03 f	1.17 f	1.20 ef	28.54 b-d	34.45 cd	68.39 cd
275	124220	1.74 a	1.99 a	2.03 a	40.84 a	52.27 a	107.52 a
	173910	1.67 a	1.76 b	1.85 ab	43.83 a	49.13 a	103.33 a
	204970	1.45 b	1.55 cd	1.63 bc	39.71 a	45.92 ab	95.89 ab
	239130	1.12 d-f	1.23 ef	1.36 d-f	32.77 b	40.21 bc	81.00 c
SE (±)		*0.05*	*0.05*	*0.06*	*1.61*	*2.19*	*3.82*
P value		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CV (%)		*6.82*	*6.01*	*6.98*	*9.78*	*10.65*	*9.05*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

4.4.7. Nitrogen use efficiency (%)

Nitrogen use efficiency of maize fodder at different cutting (50, 65 and 80 DAS) varied significantly with the effect of plant population ha^{-1} and nitrogen rates (Table 19 & Table 20).

At 50 DAS, the highest nitrogen use efficiency (10.58%) was recorded from 204970 plant population ha^{-1} which was statistically at par with the plant population of 124220 ha^{-1} and plant population of 173910 ha^{-1} while the lowest (8.70%) was found with 239130 plant population ha^{-1}. At 65 DAS, the plant population of 124220 ha^{-1} resulted the highest nitrogen use efficiency (NUS) (12.87%) which was statistically similar at par to the plant population of 173910 ha^{-1} and plant population of 204970 ha^{-1} while the lowest (10.20%) was recorded with the plant population of 239130 ha^{-1}. At 80 DAS, NUE was highest (26.52%) with the plant population of 124220 ha^{-1} which was statistically similar to the plant population of 204970 ha^{-1} whereas, the lowest (21.20%) was recorded with the plant population of 239130 ha^{-1}. Among the different cuts, nitrogen use efficiency was lowest in the early cut than that of delayed cut.

There was a significant increase in nitrogen use efficiency with the higher rates of nitrogen application. Among the different N rates, at 50 DAS, application @ 275 kg N ha^{-1} resulted in the highest nitrogen use efficiency (13.73%) while the lowest (3.81%) was found in 155 kg N ha^{-1} treatment. At 65 DAS, the highest nitrogen use efficiency (15.82%) was measured from the 275 kg N ha^{-1} which was statistically similar to 235 kg N ha^{-1} treatment whereas, the lowest (5.81%) was obtained from 155 kg N ha^{-1} treatment. Similarly, at 80 DAS, application of N @ 275 kg ha^{-1} provided the higher nitrogen use efficiency (32.90%) which was statistically similar to 235 kg N ha^{-1} treatment but 155 kg N ha^{-1} treatment provided the lower nitrogen use efficiency (11.48%). From the results, it was noticed that nitrogen use efficiency was lowest in the early cut (50 DAS) and then gradually increased with the delayed cut at all the levels of nitrogen rate.

Table 19. Effect of plant population ha^{-1} on nitrogen use efficiency of maize fodder grown in the coastal saline soil of southwestern Bangladesh

Plant population ha^{-1}	Nitrogen use efficiency (%)		
	50 DAS	65 DAS	80 DAS
124220	10.32 a	12.87 a	26.52 a
173910	9.80 ab	11.50 ab	23.87 b
204970	10.58 a	11.84 a	24.60 ab
239130	8.70 b	10.20 b	21.20 c
SE (±)	*0.45*	*0.50*	*0.97*
P value	*<0.01*	*<0.01*	*<0.01*
CV (%)	*11.26*	*10.74*	*9.91*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

Table 20. Effect of nitrogen rates on nitrogen use efficiency of maize fodder grown in the coastal saline soil of southwestern Bangladesh

Nitrogen rates ($kg\ ha^{-1}$)	Nitrogen use efficiency (%)		
	50 DAS	65 DAS	80 DAS
155	3.81 d	5.81 c	11.48 c
195	9.78 c	9.91 b	21.32 b
235	12.07 b	14.87 a	30.50 a
275	13.73 a	15.82 a	32.90 a
SE (±)	*0.45*	*0.50*	*0.97*
P value	<0.01	<0.01	<0.01
CV (%)	*11.26*	*10.74*	*9.91*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

4.4.8. Net income (BDT)

Net income of maize fodder at different cutting intervals (50, 65 and 80 DAS) varied significantly with the effect of plant population ha^{-1} and nitrogen rates (Table 21 & Table 22).

At 50 DAS, the highest net income was recorded with the plant population of 239130 ha^{-1} while the lowest was found with the plant population of 124220 ha^{-1}. At 65 DAS, the plant population of 239130 ha^{-1} resulted in the highest net income (BDT 24408) which was statistically similar to the plant population of 204970 ha^{-1} while the lowest (BDT 7596) was recorded with the plant population of 124220 ha^{-1}. At 80 DAS, net income was highest (BDT 9946) with the plant population of 239130 ha^{-1} which was statistically similar at par to the plant population of 204970 ha^{-1} while the lowest was found with the plant population of 124220 ha^{-1}. Among the different cuts, net income was lowest in the early cut (50 DAS).

There was a significant net income increase with the higher nitrogen application rates. Among the different N rates, at 50 DAS, application @ 275 kg N ha^{-1} resulted in the highest net income (BDT 16824) which was statistically similar to the 235 kg N ha^{-1} treatment while the lowest was found in the control treatment (no N added). At 65 DAS, the highest net income (BDT 60651) was measured from 275 kg N ha^{-1} treatment whereas, the lowest was obtained from no N added treatment. Similarly, at 80 DAS, the application of N @ 275 kg ha^{-1} provided the higher net income (BDT 38972) whereas, no N-added treatment provided the lower net income. From the results, it was noticed that net income was lowest in the early cut (50 DAS).

4.4.9. Benefit-cost ratio (BCR)

The benefit-cost ratio of maize fodder at different cutting intervals (50, 65 and 80 DAS) varied significantly with the effect of plant population ha^{-1} and nitrogen rates (Table 21 & Table 22).

At 50 DAS, the highest benefit-cost ratio (0.95) was recorded with the plant population of 239130 ha^{-1} which was statistically similar to the plant population of 204970 ha^{-1} while the lowest (0.76) was found with the plant population of 124220 ha^{-1}. At 65 DAS, the plant population of 239130 ha^{-1} resulted in the highest benefit-cost ratio (1.23) which was statistically similar at par to the plant population of 204970 ha^{-1}, and plant population of 173910 ha^{-1} while the lowest (1.07) was recorded with the plant population of 124220 ha^{-1}. At 80 DAS, the benefit-cost ratio was highest (1.09) with the plant population of 239130 ha^{-1} which was statistically similar at par to the plant population of 204970 ha^{-1} whereas, the lowest (0.93) was found with the plant population of 124220 ha^{-1}. Among the different cuts, the benefit-cost ratio was lowest in the early cut (50 DAS).

There was a significant increase in the benefit-cost ratio with the higher rates of nitrogen application. Among the different N rates, at 50 DAS, application @ 275 kg N ha^{-1} resulted in the highest benefit-cost ratio (1.17) which was statistically similar to 235 kg N ha^{-1} treatment while the lowest (0.27) was found in the control treatment (no N added). At 65 DAS, the highest benefit-cost ratio (1.61) was measured from the 275 kg N ha^{-1} treatment whereas, the lowest (0.33) was obtained from no N-added treatment. Similarly, at 80 DAS, the application of N @ 275 kg ha^{-1} provided a higher benefit-cost ratio (1.39) whereas, no N-added treatment provided a lower benefit-cost ratio. From the results, it was noticed that the benefit-cost ratio was lowest in the early cut (50 DAS).

Table 21. Effect of plant population ha^{-1} on net income and benefit-cost ratio of maize fodder grown in the coastal saline soil of southwestern Bangladesh

Plant population ha^{-1}	Net income (BDT)			Benefit-cost ratio		
	50 DAS	65 DAS	80 DAS	50 DAS	65 DAS	80 DAS
124220	-21170 b	7596 c	-5478 c	0.76 c	1.07 b	0.93 c
173910	-11901 a	13864 bc	2322 b	0.86 b	1.14 ab	1.02 b
204970	-7573 a	17971 ab	7358 ab	0.91 ab	1.17 a	1.07 ab
239130	-4064 a	24308 a	9946 a	0.95 a	1.23 a	1.09 a
SE (±)	*2930.4*	*3638.6*	*5658.0*	*0.03*	*0.04*	*0.06*
P value	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
CV (%)	*-71.80*	*62.54*	*33.74*	*9.41*	*8.76*	*10.80*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

Table 22. Effect of nitrogen rates on net income and benefit-cost ratio of maize fodder grown in the coastal saline soil of southwestern Bangladesh

Nitrogen rates ($kg\ ha^{-1}$)	Net income (BDT)			Benefit-cost ratio		
	50 DAS	65 DAS	80 DAS	50 DAS	65 DAS	80 DAS
No N added	-67088 d	-62020 e	-64928 e	0.27 d	0.33 e	0.30 e
155	-21232 c	2539 d	-4387 d	0.78 c	1.02 d	0.95 d
195	4019 b	32567 c	18938 c	1.04 b	1.33 c	1.19 c
235	11592 ab	45935 b	29089 b	1.11 ab	1.46 b	1.29 b
275	16824 a	60651 a	38972 a	1.17 a	1.61 a	1.39 a
SE (±)	*3276.3*	*4068.1*	*6325.8*	*0.03*	*0.04*	*0.06*
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CV (%)	*-71.80*	*62.54*	*33.74*	*9.41*	*8.76*	*10.80*

Here, SE, and CV indicate the standard error and coefficient of variation. There is no significant variation with the values having similar letter (s) in a column whereas, dissimilar letter denotes statistically significant different.

4.5. Effect of cutting age on biomass accumulation, quality attributes, net income and BCR

4.5.1. Biomass accumulation

Irrespective of plant population and N rates, significantly the highest biomass accumulation (18.97 $t\ ha^{-1}$) was found in the 80 days cut while the lowest biomass accumulation (12.15 $t\ ha^{-1}$) was found in the 50 days cut.

4.5.2. Quality attributes

Regardless of plant population and N rates, among the different cutting ages, significantly the highest ash content (9.58%) and crude fiber concentration (28.64%) were observed in the 50 days cut whereas the lowest ash content (6.22%) and crude fiber concentration (24.07%) were found in the 80 days cut. From another perspective, crude protein (6.98%) and ether extract (4.79%) were substantially higher in the 80 days cut while the lowest crude protein (5.51%) and ether extract (4.06%) were observed in the 50 days cut.

4.5.3. Net income and BCR

Irrespective of plant population and N rates among the various cutting ages, the net income (BDT 15934) and BCR (1.15) were significantly higher in the 65 days cut whereas the minimum net income and BCR were detected in the 50 days cut.

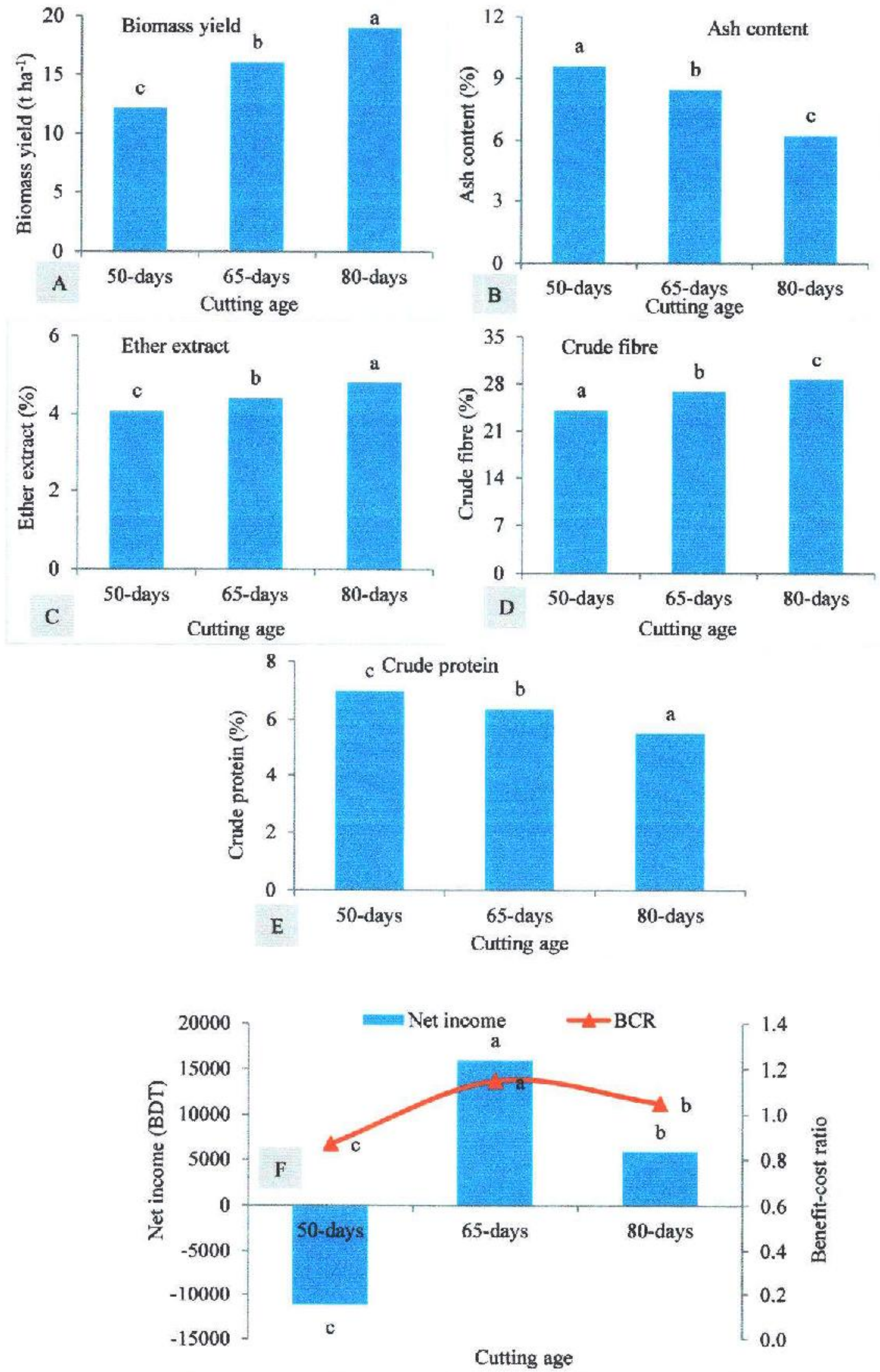

Figure 4. Effect of different cutting age on biomass yield (A), ash content (B), ether extract (C), crude fibre (D), crude protein (E), net income and benefit-cost ratio (F)

4.6 Functional relationship of plant population and N rate with biomass yield and quality attributes

4.6.1 Functional relationship between plant population and fresh biomass yield

There was a positive and significant relationship exit between plant population and biomass yield (Fig. 5). The higher plant population higher the biomass accumulation. The linear relationship between plant population and biomass accumulation at 50,65 and 80 DAS could be clarified at 99%, 98% and 92%, respectively by the equation of y = 3E-05x + 5.8062, y = 3E-05x + 9.8712 and y = 4E-05x + 13.025 respectively.

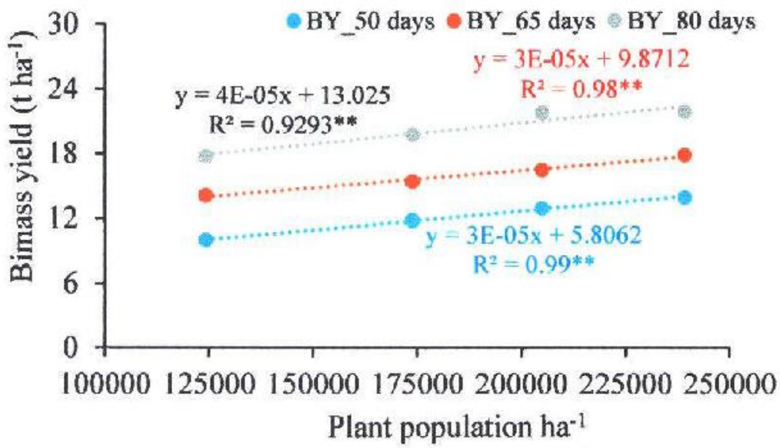

Figure 5. Functional relationship between plant population and fresh biomass yield of maize fodder

4.6.2 Functional relationship between N rate and fresh biomass yield

There was a positive and significant relationship between nitrogen rate and biomass yield (Fig. 6). The higher the plant population, the higher the biomass accumulation. The linear relationship between nitrogen rate and biomass accumulation at 50,65 and 80 DAS could be clarified at 97%, 99% and 98%, respectively by the equation of y = 0.0494x + 3.6694, y = 0.0685x + 4.2166 and y = 0.0854x + 5.6085 respectively.

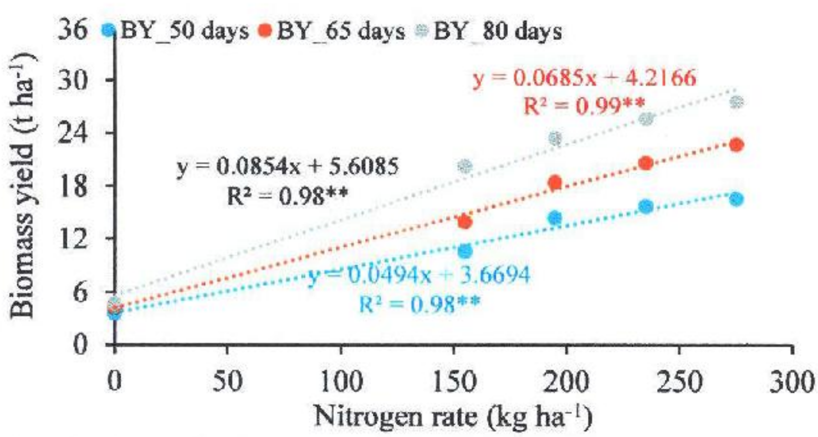

Figure 6. Functional relationship between N rate and fresh biomass yield of maize fodder

4.6.3 Functional relationship between plant population and quality attributes (CP, CF, Ash and EE)

There was a negative and significant correlation found between plant population and crude protein (Fig. 7A). The relationship between plant population and CP at 50, 65 and 80 DAS could be explained at 90%, 94% and 90% with the equation of $y = -2E\text{-}05x + 8.5279$, $y = -2E\text{-}05x + 10.274$ and $y = -2E\text{-}05x + 10.876$ respectively. Crude fibre and plant population were shown to be negatively and significantly correlated (Fig. 7B). The linear relationship between plant population and CF at 50, 65 and 80 DAS could be explained at 98%, 98% and 99% with the equation of $y = -4E\text{-}05x + 30.686$, $y = -4E\text{-}05x + 34.541$ and $y = -5E\text{-}05x + 37.388$ respectively.

The relationship between plant population and ash was significant and negative (Fig. 7C). The relationship between plant population and ash at 50, 65 and 80 DAS could be explained at 99%, 98% and 99% with the equation of $y = -1E\text{-}05x + 11.438$, $y = -8E\text{-}06x + 9.9552$ and $y = -6E\text{-}06x + 7.2471$ respectively. There was a negative and significant correlation found between plant population and ether extract (Fig. 7D). The relationship between plant population and EE at 50, 65 and 80 DAS could be explained at 91%, 80% and 97% with the equation of $y = -4E\text{-}06x + 4.8364$, $y = -3E\text{-}06x + 5.01$ and $y = -5E\text{-}06x + 5.7262$ respectively.

4.6.4 Functional relationship between N rate and quality attributes (CP, CF, Ash and EE)

There was a positive and significant correlation found between nitrogen rate and crude protein (Fig. 8A). The relationship between nitrogen rate and CP at 50, 65 and 80 DAS could be explained at 84%, 85% and 84% with the equation of $y = 0.0293x + 0.4691$, $y = 0.0292x + 1.3398$ and $y = 0.0273x + 2.293$ respectively. Crude fibre and nitrogen rate were shown to be positively and significantly correlated (Fig. 8B). The relationship between nitrogen rate and EE at 50, 65 and 80 DAS could be explained at 91%, 95% and 89% with the equation of $y = 0.0233x + 20.064$, $y = 0.0233x + 22.798$ and $y = 0.0233x + 22.798$ respectively.

The relationship between nitrogen rate and ash was significant and positive (Fig. 8C). The relationship between nitrogen rate and EE at 50, 65 and 80 DAS could be explained at 99%, 97% and 84% with the equation of $y = 0.0081x + 7.0318$, $y = 0.0141x + 7.1397$ and $y = 0.0042x + 5.4973$ respectively. There was a negative and significant correlation found between nitrogen rate and ether extract (Fig. 8D). The relationship between nitrogen rate and EE at 50, 65 and 80 DAS could be explained at 60%, 65% and 85% with the equation of $y = 0.0039x + 3.3929$, $y = 0.0041x + 3.6949$ and $y = 0.0066x + 3.6442$ respectively.

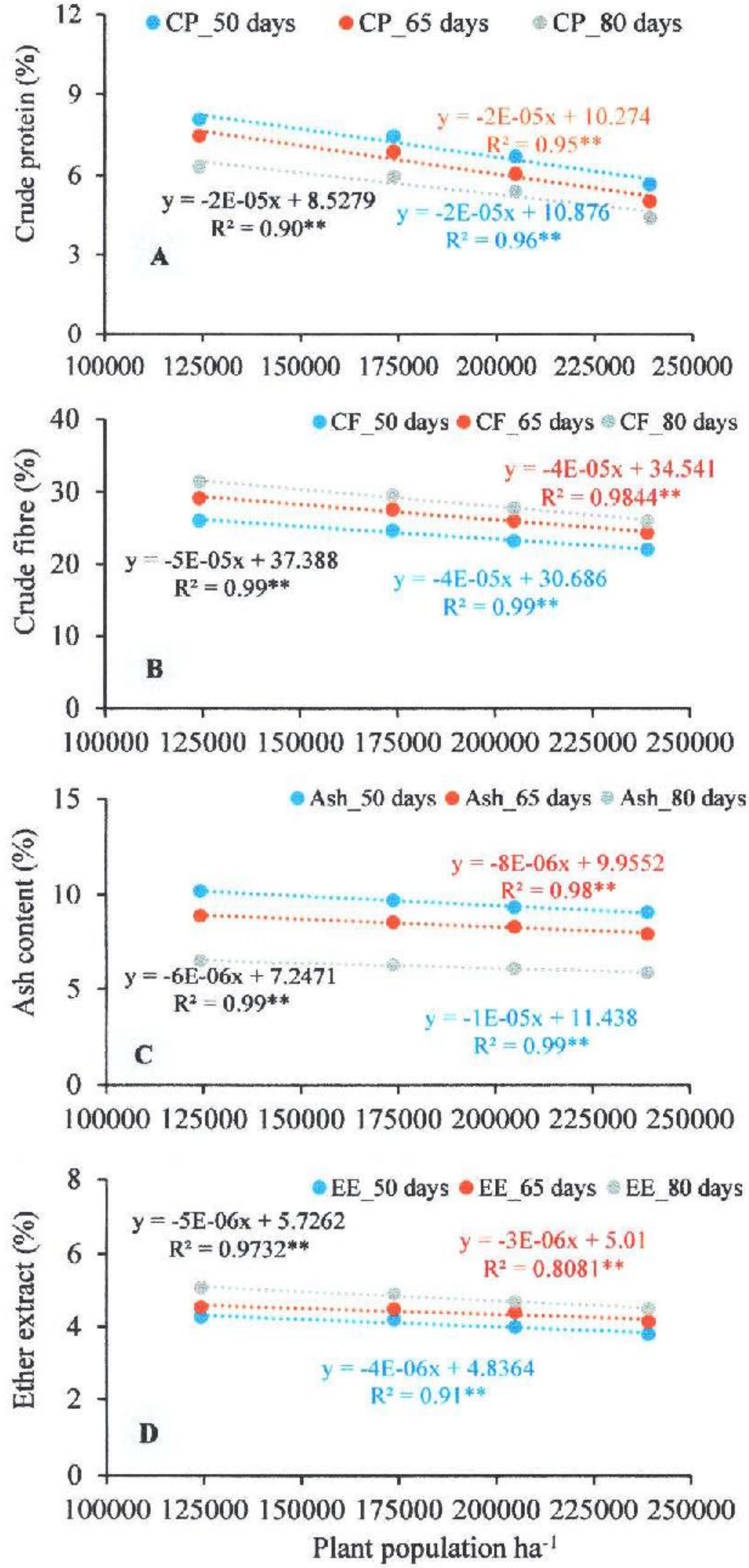

Figure 7. Functional relationship between plant population with crude protein (A), crude fibre (B), ash (C) and ether extract (D) of maize fodder

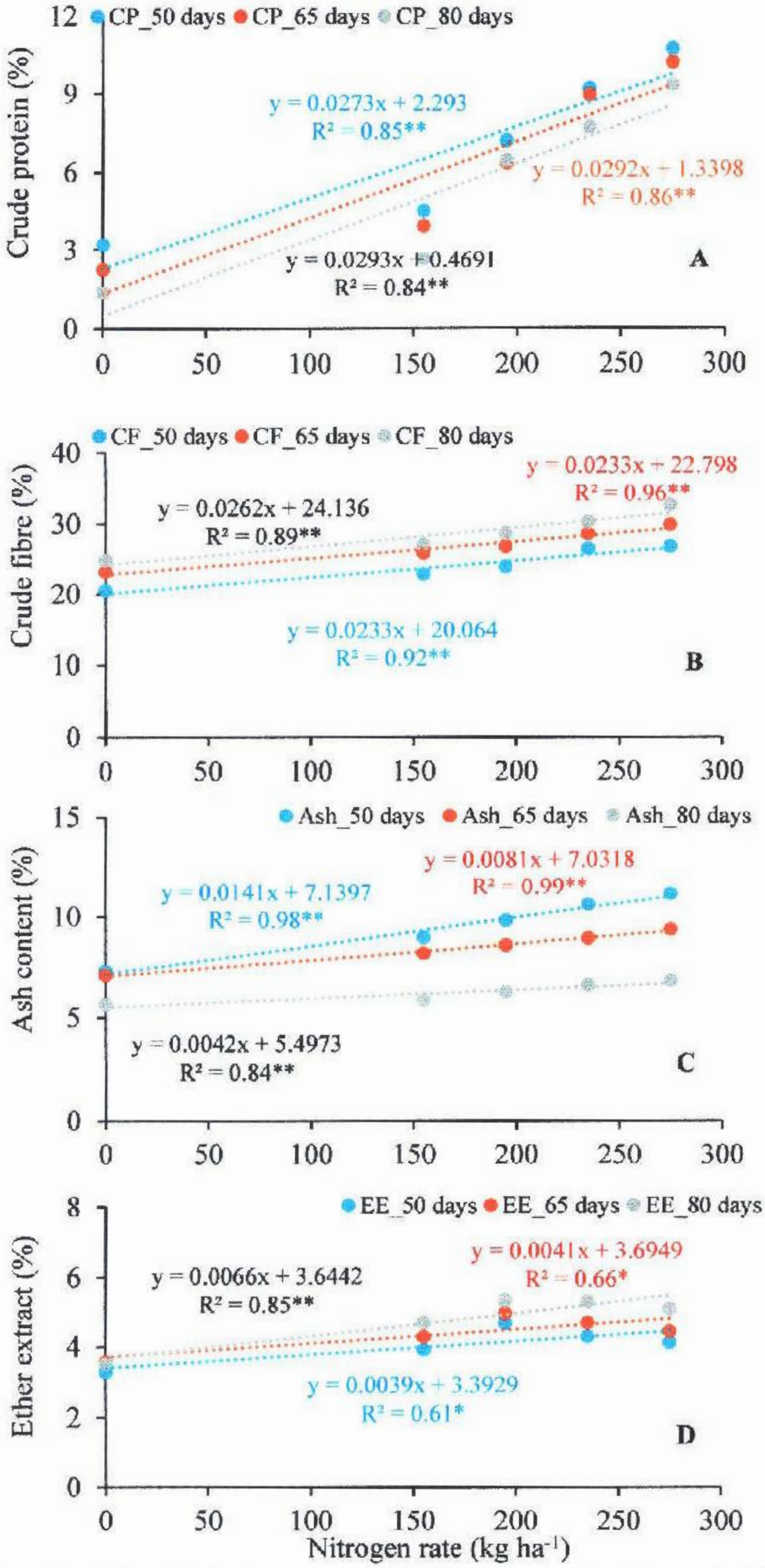

Figure 8. Functional relationship between N rate with crude protein (A), crude fibre (B), ash (C) and ether extract (D) of maize fodder

CHAPTER V

DISCUSSION

The present study aimed to investigate the effects of plant population and nitrogen rates on the biomass quality and yield of fodder maize (*Zea mays*) in the saline soil of southwestern Bangladesh. The results demonstrate that both factors significantly influenced maize performance, with notable interactions between population density and nitrogen application.

Effect of plant population on growth, biomass accumulation and quality of maize fodder

Growth, biomass accumulation and quality attributes of maize fodder significantly varied with the plant population. The data showed that plant height, leaf number, stem diameter and leaf chlorophyll content index at 50, 65, and 80 days after sowing (DAS) were greater in wider row spacing (30 cm × 30 cm) than in narrower spacing. This could be attributed to more effective use of growth resources such as sunlight, moisture, and nutrients in wider spacing. These results align with the findings of Muniswamy et al. (2007), Boomsma et al. (2009), Dar et al. (2014), Dutta et al. (2015), Chavan et al. (2017), Kumari et al. (2017), and Neelam and Dutta (2018).

The study on maize fodder grown at varying planting densities found that biomass yield increased as the plant population rose. Ayub et al. (1999) and Norwood (2001) highlighted that proper plant spacing influences yield components. Studies by Mazaheri et al. (2002) and Hassanzadeh and Basafa (2006) also observed a significant rise in forage yield with higher planting spacing. Similarly, Malik et al. (2007) and Osman et al. (2010) found notable improvements in fodder yield at greater plant populations, attributing the increase to a larger number of plants per unit area, greater plant height, and higher leaf area index. Amanullah et al. (2009) reported comparable findings. This present study revealed that the biomass yield increased significantly with an increase in plant population up to 239,130 plants/ha. This suggests that a higher plant population results in more plants per unit area, assuming the seeds have similar viability. Additionally, the number of seeds planted rose as seed rates increased, leading to a greater plant population. These findings are consistent with those reported by Ayub et al. (2002) and Ayub et al. (2007).

The crude protein and crude fibre percentages were significantly influenced by plant population, with higher plant populations leading to a reduction in crude protein and crude fibre content. The highest protein and fibre content were recorded with the plant population of

124220 ha^{-1}. The increased protein content at lower plant populations may be attributed to reduced competition among plants for nutrients. Similar findings, showing a decline in protein content with increasing plant population, were also reported by Verma and Singh (1976). Shun et al. (1989) observed reduced crude fiber content as plant density increased. Seeding densities had a significant impact on ether extract percentage and ash percentage. The highest fat value and ash percentage were recorded with the lowest plant population. According to Qureshi (1964), an increase in plant population has been associated with reducing the fat and ash content of maize fodder.

Effect of nitrogen on growth, biomass accumulation and quality of maize fodder

Growth, biomass accumulation and quality attributes of maize fodder significantly varied with the variation of nitrogen rate. The tallest plant height was achieved with the application of the highest nitrogen dose of 275 kg ha^{-1}. The increase in plant height with higher nitrogen doses suggests that plants utilize nitrogen during active cell division to create proteins, which are essential for cell elongation (Iqbal et al., 2006). The increase in the number of leaves with higher nitrogen levels (275 kg ha^{-1}) may be attributed to the rapid and active cell division within the plant leaves, leading to larger leaf blades (Nadeem et al., 2009). Maximum stem diameter was achieved with the application of the highest nitrogen dose of 275 kg ha^{-1}. An increased nitrogen concentration may stimulate cell division, which ultimately contributes to a consistent growth in stem diameter (Mahdi et al., 2011). The highest chlorophyll content was observed in plants that received 275 kg N ha^{-1}. The rising levels of chlorophyll content with increasing nitrogen doses suggest that the fodder maize plants are effectively absorbing more nitrogen, leading to greener leaves (Ayub et al., 2007; and Hassan et al., 2010).

The study involved experimental plots treated with different amounts of nitrogenous fertilizer (urea), which had a significant impact on yield across the treatments. Numerous studies (Krishna et al., 1998; Cox and Cherney, 2001; Girija, 2002) have documented that applying nitrogen fertilizer at varying levels enhances maize fodder production. The differences in yield across nitrogen levels can be attributed to the increased availability of nitrogen with higher application rates. These findings align with the results reported by Aslam et al. (2011), Shehzad et al. (2012), and Ayub et al. (2013). The higher nitrogen fertilizer application likely enhanced soil nitrogen availability, which could have stimulated meristematic growth and led to increased maize fodder yield (Hasibul et al., 2014). The biomass yield in the nitrogen treatments significantly increased with higher nitrogen application, with the 275 kg N ha^{-1} treatment producing the highest yield compared to other nitrogen treatments. The findings align with those of Johnston (2000) and Mahmud et al. (2003), emphasizing that nitrogen is a crucial element for plant growth and development. According to Almodares et al. (2009), an application rate of 200 kg N ha^{-1} resulted in the highest maize fodder biomass, while exceeding this limit led to reduced yields (Mengel and Kirkby, 2001).

The highest crude protein content in fodder maize was recorded with the application of the highest nitrogen dose (275 kg ha^{-1}). Crude protein is an essential nutrient in all animal diets. Deficiencies in crude protein can manifest as reduced appetite, weight loss, stunted growth, diminished reproductive performance, and lower milk production. Young, growing, and lactating animals are particularly in need of crude protein supplementation. Ensuring sufficient crude protein in animal diets is crucial for maintaining animal health and productivity, as well as for the profitability of ranching (Firdous et al., 1996; Kebede et al., 2012). The linear increase in crude protein percentage with higher nitrogen concentrations may be attributed to nitrogen being a key component of protein molecules and a fundamental building block of amino acids. A similar pattern was noted by Aslam et al. (2011) with the highest nitrogen application. Likewise, the maximum crude fiber content was achieved when fodder maize plants were supplied with the highest nitrogen dose (275 kg ha^{-1}). Crude fiber is essential for normal rumen function and metabolism and serves as a beneficial dietary component. The physical properties of fiber, especially particle size, play a crucial role in regulating passage rate, rumination, salivation, and the pH levels in the rumen (Johnston et al., 2003; Kebede et al., 2012). The increase in crude fiber percentage with higher nitrogen levels may be linked to greater stem diameter and plant height. Similar findings were reported by Aslam et al. (2011). Plants supplied with a higher nitrogen dose (275 kg ha^{-1}) produced the highest ash content. The study showed that the total ash percentage increased with higher nitrogen levels, likely due to greater dry matter production in plants, which contributed directly or indirectly to mineral biosynthesis. Safdar (1997) also found an increase in ash content with higher nitrogen rates in fodder maize. Likewise, Ayub et al. (2003) reported a significant rise in ash percentage with increasing nitrogen levels.

Effect of cutting age on biomass accumulation and quality of maize fodder

Biomass accumulation and quality attributes of maize fodder significantly varied with the variation of cutting age. The maximum yield of green forage and dry matter was observed under the cutting management at 80 DAS. A similar pattern of results was reported by Tahira et al. (2018), Sharma et al. (2016), and Pathan et al. (2020). The highest levels of crude protein, ether extract, nitrogen concentration and total nitrogen uptake were recorded when forage with the lowest rates of nitrogen. The 275 kg N ha^{-1} treatment had the highest levels of crude protein (10.74%), crude fiber (32.55%), nitrogen (1.71%), and total nitrogen intake (96.93 kg ha^{-1}), while the no N added treatment had the lowest levels of those parameters. Application @ 195 kg N ha^{-1} resulted in the highest ether extract (5.34%) and application @ 275 kg N ha^{-1} resulted in the highest ash content (11.17%) and nitrogen use efficiency (32.90%) which was statistically similar to the 235 kg ha^{-1} whereas the lowest value of those parameters was recorded with no N added treatment. Nutrient qualities were significantly enhanced with the higher nitrogen rates but gradually declined with the decrease in nitrogen levels. The highest biomass accumulation (27.6 t ha^{-1}) on a fresh weight basis and the highest biomass accumulation (5.7 t ha^{-1}) on a dry weight basis, maximum net income (BDT 60651) and benefit-cost ratio (1.61) were recorded with the 275 kg N ha^{-1} treatment, which was statistically at par with the 235 kg N ha^{-1} treatment whereas the lowest value of those parameters was recorded with no N added treatment. Higher nitrogen rates greatly increased biomass yield, but as nitrogen levels decreased, biomass yield progressively decreased.

Among the different interactions of N rates and plant population ha^{-1} the highest crude protein (12.69%) and highest nitrogen concentration (2.03%) were measured from the interaction of 275 kg N ha^{-1} with the plant population of 124220 ha^{-1} which was statistically similar to 275 kg N ha^{-1} with the plant population of 173910 ha^{-1}. The highest total nitrogen uptake (107.52 kg ha^{-1}) was measured from the interaction of 275 kg N ha^{-1} with the plant population of 124220 ha^{-1} which was statistically similar at par to 275 kg N ha^{-1} with the plant population of 173910 ha^{-1} and 275 kg N ha^{-1} with the plant population of 204970 ha^{-1}. The highest crude fibre concentration (35.84%) was found with the interaction of 275 kg N ha^{-1} with the plant population of 124220 ha^{-1} and the highest ash content (11.52%) was measured from the interaction of 275 kg N ha^{-1} with the plant population of 124220 ha^{-1} which was statistically at par to 275 kg N ha^{-1} with the plant population of 173910 ha^{-1}, 275 kg N ha^{-1} with the plant population of 204970 ha^{-1}, 275 kg N ha^{-1} with the plant population of 239130 ha^{-1}, 235 kg N ha^{-1} with the plant population of 124220 ha^{-1} and 195 kg N ha^{-1} with the plant population of 124220 ha^{-1}. The application of N rate (235 kg ha^{-1}) with the plant population of 124220 ha^{-1} resulted in the maximum ether extract (5.68%) which was statistically similar at par to 195 kg N ha^{-1} with the plant population of 173910 ha^{-1}, 195 kg N ha^{-1} with the plant population of 204970 ha^{-1}, 235 kg N ha^{-1} with the plant population of 124220 ha^{-1}, 235 kg N ha^{-1} with the plant population of 173910 ha^{-1}, and 275 kg N ha^{-1} with the plant population of 124220 ha^{-1}. Alternatively, the application of no N-added treatment with the plant population of 239130 ha^{-1}

resulted in the lowest crude protein (1.19%), lowest ether extract (3.09%), lowest nitrogen concentration (0.19%), lowest crude fibre concentration (19.38%) and lowest ash content (5.41%). The lowest total nitrogen uptake (1.42 kg ha^{-1}) was found in no N-added treatment with the plant population of 124220 ha^{-1}.

Among the different cutting ages, the highest biomass accumulation (18.97 t ha^{-1}), highest crude fibre (28.64%) and ether extract (4.79%) were identified in the 80 days cut. Similarly, the highest ash content (9.58%) and crude protein concentration (6.98%) were observed in the 50 days cut and the maximum net income (BDT 15934) and benefit-cost ratio (1.15) were identified in the 65 days cut whereas the lowest biomass accumulation (12.15 t ha^{-1}), lowest crude fibre (24.07%) and ether extract (4.06%) were found in the 50 days cut. The lowest ash content (6.22%) and crude protein concentration (5.51%) were observed in the 80 days cut and the minimum net income and benefit-cost ratio were detected in the 50 days cut.

Conclusion

From the finding of the study and relevant discussion, it could be suggested that application of N @ 235-275 kg ha^{-1} and 204970-239130 plant population ha^{-1} with a 65 days cut is suitable for maize fodder in the coastal saline soils of southwestern coastal Bangladesh in respect of yield, quality attributes and net profit.

Recommendations

However, to reach a specific conclusion, it can be recommended that-

- This experiment needs to be repeated at least one more year to better understanding and validate the results.
- The experiment should be conducted in the farmers' fields across various locations in the southwestern coastal region.

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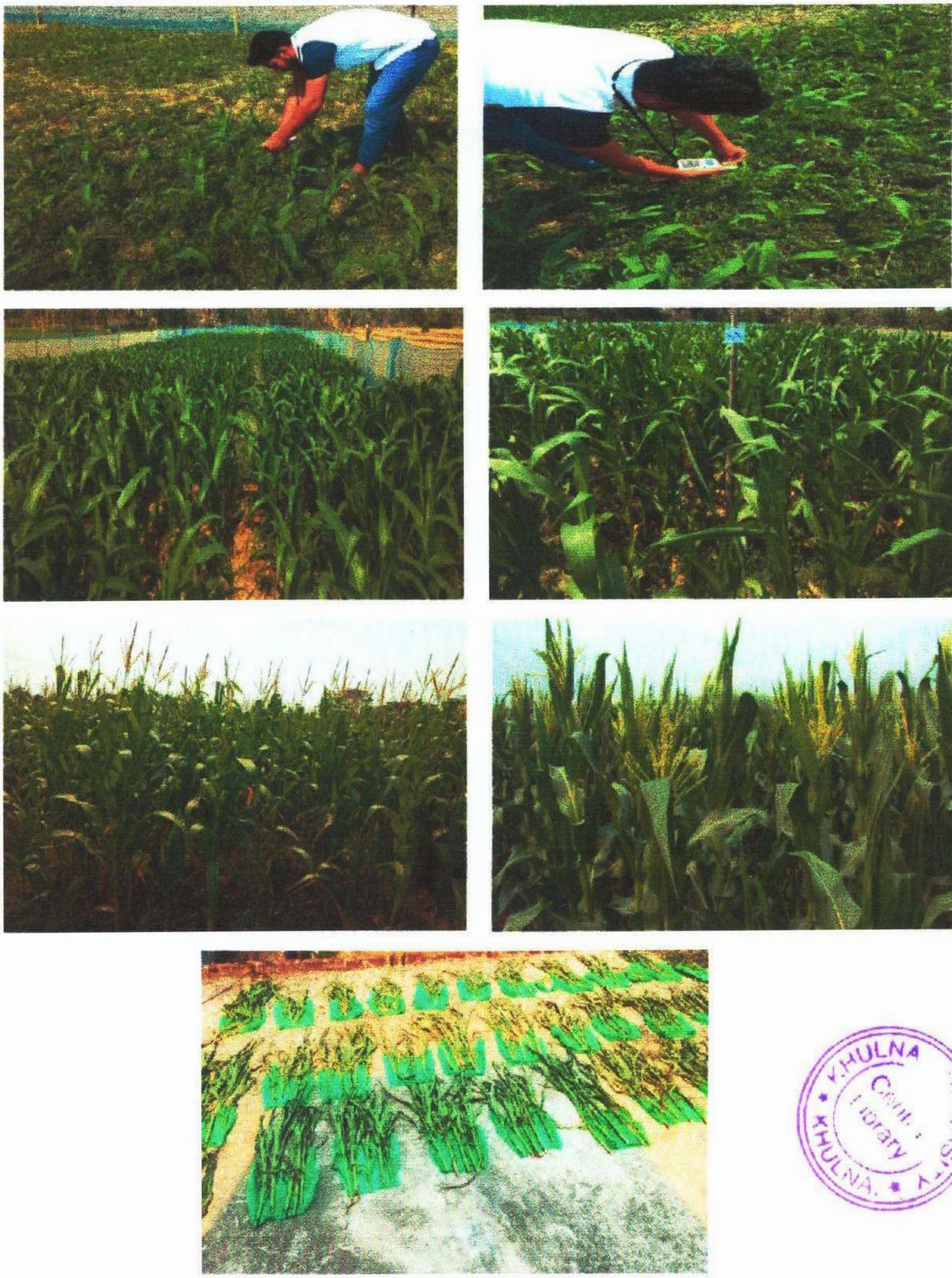
APPENDICES

Photograph 1. Field activities of the experimental plot



Photograph 2. Data measurement and harvesting of crop