GROWTH AND YIELD PERFORMANCE OF A SHORT STATURE EARLY WHITE MAIZE UNDER VARYING INTER ROW AND INTRA PLANT SPACING

NAIMUR RAHMAN DURJOY

REGISTRATION NO: 13-05374

DEPARTMENT OF AGRONOMY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA -1207

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BY

NAIMUR RAHMAN DURJOY

REGISTRATION NO: 13-05374

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Approved by:

Dr. Md. Jafar Ullah
Professor
Department of Agronomy
SAU, Dhaka
Supervisor

Dr. Md. Abdullahil Baque
Professor
Department of Agronomy
SAU, Dhaka
Co-Supervisor

Dr. Md. Shahidul Islam
Chairman
Examination Committee

DEPARTMENT OF AGRONOMY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled “**GROWTH AND YIELD PERFORMANCE OF A SHORT STATURE EARLY WHITE MAIZE UNDER VARYING INTER ROW AND INTRA PLANT SPACING**” submitted to the Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.)** in **AGRONOMY**, embodies the result of a piece of bonafide research work carried out by **NAIMUR RAHMAN DURJOY**, Registration No. **13-05374** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

June, 2020
Dhaka, Bangladesh

(Dr. Md. Jafar Ullah)
Professor
Department of Agronomy
SAU, Dhaka

Dedicated to

My

Beloved Parents

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The Author

GROWTH AND YIELD PERFORMANCE OF A SHORT STATURE EARLY WHITE MAIZE UNDER VARYING INTER ROW AND INTRA PLANT SPACING

ABSTRACT

An experiment was carried out to study the growth and yield performance of a short stature early white maize under varying inter row and intra plant spacing. The field experiment was conducted at the Agronomy Field of Sher-e-Bangla Agricultural University, during March to June, 2019. Fifteen plant spacing *viz.* T_1 = 40 cm × 15 cm, T_2 = 40 cm × 20 cm, T_3 = 40 cm × 25 cm, T_4 = 45 cm × 15 cm, T_5 = 45 cm × 20 cm, T_6 = 45 cm × 25 cm, T_7 = 50 cm × 15 cm, T_8 = 50 cm × 20 cm, T_9 = 50 cm × 25 cm , T_{10} = 55 cm × 15 cm, T_{11} = 55 cm × 20 cm, T_{12} = 55 cm × 25 cm, T_{13} = 60 cm × 15 cm, T_{14} = 60 cm × 20 cm and T_{15} = 60 cm × 25 cm were used under the present study. Results showed that the plant spacing T_3 showed maximum plant height, but maximum tassel length was found from T_8. The highest leaf length, breadth and area were found from T_{13}, while the highest cob-leaf length, breadth and area were found from T_{15}. The highest dry weight plant^{-1} was found from T_8. In terms of yield contributing parameters, the highest cob length (14.00 cm) and cob breadth (13.58 cm) were found from T_{14}, while the highest 100 grain weight (26.88 g) and grain weight cob^{-1} (68.74 g) were recorded from T_8. The highest grain yield (7.33 t ha^{-1}) and harvest index (49.33%) were recorded from the treatment T_8 while the lowest grain yield ha^{-1} (4.01 t ha^{-1}) was found from T_{12} and lowest harvest index (39.53%) was found from T_1. From the above results, it may be concluded that the plant spacing 50 cm × 20 cm showed highest grain yield (7.33 t ha^{-1}) and harvest index (49.33%) and this plant spacing can be considered as the best compared to other plant spacing.

LIST OF CONTENTS

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

AEZ = Agro-Ecological Zone
BBS = Bangladesh Bureau of Statistics
BCSIR = Bangladesh Council of Scientific and Industrial Research
cm = Centimeter
CV % = Percent Coefficient of Variation
DAS = Days After Sowing
DMRT = Duncan’s Multiple Range Test
et al., = And others
e.g. = exempli gratia (L), for example
etc. = Etcetera
FAO = Food and Agriculture Organization
g = Gram (s)
i.e. = id est (L), that is
Kg = Kilogram (s)
LSD = Least Significant Difference
m^2 = Meter squares
ml = MilliLiter
M.S. = Master of Science
No. = Number
SAU = Sher-e-Bangla Agricultural University
var. = Variety
^{o}C = Degree Celceous
% = Percentage
NaOH = Sodium hydroxide
GM = Geometric mean
mg = Miligram
P = Phosphorus
K = Potassium
Ca = Calcium
L = Litre
µg = Microgram
USA = United States of America
WHO = World Health Organization

CHAPTER I

INTRODUCTION

Maize (*Zea mays* L.) is a versatile crop having wider adaptability under varied environmental situations. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. It is cultivated on nearly 150 m ha in about 160 countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36% (782 MT) in the global grain production (Nand *et al*., 2018). The USA is the largest producer of maize contributes nearly 35 % of the total production in the world and maize is the driver of the US economy. In Bangladesh, it covers about 3.5 lac hectares of land producing 23 lac metric tons grains (Baral, 2016).

White maize, although having no anthocyanin or Vit-A, is preferred for human consumption because degradation of carotenoids during baking or frying causes a strong aroma and flavor. Commercial quality requirements for white maize are quite strict for purity of the white color, large uniform size of kernels, high specific density, hard endosperm, and white cob (Watson, 1988). It is also one of the most important cereal crops in the world agricultural economy both as food for man and feed for animals including poultry. Green cobs are roasted and consumed by people with great interest. The ‘popcorn’, are characterized by a hard corneous interior structure are converted into the ‘popped’ form, which is the favourite food for children in urban areas.

Maize is a major cereal crop for both livestock feed and human nutrition, worldwide. With its high content of carbohydrates, fats, proteins, some important vitamins and minerals, maize acquired a well-deserved reputation as a ‘poor man nutricerea (Prasanna *et al.,* 2001). So, maize can contribute in food and nutritional security program in Bangladesh because of its higher productivity and nutritional value. Maize grain contains about 72% starches, 10% protein, 4.8% oil, 5.8% fiber, 3.0% sugar and 1.7% ash (Chaudhry, 1983).

Owing to higher yield productivity and short life cycle, maize has higher value for food, forage and feed for livestock and poultry and a cheaper source of raw material for agro based industry, where it is widely used for preparation of corn starch, corn oil, dextrose, corn syrup and corn flakes (Delorite and Ahlgren. 1976).

Maize can be grown twice a year in Bangladesh. At present, maize crop is cultivated in Bangladesh on an area of 990 thousand acres with total annual grain production of 3288 thousand tons (BBS, 2018). Soil and climatic conditions of Bangladesh are ideal for maize production. Despite suitable production environment and high yielding varieties, the yield of maize in Bangladesh is very low which can be attributed to injudicious use of inputs, lack of modern production technology and presence of weeds. Among other agronomic factors responsible for low yield, appropriate planting technique is of primary importance. The development of new varieties necessitates the optimization of their planting geometries.

Maize yield largely depends on plant population. More plants mean higher yield. However, there is limitation to increasing plant population under humid, tropical conditions. Maize becomes more susceptible to pests and diseases when temperature, rainfall, and humidity are high. The population density is influenced by the distance between row, the distance between plants in row and the number of plants in a hill. An optimum plant spacing that allows for ease of the field operations, such as fertilizer application and weeding, minimizes competition among plants for light, water and nutrients and creates a favourable micro-climate in the canopy that reduce the risk for pests and diseases. Close row width of about 50 to 70 cm is recommended to ensure that sunlight falls on the plants and not on bare soil. This reduced weed competition and loss of soil moisture from evaporation (Nand *et al*., 2018).

Under varying environments, maize crop demands different plant spacing for higher grain yield. Both narrow and wider spacing are influencing factor for yield of maize (Luque *et al*., 2006). Generally narrow row spacing for maize has been shown to increase corn yield (Bullock *et al*., 1988). Closer spacing may enhance available soil moisture to the crop (Karlen and Camp, 1985). Narrow rows may also increase light interception by the crop, for example, corn and soybean (*Glycine max* L.) and therefore lead to increased crop growth (Tollenaar *et al*., 1994). Narrowing crop rows may also result in early canopy closure and reduced weed growth (by increased shading of weeds), and thereby improvement in yield (Chauhan and Johnson, 2010).

The population of maize can be manipulated through plant spacing for higher yield. In this context, this experiment was designed to evaluate growth, yield and phenology of a short stature early white maize under inter row and intra plant spacing with the following objectives:

1. To select suitable row to row spacing for the cultivation of white maize.
2. To find out suitable plant to plant distance in a row on growth and yield performance of white maize.

CHAPTER II

REVIEW OF LITERATURE

Maize (*Zea mays* L.) is the third most cereal crops after rice and wheat on the basis grain production in the world. It is rich in many important nutrients and it has diverse use. But yield of maize crop is alarmingly affected due to lack of proper cropping technique. The available findings relating to spacing have been briefly reviewed below:

Nand *et al*. (2018) reviewed that maize is one of the most important cereal crops in the world agricultural economy both as food for man and feed for animals including poultry. It is also called "queen of cereals'' because of very high yield potential, it is giving low yields because of lack of appropriate information about plant geometry and fertilizer management. Nitrogen, phosphorus and potassium are the major plant nutrients, which limit normal plant growth. Increasing yield per unit area through agronomic management is one of the important strategies to increase the production of maize grain. Keeping this in view, various experiments were have been carried out on the effect of plant geometry and different dose of various inorganic fertilizers have seen very widely on hybrid and composite variety of maize in winter season.

Koirala *et al*. (2020) carried out a field trial to study the effect of different row spacings on different maize varieties. Four levels of spacings (board-casting and three row spacings of 45, 60 and 75 cm) and two maize varieties (Rampur Composite and Arun-2) were evaluated using randomized complete block design with three replications. The greatest grain yield was found in Rampur Composite and Arun-2 while they were planted with row spacing of 60 cm with plant to plant spacing of 25 cm. The most grain yield, cob length, cob circumference, number of rows per cob, thousand grain weight were reported when maize was planted in the row spacing 60×25cm. Among the maize varieties, Rampur Composite produced the highest grain yield, cob length, cob circumference, number of rows per cob as compared to Arun-2. That study suggested that maize production could be increased by cultivating maize varieties with row spacing of 60 cm with plant to plant spacing of 25 cm.

Fromme *et al*. (2019) performed a field studies to find out the proper plant density levels on plant height, ear height, stalk diameter, lodging, corn grain yield, test weight, and photosynthetically active radiation with modern corn hybrids in central Louisiana and to test the hypothesis that the response of grain yield to plant population density would depend on the reproductive plasticity (flex, semiflex, or fixed ear) of the hybrids evaluated. Higher plant height was achieved with lower populations. Grain increased as plant populations increased. Test weights were less with the fixed ear hybrid and the effect of plant populations was inconsistent with increased populations resulting in greater test weight in one of two years. Lodging increased as plant populations increased with the fixed ear hybrid resulting in greater lodging in one of two years. Effect of plant populations is an important factor for corn yield; however, yield gains associated with closer spacing may be dependent on the genetic predisposition of corn hybrids (regardless of the reproductive plasticity) to tolerate various environmental conditions and stresses associated with higher populations.

Shrestha and Yadav (2018) made a study five levels of nitrogen as 0, 50, 100, 150 and 200 kg N/ha and three levels of the plant population as 55555, 66666 and 83333 plants/ha to estimate the effects of the said treatment. at Mangalpur VDC-3, Anandapur, Chitwan, Nepal during 2006-07 winter season. The days of flowering (tasseling and silking) was early with increasing nitrogen level up to 200 kg N/ha and elongated with increasing plant population up to 83333 plants/ha). Physiological maturity and grain yield increased with increasing level of nitrogen up to 200 kg N/ha and plant population up to 83333 plants/ha. The highest grain yield (6925.79 kg/ha) was obtained with 200 kg N/ha + 66666 plants/ha.

Katuwal, Y. (2018) conducted a field experiment with two variety (Arun-2 and Arun-4) and three levels of spacing (80 cm x 25 cm, 60 cm x 25 cm and 40 cm x 25 cm). The highest grain yield (4.93 t ha^{-1}) was obtained from the highest plant population (100000 plants ha^{-1}) followed by lowest plant population (50000 plants ha^{-1}) (4.38 t ha^{-1}) and medium plant population (66666 plants ha^{-1}) (3.83 t ha^{-1}). In respect of the interaction effect between variety x spacing, there was statistically highly significant effect found on grain yield. The comparison of the mean values of the grain yield for interaction between variety and spacing showed that Arun-4 cultivar in 40 x 25 cm plant had the highest grain yield (5.1 t ha^{-1}) followed by Arun-2 with the same spacing (4.8 t ha^{-1}). The greater grain yield in high plant density plots might be due to higher number of effective plants ha^{-1} (73281) with high number of cobs ha^{-1} compared to medium plant density (50104 plants ha^{-1}) and low plant density (38946 plants ha^{-1}). Comparatively, the variety Arun-4 was superior on final grain yield (4.43 t ha^{-1}) compared to Arun-2 (4.34 t ha^{-1}). From the results, it is concluded that Arun-4 variety with the highest plant population (100000 plants ha^{-1}) is better to grow in rainfed lowland (Khet land) as spring maize.

Zeleke *et al*. (2018) evaluated three planting densities and four N levels in a field experiment to determine planting density on maize yield. There were significant differences among panting densities. Plant height, ear height, and leaf area index were significantly increased with increasing planting density from 44444 to 88888 plants ha^{-1}. However, the cob diameters, cob length, numbers of kernels per cob were decreased with increasing plating density. The grain yield was increased by 65.16% on 88888 plants ha^{-1} as compared to 44444 plants ha^{-1}.

Jiang *et al*., (2013) conducted a field study using planted in rectangular tanks (0.54 m x 0.27 m x 1.00 m) under 27 cm (normal) and 6 cm (narrow) plant spacing and treated with zero and 7.5 g nitrogen (N) per plant. Compared to conventional plant spacing, narrow plant spacing generated less root dry matter in the 0-20 cm zone under both N rates, slight reductions of dry root weight in the 20-40 cm and 40-70 cm zones at the mid-grain filling stage, and slight variation of dry root weights in the 70-100 cm zone during the whole growth period. Narrow plant spacing decreased root reductive activity in all root zones, especially at the grain-filling stage. Grain yield and total biomass were 5.0% and 8.4% lower in the narrow plant spacing than with normal plant spacing, although narrow plant spacing significantly increased N harvest index and N use efficiency in both grain yield and biomass, and higher N translocation rates from vegetative organs. These results explained that the reductive activity of maize roots in all soil layers and dry weights of shallow roots were significantly decreased under narrow plant spacing conditions, resulting in lower root biomass and yield reduction at maturity.

Enujeke (2013) examined three hybrid maize varieties under three different plant spacing for such growth characters as plant height, number of leaves, leaf area and stem girth. Regarding spacing, plants sown on 75 cm x 15 cm had higher mean height and number of leaves of 176.7 cm and 13.8, respectively while plants sown on spacing of 75 cm x 35 cm had higher mean leaf area of 713.7 cm^2 and stem girth of 99.4 mm, respectively. Based on the findings of this study, it is recommended that (i) hybrid variety 9022-13 be grown in the study area of enhanced growth characters which interplay to improve grain yield of maize (ii) spacing of 75 cm x 35 cm be used to enhance increased stem girth and leaf area whose photosynthetic activities could positively influence maize yield.

Fanadzo *et al*. (2010) examined the effects of inter-row spacing (45 and 90 cm) and plant population (40000 and 60000 plants ha^{-1}) on weed biomass and the yield of both green and grain materials of maize plants. The experiment was set up as 2 × 2 factorial in a randomized complete block design with three replications. Plant population had no significant effects and interaction among factors was not significant on weed biomass. Narrow rows of 45 cm reduced weed biomass by 58%. Planting maize at 40000 plants ha^{-1} resulted in similar green cob weight regardless of inter-row spacing. Cob length decreased with increase in plant population and with wider rows. Similar grain yield was obtained regardless of inter-row spacing when maize was grown at 40000 plants ha^{-1}, but at 60000 plants ha^{-1}, 45 cm rows resulted in 11% higher grain yield than 90 cm rows. Increasing plant population from 40000 to 60000 plants ha^{-1} resulted in a 30% grain yield increase. The trial showed that growers could obtain higher green and/or grain yield by increasing plant population from the current practice of 40000 to 60000 plants ha^{-1} and through use of narrow rows.

Stephanus *et al*. (2018) stated that maize (*Zea mays* L.) productivity has increased globally as a result of improved genetics and agronomic practices. Plant population and row spacing are two key agronomic factors known to have a strong influence on maize grain yield. A detailed review was conducted by Stephanus *et al*. (2018) to investigate the effects of plant population on maize grain yield, differentiating between rainfall regions, N input, and soil tillage system (conventional tillage [CT] and no-tillage [NT]). Data were extracted from 64 peer-reviewed articles reporting on rainfed field trials, representing 13 countries and 127 trial locations. In arid climates, maize grain yield was low (mean maize grain yield = 2448 kg ha$^{−1}$) across all plant populations with no clear response to plant population. Difference in maize grain yield was high in semiarid environments where the polynomial regression ($p < 0.001$, $n = 951$) had a maximum point at 140,000 plants ha−1, which reflected a maize grain yield of 9000 kg ha$^{−1}$. In subhumid climates, maize grain yield had a positive response to plant population ($p < 0.001$). Maize grain yield increased for both CT and NT systems as plant population increased. In high-N-input ($r2 = 0.19$, $p < 0.001$, $n = 2\ 018$) production systems, the response of plant population to applied N was weaker than in medium-N-input ($r2 = 0.49$, $p < 0.001$, $n = 680$) systems. There existed a need for more metadata to be analyzed to provide improved recommendations for determining plant populations across different climatic conditions and rainfed maize production systems. Overall, the importance of optimizing plant population to local environmental conditions and farming systems is illustrated.

Hasan *et al*. (2018) investigated the effect of variety and plant spacing on yield attributes and yield of maize. The experiment comprised of five varieties viz., Khoi Bhutta, BARI hybrid maize 7, BARI hybrid maize 9, C-1921, P-3396 and five plants spacing viz., 75 cm × 20 cm, 75 cm × 25 cm, 75 cm × 30 cm, 75 cm × 35 cm and 75 cm × 40 cm. The highest plant height, highest cob, maximum diameter of cob, highest number of kernel cob^{-1} , the highest 1000- grain weight, maximum grain yield and stover yield was observed in the spacing of 75 cm × 25 cm. In contrast, the spacing of 75 cm × 30 cm produced the lowest values of the above mentioned plant parameters and also showed the lowest grain yield. In respect to interaction effect of variety and spacing, the highest plant height (232.67 cm), maximum number of cob plant^{-1} (1.73), maximum diameter of cob (4.60 cm), highest number of kernel cob-1 (34), maximum stover yield (12.38 t ha^{-1}) were observed at the spacing of 75 cm × 25 cm with BARI hybrid maize 7 and resulting in the highest grain yield (9.04 t ha^{-1}). The least values of the above parameters were recorded in the narrowest plant spacing of 75 cm × 35 cm with Khoi bhutta. Depending on the experimental results, it may be concluded that maize (cv. BARI hybrid maize 7) can be cultivated with a spacing of 75 cm × 25 cm for appreciable grain yield.

Rahman *et al*. (2016) made an experiment to investigate the effect of planting spacing and nitrogen levels on yield attributes and yield of maize cv. Khaibhutta. Results revealed that nitrogen levels and plant spacing had significant effect on yield parameters and yield of Khaibhutta. The highest number of cobs plant^{-1}, grain rows cob^{-1}, grains row^{-1}, grains cob^{-1}, 1000-grain weight, grain yield and harvest index were recorded at 75 cm × 25 cm spacing. In contrast, the closest spacing of 50 cm x 20 cm produced the least values of grain rows cob^{-1}, grains row^{-1}, grains cob^{-1}, 1000-grain weight and grain yield.

Muranyi (2015) examined different row distances of 45 and 76 cm, just as plant densities of 50000, 70000 and 90000 plants ha^{-1} were set. The yield showed decreasing tendency parallel to the increasing plant densities, that is confirmed by the fact that plant densities of 50000 and 65000 plants ha^{-1} proved to be more favourable. Regarding the treatments with a row distance of 76 cm, hybrids obtained their yield maximums by 80327 plants ha^{-1}.

In another trial, three plant spacing i.e. 20 cm, 30 cm and 40 cm, with one row spacing of 75 cm along with six nitrogen rates i.e. 0 kg ha^{-1}, 23 kg ha^{-1}, 46 kg ha^{-1}, 69 kg ha^{-1}, 92 kg ha^{-1} and 115 kg ha^{-1} were tested by Golla and Chalchisa (2019) to determine the response of maize phenology and grain yield for various nitrogen fertilizer rates and plan spacing. The experiment was set in a Randomized Complete Block Design in factorial combination with three replications. The results showed that reduction in plant spacing and nitrogen starvation resulted delaying to attain 50% tasseling and silking while it speeding up maturity period. The greatest grain yield (10,207.8 kilo gram ha^{-1}) obtained under the narrowest plant spacing (20 centimeters) with application of the highest rate of nitrogen (115 kilo gram nitrogen per hectare). This yield result surpassed by 8.9% compared to the standard check. The experiment showed an increasing trend of grain yield with increasing N rate and decreasing plant spacing, so further increasing of N rates and reducing plant spacing might further increased the grain yield.

An experiment as designed by Sarjamei *et al*. (2014) to investigate the effect of planting method and plant density, on morpho-phenological traits of maize (*Zea mays* L.) variety KSC 704. Three levels of plant density (D_1: 90,000; D_2: 120,000 and D_3: 150,000 plant ha^{-1}) were tried. The highest and lowest ear yield belonged to D_2 and D_1 plant density by 9987 and 8780 kg ha^{-1} ear production respectively. D_3 had the highest de husked ear yield by mean of 1969 kg ha^{-1}.

To study the effect of crop geometry on growth and yield of maize (Var. G-5414), a study was conducted by Bairagi *et al*. (2015) using three levels of plant population *viz*. 45 × 30 cm (S_1), 45 × 20 cm (S_2) and 45 × 10 cm (S_3). Corn yield and fodder yield were higher when maize planted in wider spacing of 45 × 30 cm. whereas, closer spacing of 45 × 10 cm resulted in reduction of both corn and fodder yield per plant. The yield attributes of maize were clearly indicative that they were thermo- sensitive and maize cobs and fodder yield are higher at closer spacing.

Singh *et al*. (2015) using two varieties (VL Baby Corn-1 and HM 4), two spacings (45×25 cm and 60×25 cm) and three sowing dates (1st October, 30th October and 29th November) indicated that the maximum corn yield (32.55%) and fodder yield (26.21%) was found to be higher from 45×25 cm spacing over 60×25 cm spacing.

Chamroy *et al*. (2017) evaluated the growth and yield response of maize (*Zea mays* L.) to planting geometry". Four levels of sowing periods (i.e. Last week of Aug., Sept., Oct. and Nov.) and five different crop geometry (30 cm × 30 cm, 45 cm × 15 cm, 45 cm × 30 cm, 60 cm × 15 cm and 60 cm × 30 cm) were used. It was observed that the yield parameters such as, number of cobs plant^{-1}(3.43), cob weight (9.87 g) and cob yield plant^{-1} without husk (31.64 g) were found highest in S_5 (60 × 30 cm). However, S_2 (45 × 15 cm) exhibited highest yield hectare^{-1} (81.10 q).

Among others, one of the additional benefits of planting the hybrid maize was the ability of the grower to raise plant density levels. Cardwell (1982) reported a 2% increase year^{-1} in seeding rates for fifty years in Minnesota, which initially began with the introduction of hybrid seed to growers. Since the 1980s, seeding rates have continued this upward trend, but only at = 1.0% year^{-1} (Anonymous, 2011). A positive trend between higher seeding rates and higher yields that has been observed for the past 80 years. Therefore, a projected increase in grain yield over the next few decades would most likely involve the incorporation of higher plant densities. The inherent problems associated with higher plant density is the inter-plant competition that tends to occur at more frequent intervals. Tollenaar and Wu (1999) reported that uniform stands are essential at higher plant density levels in order to avoid yield reductions affiliated with inter-plant competition. The commonest ways to reduce inter-plant competition is to alter the spacing pattern between plants.

It was manifested that the spacing between planted rows has trended downward since the 1930s. Row configuration was inversely correlated to grain yield and plant density, whereby as yield and density increased through the decades, row spacing has decreased over the decades. Cardwell (1982) showed a reduction in row spacing from 1.07 m in the 1930s to around 0.90 m in the 1970s for Minnesota growers. This reduction in row spacing resulted in a 4% increase in grain yield for Minnesota farmers according to Cardwell. Eventually row spacing was reduced to the 0.76 m spacing pattern that is predominantly used by growers today due to its yield advantages. Planting configurations combined with hybrid use were two influential factors that led to increases in plant density and resulting higher yields. Since density levels likely need to increase to further increase yield, a popular approach to increasing densities involves the narrowing of rows more than the current 0.76 m practice.

In a trial it was observed that the most common closer rows tested are 0.38 m rows and twin rows, which are spaced 0.19 m apart (0.57 m between rows), but are on 0.76 m centers. The 0.19 m twin row is the more popular of the two narrow row strategies because it allows producers to use the same harvesting equipment that is used for 0.76 m rows. The benefit of narrower rows was better light interception by the crop during vegetative growth. One of the drawbacks associated with 0.76 m rows includes the inability of the crop canopy to intercept all of the available light until late into vegetative growth or early reproductive stages, while narrower rows allow the canopy to intercept light more efficiently than 0.76 m rows during vegetative growth (Nafziger, 2006). Decreasing row spacing further than 0.76 m would hopefully increase yield through better light interception and limiting inter-plant competition.

The studies of the past 2 decades compared 0.76 m rows to narrower row configurations across several plant densities, which mostly ranged between 62,000 and 99,000 plants ha^{-1}. In Indiana, Nielsen (1988) found that 0.38 m rows yielded 0.2 Mg ha^{-1} higher than 0.76 m rows when averaged over nine site years, two hybrids and four plant density levels. However, there was only a significant difference in grain yield between row configurations at the lowest plant density of 44,000 plants ha^{-1}. On the other hand, in Iowa, Farnham (2001) found that 0.76 m rows had a higher average yield (0.2 Mg ha^{-1}) than 0.38 m rows when averaged over six locations and three years. Farnham only reported a significant difference at the 89,000 plants ha^{-1} density level where on average, 0.76 m rows yielded 0.3 Mg ha^{-1} higher than 0.38 m rows. In the Chesapeake region of Maryland and Delaware, Kratochvil and Taylor (2005) reported a yield advantage of 0.3 Mg ha^{-1} for 0.76 m rows over 0.19 m twin rows when averaged over all years, hybrids and populations. Different plant stands did not result in one row configuration consistently being better than the other. In the gulf region, Balkcom *et al.* (2011) reported higher average yields for 0.19 m twin rows over 0.76 m rows at medium to higher density stands, although the only significant difference was at the high (81,000 plants ha^{-1}) density treatment. On an average across the hybrids, both row configurations significantly increased yield from the low-density stand (42,000 plants ha^{-1}) to the medium (62,000 plants ha^{-1}) density stand, but yield only further increased for 0.19 m twin rows when density increased to 81,000 plants ha^{-1}. In Missouri, Nelson and Smoot (2009) found that yields did not differ significantly between 0.76 m, 0.19 m twin, or 0.38 m rows when averaged across density levels ranging from 62,000 - 99,000 plants ha^{-1}. In Minnesota, Sharratt and McWilliams (2005) reported significant differences in grain yield between row configurations in 1999, but not in 1998. In 1999, 0.38 m rows yielded significantly better than 0.19 m twin and 0.76 m rows for two hybrids at 75,400 plants ha^{-1}. Along with university research, industry has also conducted many studies concerning rows narrower than 0.76 m. In 2010, Pioneer (Pioneer Hi-bred, Johnston, IA) conducted field research in Illinois, Iowa, and Minnesota and found on average that yield differences did not occur between 0.76 m and 0.19 m twin rows for varying plant density stands (Jeschke, 2010). Overall, most research has found that altering row configuration to narrower than 0.76 m resulted in minimal yield differences compared to 0.76 m rows regardless of plant density.

It was also examined how different hybrids might influence yield for different row configurations. Farnham (2001) tested six different hybrids with varying relative maturities (RM) and detected a small row configuration x hybrid interaction for two of the six hybrids when averaged across all plant densities. One of the shorter RM hybrids (< 100 d) yielded significantly better in 0.76 m rows, while a longer RM hybrid (> 110 d) performed significantly better in 0.38 m rows. Farnham stated that hybrids may respond differently to altering row configurations, which may be partly influenced by RM. Conversely, many studies have found that yield is not significantly different between row configurations for different hybrids (Jeschke, 2010, Kratochvil and Taylor, 2005, Sharratt and McWilliams, 2005). Pioneer was tested with RM dates ranging from 94 d to 111 d and found no statistical differences in grain yield between 0.76 m and 0.19 m twin rows (Jeschke, 2010). Overall, there is no definitive evidence to suggest that hybrids do or do not yield differently under alternative row configurations, and further research is needed to determine if hybrid selection is an important factor that affects yield under varying row configurations.

Another cultural practice that has facilitated gains in grain yield through the decades is the application of fertilizers (Aref and Wander, 1998). Manure application was historically the key contributor to soil fertility, but that all changed during the latter half of the 21st century with synthetic fertilizers.

Since the 1960s, total fertilizer application of N, P, and K has grown by 150% and contributed largely to increases in yield per unit land area (USDA, 2011). Since projected increases in yield will undoubtedly involve an increase in plant density, strategies to reduce plant-to-plant competition involve improved plant management through better fertility practices.

CHAPTER III

MATERIALS AND METHODS

The trial was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the Kharif season from March to June, 2019 to study the growth and yield performance of a short stature early white maize under varying inter row and intra plant spacing. The materials used and methodology followed in the investigation have been presented details in this chapter .

3.1 Location of the study area

The experimental site was situated at $23^0$77' N latitude and $90^0$33' E longitude at an altitude of 9 meter above the sea level .

3.2 Agro-ecological region of the study area

The trial site belongs to the Agro-ecological zone of “The Modhupur Tract”, AEZ-28 . This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain . The experimental site was shown in the map of AEZ of Bangladesh in Appendix I .

3.3 Soil

The soil belongs to the general soil type, shallow red brown terrace soil under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH ranged from 5.6-6.5 and had organic matter 1.10-1.99%. The experimental area was flat having available irrigation and drainage system and above flood level. The physico-chemical properties of soil is presented in Appendix III.

3.4 Climate

The location was under the subtropical climate which was characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (April- September) and scanty rainfall associated with moderately low temperature during the Rabi season (October-March). Climatic condition of the experimental site is presented in Appendix II.

3.5 Experimental details

3.5.1 Treatments

The single factor experiment had the following plant spacing:

1. T_1 = 40 cm × 15 cm
2. T_2 = 40 cm × 20 cm
3. T_3 = 40 cm × 25 cm
4. T_4 = 45 cm × 15 cm
5. T_5 = 45 cm × 20 cm
6. T_6 = 45 cm × 25 cm
7. T_7 = 50 cm × 15 cm
8. T_8 = 50 cm × 20 cm
9. T_9 = 50 cm × 25 cm
10. T_{10} = 55 cm × 15 cm
11. T_{11} = 55 cm × 20 cm
12. T_{12} = 55 cm × 25 cm
13. T_{13} = 60 cm × 15 cm
14. T_{14} = 60 cm × 20 cm
15. T_{15} = 60 cm × 25 cm

3.5.2 Layout of the experiment

The study was laid out into Randomized Complete Block Design (RCBD) with three replications. There were 15 plant spacing, in total 45 plots for 3 replications. Each block consisted of 15 unit plots. The size of each unit plot was 3.5 m × 1.8 m. The distance maintained between two replications and two plots were 0.5 m and 0.5 m, respectively. The layout of the experiment is shown in Appendix III.

3.5.3 Planting materials

In this research work, a white maize line was used as plant materials and the seeds were collected from SAU, Dhaka.

3.6 Preparation of the experimental field

The land was ploughed with the help of a tractor drawn disc harrow on March 15, 2019, and then ploughed with rotary plough twice followed by laddering to achieve a medium tilth required for the crop under consideration. Weeds and other plant remnants of the previous crop were removed from the field.

3.7 Fertilizer application

The recommended doses of fertilizers were as follows:

Name of fertilizer	**Rate ha^{-1}**
Urea	300 kg
TSP	150 kg
MOP	100kg
Gypsum	150 kg
$ZnSO_4$	10 kg

Source: BARI, 2014 (Krisi Projukti Hat Boi, P. 54)

The total amount of nitrogen in the form of urea was divided into three equal portions; one third was applied during final land preparation. The rest two portions were applied as split doses at 25 DAS and 45 DAS, respectively. Whole amount of TSP, MOP, Gypsum and $ZnSO_4$ were applied at the time of final land preparation.

3.8 Seed sowing

The seeds were sown maintaining plant to plant and row to row distance as per treatments having 2 seeds hole^{-1} under direct sowing in the well prepared plot on 23 March, 2019.

3.9 Intercultural operations

3.9.1 Thinning and gap filling

The plants were thinned out and gap filled 15 days after sowing having single plant hill^{-1} to maintain a uniform plant stand.

3.9.2 Weeding

The crop field was weedeed; two hand weedings were done; first weeding was done at 25 days after sowing followed by second weeding at 45 days after sowing.

3.9.3 Earthen up

Earthen up was done twice at 25 days after sowing and 45 days after sowing.

3.9.3 Irrigation and drainage

Irrigation was applied to each plot, first irrigation was done as pre-sowing and others were applied at 20, 40 and 60 days after sowing. Drainage channels were properly prepared to easy and quick drained out of excess water.

3.9.4 Plant protection measures

Ripcord 10 EC @500 ml in 20 L water was sprayed at 46 days after sowing.

3.10 Harvesting and post-harvest operations

At 26 June, 2019, the cobs of five randomly selected plants from each plot were separately harvested for recording yield attributes and other data. Five cobs were harvested for recording cob yield and other data.

3.11 Recording of data

Data were collected at harvest time. Five plants were randomly selected and fixed in each plot from the inner row of the plot for recording data. Dry weight of plants were measured by harvesting five plants at different specific dates from the inner rows leaving border plants and harvest area for cob of the maize.

The following data were recorded:

3.8.1 Growth parameters

1. Plant height (cm)
2. Tassel length plant^{-1}
3. Leaf area plant^{-1}
4. Dry weight plant^{-1} (g)

3.8.2 Yield contributing parameters

1. Cob length (cm)
2. Cob breadth (cm)
3. Number of rows cob^{-1}
4. Number of grains row^{-1}
5. Number of grains cob^{-1}
6. Weight of 100 seeds (g)

4.8.3 Yield parameters

1. Grain weight cob^{-1} (g)
2. Shell weight cob^{-1} (g)
3. Chaff weight cob^{-1} (g)
4. Grain yield ha^{-1}
5. Stover yield ha^{-1}
6. Biological yield ha^{-1}
7. Harvest Index

3.12 Procedures of recording data

A brief outline of the data recording procedure followed during the study is given below:

3.12.1 Growth characters

Plant height (cm)

The height of plant was recorded as the average of 5 plants selected from the inner rows of each plot. The height was measured from the ground level to tip of the plant.

Tassel length plant^{-1}

Tassel length was measured from base to top of tassel from five selected plants of each plot and the average data were recorded at harvest.

Leaf area

Leaf area was measured with the help of meter scale by taking leaf length and breadth in cm.

Dry matter content plant^{-1}

Dry matter content plant^{-1} was measured dissecting the plant into three; below cob-node, at cob-node and above cob-node at two different growth stages; vegetative and at harvest. Sample plants from each plot were collected. The plant parts were packed in paper packets then kept in the oven at 80°C for 72 hrs to reach a constant weight. Then the dry weights were measured with an electric balance. The mean values were determined.

3.12.2 Yield contributing parameters

Cob length (cm)

Cob length was monitored in centimeter from the base to the tip of the ear of 5 plants from the five selected plants in each plot with the help of a meter scale then average data were recorded.

Cob breadth (cm)

The breadth of cob was measured from five randomly selected cobs from the five selected plants in each plot in centimeter and averaged.

Number of grains cob^{-1}

Total number of grains from five randomly selected cobs from the five selected plants plot^{-1} were counted and finally averaged.

Weight of 100 seeds (g)

One hundred cleaned dried grains were counted randomly from each plot and weighed by using a digital electric and the mean weight was expressed in gram.

3.12.3 Yield parameters

Grain yield ha^{-1} (t)

Weight of grains collected from each plot was taken after final completion of cob harvest and converted into hectare and were expressed in t ha^{-1}.

Stover yield ha^{-1} (t)

Weight cleaned and well dried stover were collected from each plot were taken and converted into hectare and were expressed in t ha^{-1}.

Biological yield ha^{-1} (t)

Cob (dehusked) yield and stover yield were all together regarded as biological yield. Biological yield was calculated with the following formula:

$$\text{Biological yield (t ha}^{-1}\text{)} = \text{Cob yield (t ha}^{-1}\text{)} + \text{Stover yield (t ha}^{-1}\text{)}$$

Harvest Index (%)

It denotes the ratio of economic yield to biological yield and was calculated with following formula.

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.13 Statistical analysis

The data were statistically analyzed using MSTATC software. The mean values were assessed which were evaluated by performing the ‘F’ test. The significance of the difference among the treatments means was estimated by the Least Significant Difference Test (LSD) at 5% level of probability .

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to observe the growth and yield performance of a short stature early white maize under varying inter row and intra plant spacing. Data on different growth and yield parameters were recorded. The analysis of variance on different growth and yield contributing characters as well as yield of maize was influenced by different plant spacing presented in Appendices. The results have been presented and discussed with the help of tables or graphs and possible interpretations have been given under the following headings.

4.1 Growth parameters

4.1.1 Plant height

Significant influence was recorded on plant height of maize at different growth stages as affected by different plant spacing (Fig. 1 and Appendix V). Plant height was recorded at the time of harvest. Results showed that the highest plant height (182.40 cm) at harvest was recorded from the treatment T_2 which was significantly different from other treatments and followed by T_1, T_5 and T_8. The lowest plant height (117.50 cm) was found from the treatment T_{14} which was significantly different from other treatments. The result obtained from the present study was similar with the findings of Nand *et al.* (2018) and Fromme *et al.* (2019) who found higher plant height in lower plant spacing .

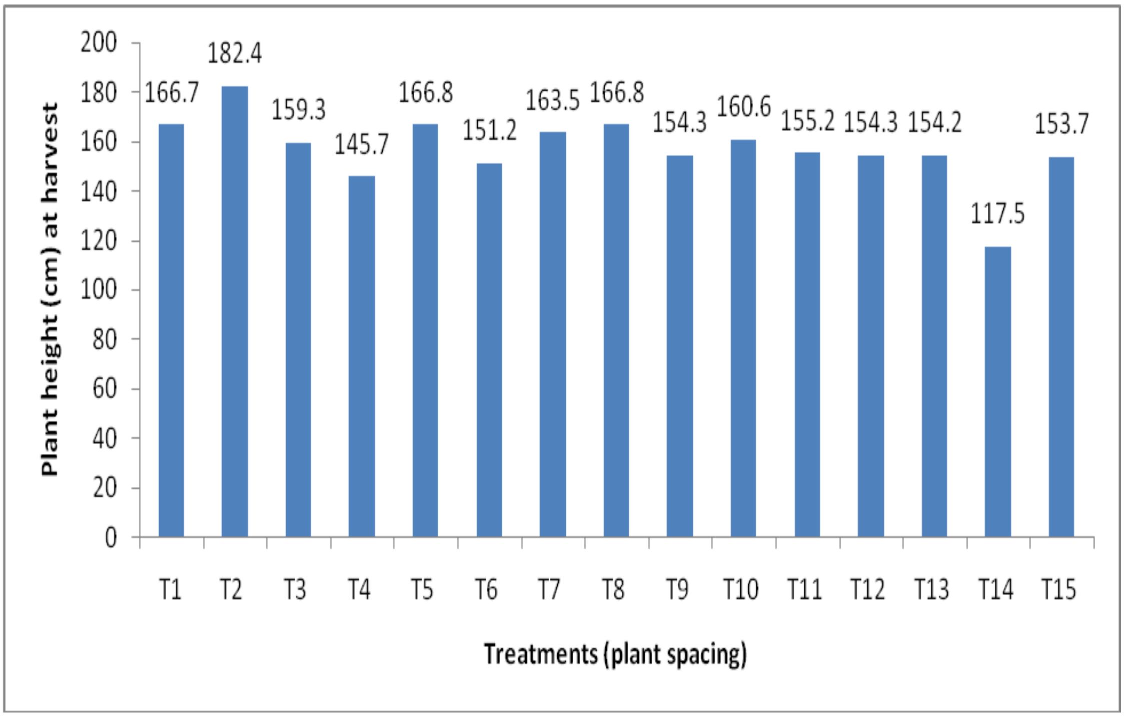

Fig. 1. Plant height of maize as influenced by different plant spacing ($LSD_{0.05}$ = 4.37) at harvesting stage .

4.1.2 Tassel length (cm) at harvest

Significant influence was found on tassel length of maize affected by different plant spacing (Fig. 2 and Appendix V). It was found that the highest tassel length (32.43 cm) was recorded from the plant spacing T_8 which was significantly different from other treatments and followed by T_{11} and T_{15}. The lowest tassel length (24.27 cm) was recorded from the plant spacing T_1 which was significantly different from other treatments which was very close to T_2 and T_3 but significantly different from T_1. Similar result was also observed by Shrestha and Yadav (2018) and Golla and Chalchisa (2019).

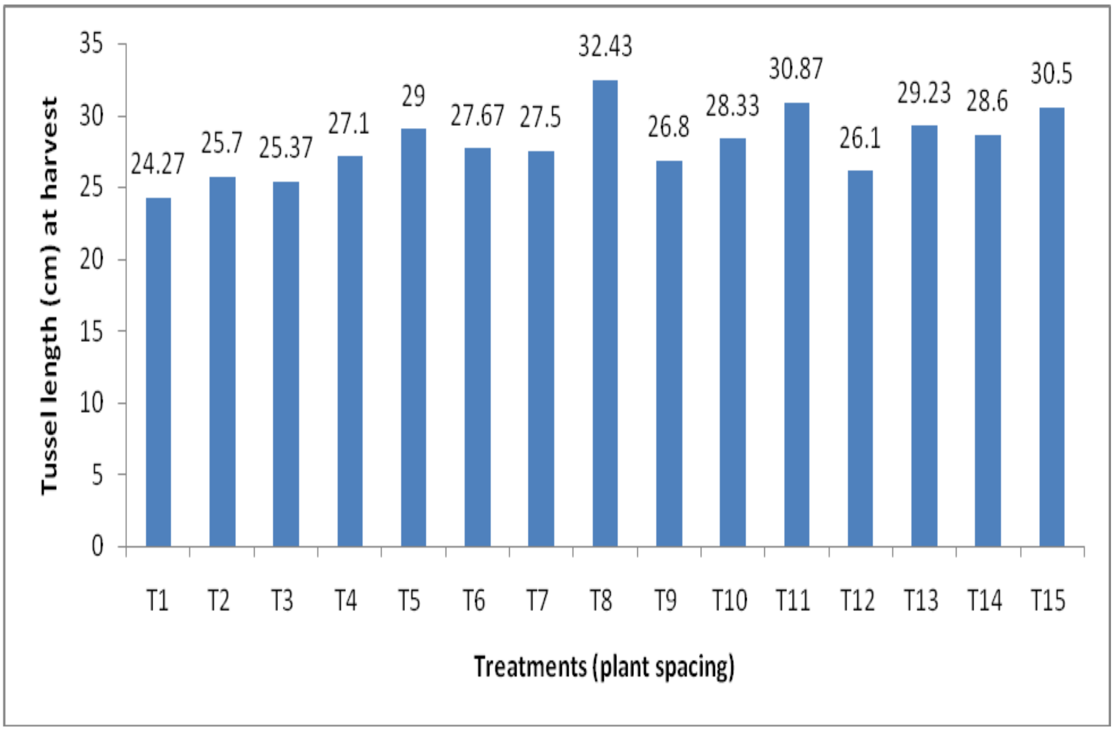

Fig. 2. Tassel length of maize as influenced by different plant spacing ($LSD_{0.05}$ = 0.93)

4.1.3 Leaf Length

The recorded data on leaf length was significantly influenced by different plant spacing (Table 1 and Appendix VI). Results exhibited that the highest average leaf length plant^{-1} (71.56 cm) was recorded from the plant spacing T_{13} which was significantly different from other plant spacing followed by T_{15}. The lowest average leaf length plant^{-1} (39.60 cm) was recorded from the plant spacing T_1 which was significantly different from other treatments but statistically similar to T_4.

4.1.4 Leaf breadth

Significant influence was recorded on leaf breadth of maize affected by different plant spacing (Table 1 and Appendix VI). It was found that the highest leaf breadth plant^{-1} (6.59 cm) was recorded from the plant spacing T_{13} which was statistically identical with T_{15} and followed by T_{10} and T_{14}. The lowest leaf breadth plant^{-1} (4.69 cm) was recorded from the plant spacing T_1 which was significantly different from other treatments which was statistically similar with T_2.

Table 1. Leaf length and breadth of maize as influenced by different plant spacing

Treatment	Average leaf length and breadth	
	Leaf length (cm)	Leaf breadth (cm)
T_1	39.60 h	4.69 h
T_2	45.12 f	4.87 gh
T_3	43.24 fg	5.01 g
T_4	41.71 gh	5.06 g
T_5	43.33 fg	5.56 ef
T_6	44.97 f	5.72 ef
T_7	45.74 f	5.51 f
T_8	48.39 e	6.02 bcd
T_9	55.11 c	5.80 cde
T_{10}	45.19 f	6.06 b
T_{11}	39.29 h	6.04 bc
T_{12}	51.26 d	5.80 de
T_{13}	71.56 a	6.59 a
T_{14}	50.23 de	6.05 b
T_{15}	59.76 b	6.37 a
$LSD_{0.05}$	2.545	0.224
CV(%)	11.66	9.26

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance .

4.1.5 Leaf area

Significant influence was recorded on leaf area of maize affected by different plant spacing (Fig. 3 and Appendix VI). It was found that the highest leaf area plant^{-1} (365 cm^2) was recorded from the plant spacing T_{13} which was significantly different from other treatments and followed by T_{15} whereas the lowest leaf area plant^{-1} (208 cm^2) was recorded from the plant spacing T_1 which was significantly different from other treatments but statistically similar with T_2. Similar result was also observed by Nand *et al*. (2018).

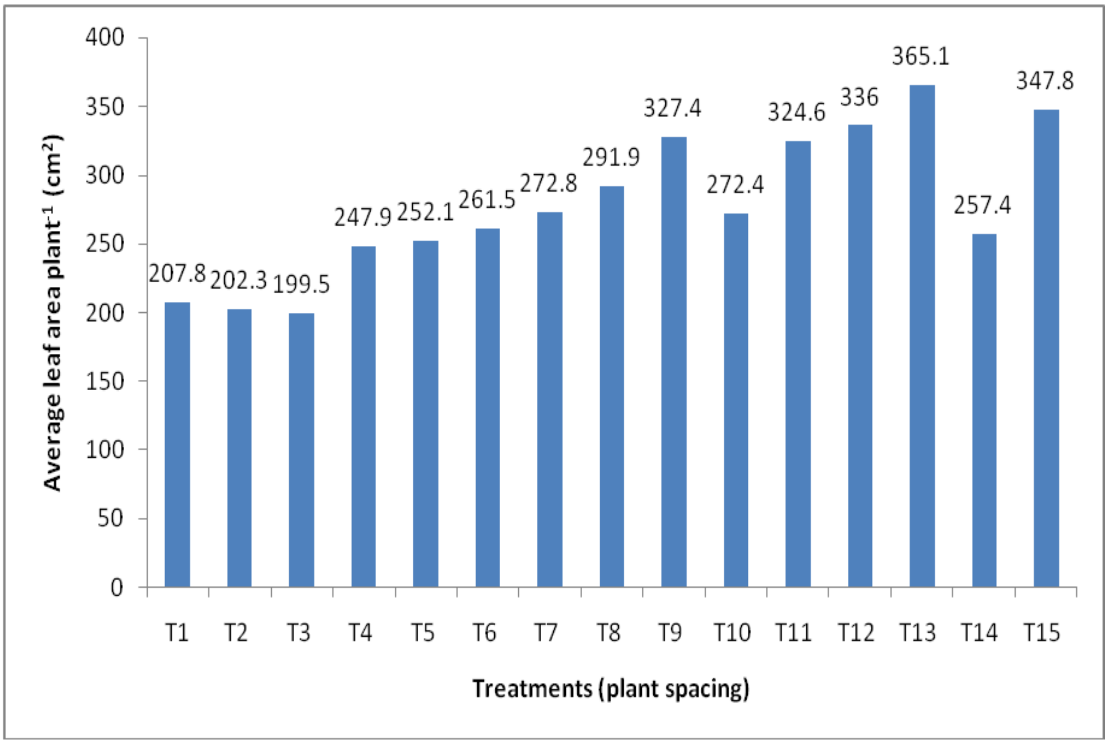

Fig. 3. Leaf area of maize as influenced by different plant spacing ($LSD_{0.05}$ = 5.85)

4.1.6 Cob-leaf length (cm)

Significant influence was recorded on cob leaf length of maize affected by different plant spacing (Table 2 and Appendix VII). The highest cob leaf length (72.83 cm) was recorded from the plant spacing T_{15} which was statistically similar with T_{14}. The lowest cob leaf length (56.00 cm) was recorded from the plant spacing T_1 which was significantly different from other treatments but statistically similar with T_2

Table 2. Cob-leaf length and breadth of maize as influenced by different plant spacing

Treatment	Cob-leaf length and breadth	
	Cob leaf length (cm)	Cob leaf breadth (cm)
T_1	56.00 i	6.10 i
T_2	55.33 i	6.23 hi
T_3	56.67 hi	6.33 gh
T_4	61.67 fg	6.33 gh
T_5	59.17 gh	6.36 gh
T_6	63.67 ef	6.96 d
T_7	62.90 f	6.76 e
T_8	66.33 de	7.13 c
T_9	63.03 f	6.83 de
T_{10}	66.90 cd	6.83 de
T_{11}	62.67 f	6.56 f
T_{12}	68.50 cd	7.13 c
T_{13}	69.50 bc	6.43 fg
T_{14}	72.00 ab	7.63 b
T_{15}	72.83 a	8.50 a
$LSD_{0.05}$	2.820	0.139
CV(%)	10.74	9.56

In a column means having similar letter(s) arc statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance .

4.1.7 Cob-leaf breadth

Significant influence was recorded on cob leaf breadth of maize affected by different plant spacing (Table 2 and Appendix VII). The highest cob leaf breadth (8.50 cm) was recorded from the plant spacing T_{15} which was significantly different from other treatments and followed by T_{14}. The lowest cob leaf breadth (6.10 cm) was recorded from the plant spacing T_1 which was significantly different from other treatments which was statistically similar with T_2.

4.1.8 Cob-leaf area

Significant influence was recorded on cob leaf area of maize affected by different plant spacing (Fig. 4 and Appendix VII). It was found that the highest cob leaf area (676.00 cm^2) was recorded from the plant spacing T_{15} which was significantly different from other treatments and followed by T_{14} whereas the lowest cob leaf area (343.30 cm^2) was recorded from the plant spacing T_1 which was significantly different from other treatments. Nand *et al.* (2018) also found similar result with the present study.

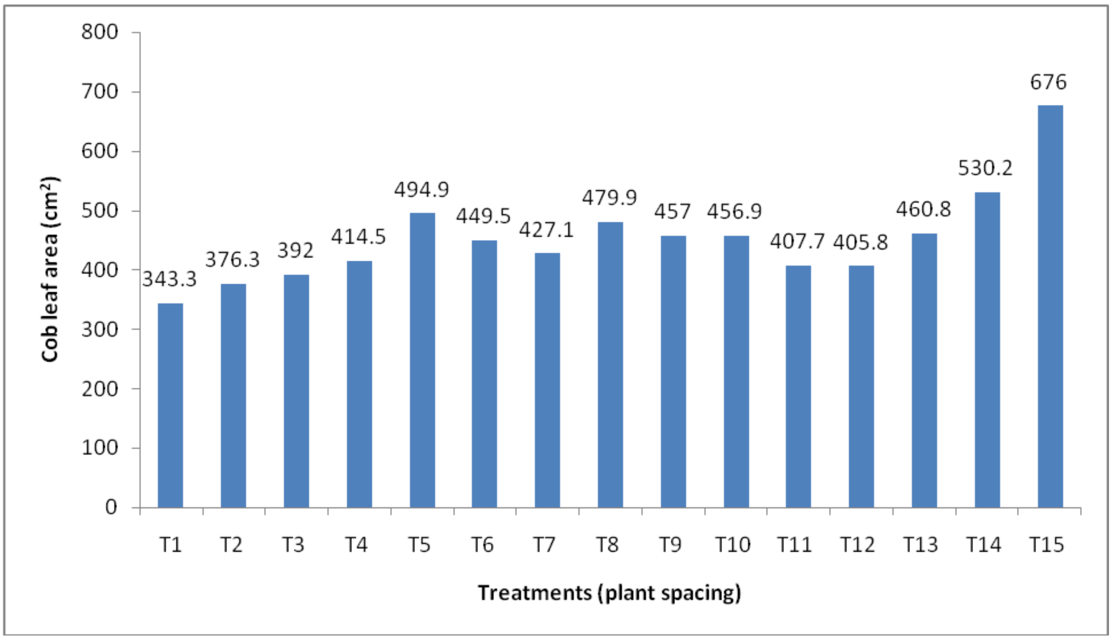

Fig. 4. Cob leaf area of maize as influenced by different plant spacing ($LSD_{0.05}$ = 10)

4.1.9 Shoot weight at vegetative stage

Significant variation was observed on dry matter content of maize at vegetative stage of different portion of plant as influenced by different plant spacing (Table 3). Dry matter content at vegetative stage was recorded at three different parts of the maize plant *viz.* at below cobs-node, at cob-node and above cob-node (Table 3).

At below cobs-node, the highest dry matter content at vegetative stage (19.19 g plant^{-1}) was recorded from the treatment T_8 which was statistically similar with T_{14} and followed by T_{10} whereas the lowest dry matter content at vegetative stage (10.79 g plant^{-1}) was found from the treatment T_1 which was significantly different from other treatments.

At cob-node, the highest dry matter content at vegetative stage (13.57 g plant^{-1}) was recorded from the treatment T_8 which was significantly different from other treatments and followed by T_2 whereas the lowest dry matter content at vegetative stage (9.45 g plant^{-1}) was found from the treatment T_1 which was significantly different from other plant spacing.

Above cob-node, the highest dry matter content plant^{-1} (10.41 g plant^{-1}) at vegetative stage was recorded from the treatment T_8 which was statistically identical with T_{15} whereas the lowest dry matter content at vegetative stage (15.46 g plant^{-1}) was found from the treatment T_1 which was significantly different from other plant spacing. Similar result was also observed by Nand *et al.* (2018).

Table 3. Dry weight plant^{-1} of maize at vegetative stage as influenced by different plant spacing

Treatment	Dry weight plant^{-1} (g) at vegetative stage		
	Below cob-node	At cob-node	Above cob-node
T_1	9.897 i	9.453 i	3.627 i
T_2	11.59 g	10.05 h	7.780 f
T_3	12.73 f	10.78 fg	4.740 h
T_4	10.79 h	10.56 g	6.700 g
T_5	14.27 e	10.54 g	7.710 f
T_6	14.12 e	10.91 fg	7.703 f
T_7	12.86 f	12.11 d	9.720 c
T_8	19.19 a	13.57 a	10.41 a
T_9	12.20 fg	11.35 e	4.803 h
T_{10}	17.88 b	11.03 ef	9.913 b
T_{11}	13.99 e	12.53 c	8.050 e
T_{12}	16.73 c	13.04 b	8.917 d
T_{13}	13.89 e	11.94 d	8.133 e
T_{14}	18.46 ab	12.89 bc	9.913 b
T_{15}	15.75 d	12.01 d	9.710 c
$LSD_{0.05}$	0.7737	0.4063	0.1587
CV(%)	9.46	10.71	8.63

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance .

4.1.10 Dry weight plant^{-1} at harvest

Significant variation was observed on dry matter content of maize at harvest as influenced by different plant spacing (Table 4 and Appendix IX). Dry matter content at harvest was recorded at three different parts of the maize plant *viz.* at below cobs-node, at cob-node and above cob-node (Table 4).

At below cobs-node, the highest dry matter content at harvest (21.12 g plant^{-1}) was recorded from the treatment T_8 which was significantly different from other plant spacing and followed by T_{14} whereas the lowest dry matter content at harvest (9.47 g plant^{-1}) was found from the treatment T_1 which was statistically similar with T_2.

At cob-node, the highest dry matter content at harvest (10.55 g plant^{-1}) was recorded from the treatment T_8 which was significantly different from other treatments and followed by T_6 and T_{14} whereas the lowest dry matter content at harvest (5.87 g plant^{-1}) was found from the treatment T_1 which was statistically similar with T_2, T_3 and T_{11}.

Above cob-node, the highest dry matter content plant^{-1} (12.93 g plant^{-1}) at harvest was recorded from the treatment T_8 which was statistically similar with T_{14} whereas the lowest dry matter content at harvest (7.61 g plant^{-1}) was found from the treatment T_1 which was statistically similar with T_2. The result obtained from the present study was similar with the findings of Nand *et al.* (2018).

Table 4. Dry weight plant^{-1} at harvest as influenced by different plant spacing

Treatment	Dry weight plant^{-1} (g) at harvest		
	Below cobs-node	At cob-node	Above cob-node
T_1	9.47 h	5.87 e	7.61 g
T_2	10.45 h	6.05 e	7.75 g
T_3	12.58 fg	6.65 de	8.55 f
T_4	12.53 fg	6.05 e	9.73 d
T_5	14.14 de	7.03 bcd	9.60 de
T_6	14.56 d	7.90 b	9.17 e
T_7	13.21 efg	7.66 bc	9.97 cd
T_8	21.12 a	10.55 a	12.93 a
T_9	12.05 g	7.61 bc	8.57 f
T_{10}	13.64 def	5.93 e	8.35 f
T_{11}	12.77 fg	6.54 de	10.06 cd
T_{12}	13.25 efg	7.01 bcd	10.88 b
T_{13}	16.04 c	6.95 cd	10.33 bc
T_{14}	18.98 b	7.84 b	12.62 a
T_{15}	16.86 c	6.93 cd	10.62 b
$LSD_{0.05}$	1.068	0.786	0.5315
CV(%)	7.41	8.57	10.40

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance .

4.2 Yield contributing parameters

4.2.1 Cob length (cm)

The recorded data on cob length was significantly influenced by different plant spacing (Table 5 and Appendix X). Results exhibited that the highest cob length plant^{-1} (14.00 cm) was recorded from the plant spacing T_{14} which was significantly different from other treatments and followed by T_{15} whereas the lowest cob length plant^{-1} (11.80 cm) was recorded from the plant spacing T_1 which was significantly different from other treatments. Similar result was also observed by Koirala *et al*. (2020) and Zeleke *et al*. (2018).

4.2.2 Cob breadth

Significant variation on cob breadth was found as influenced by different plant spacing (Table 5 and Appendix X). Results exhibited that the highest cob breadth plant^{-1} (13.58 cm) was recorded from the plant spacing T_{14} which was significantly different from other treatments and followed by T_8 whereas the lowest cob breadth plant^{-1} (10.13 cm) was recorded from the plant spacing T_1 which was significantly different from other treatments. Similar result was also observed by Koirala *et al*. (2020) and Zeleke *et al*. (2018).

Table 5. Cob length and breadth of maize at harvest as influenced by different plant spacing

Treatment	Cob length and breadth	
	Cob length (cm)	Cob breadth (cm)
T_1	11.80 i	10.13 i
T_2	12.17 h	11.78 h
T_3	12.67 ef	12.43 fg
T_4	12.83 de	13.02 cd
T_5	11.83 i	12.88 de
T_6	13.00 cd	12.33 g
T_7	13.17 c	12.60 f
T_8	13.75 b	13.27 b
T_9	12.50 fg	12.48 fg
T_{10}	12.33 gh	12.80 e
T_{11}	12.83 de	12.45 fg
T_{12}	13.67 b	13.12 bc
T_{13}	13.08 c	12.78 e
T_{14}	14.00 a	13.58 a
T_{15}	13.67 b	12.90 de
$LSD_{0.05}$	0.2244	0.1754
CV(%)	6.19	7.83

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance .

4.2.3 Weight of 100 grains

The recorded data on 100 grain weight was significantly influenced by different plant spacing (Table 6 and Appendix XI). Results exhibited that the highest 100 grain weight (26.88 g) was recorded from the plant spacing T_8 which was significantly different from other treatments but statistically similar with T_{10}, T_{12} and T_{13} whereas the lowest 100 grain weight (20.39 g) was recorded from the plant spacing T_1 which was significantly different from other treatments. Similar result was also observed by Hasan *et al*. (2018) and Rahman *et al*. (2016).

4.2.4 Number of grains cob^{-1}

Significant variation on number of grains cob^{-1} was found as influenced by different plant spacing (Fig. 5 and Appendix V). Results exhibited that the highest number of grains cob^{-1} (261 g) was recorded from the plant spacing T_{14} which was significantly different from other treatments but statistically similar with T_{11}. The lowest number of grains cob^{-1} (171 g) was recorded from the plant spacing T_3 which was significantly different from other treatments. Similar result was also observed by Rahman *et al*. (2016).

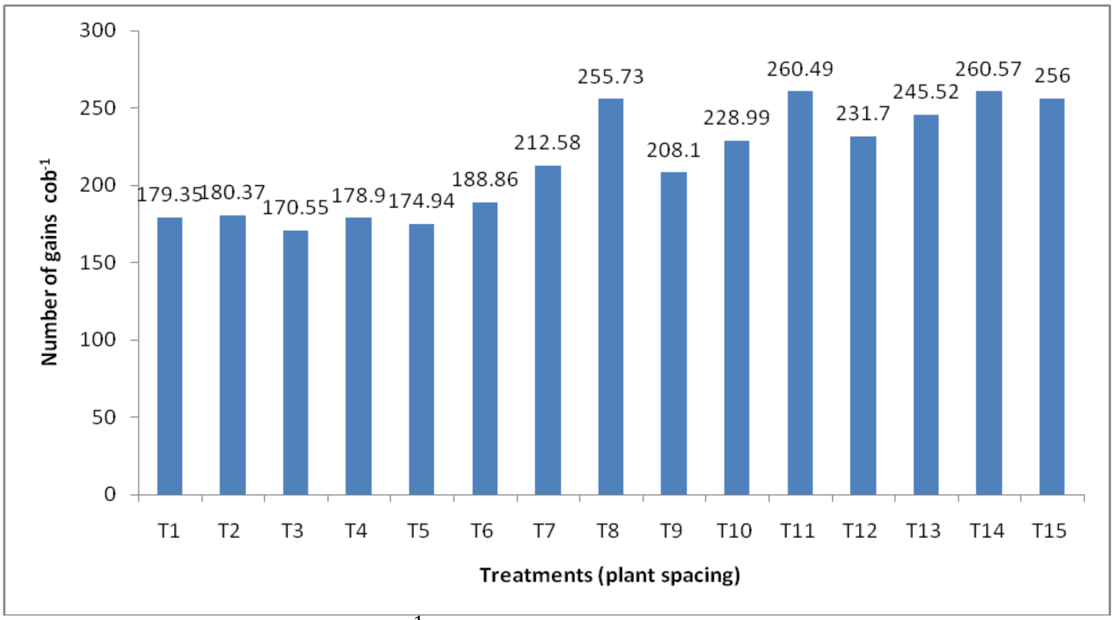

Fig. 5. Number of grains cob^{-1} of maize as influenced by plant spacing ($LSD_{0.05}$ = 6.81)

4.2.5 Grain weight cob^{-1} (g)

There was a significant variation on grain weight cob^{-1} was influenced by different plant spacing (Fig. 6). Results exhibited that the highest grain weight cob^{-1} (68.74 g) was recorded from the plant spacing T_8 which was significantly different from other treatments and followed by T_{11}, T_{13} and T_{15} whereas the lowest grain weight cob^{-1} (36.57 g) was recorded from the plant spacing T_1 which was significantly different from other treatments. Similar result was also observed by Rahman *et al*. (2016).

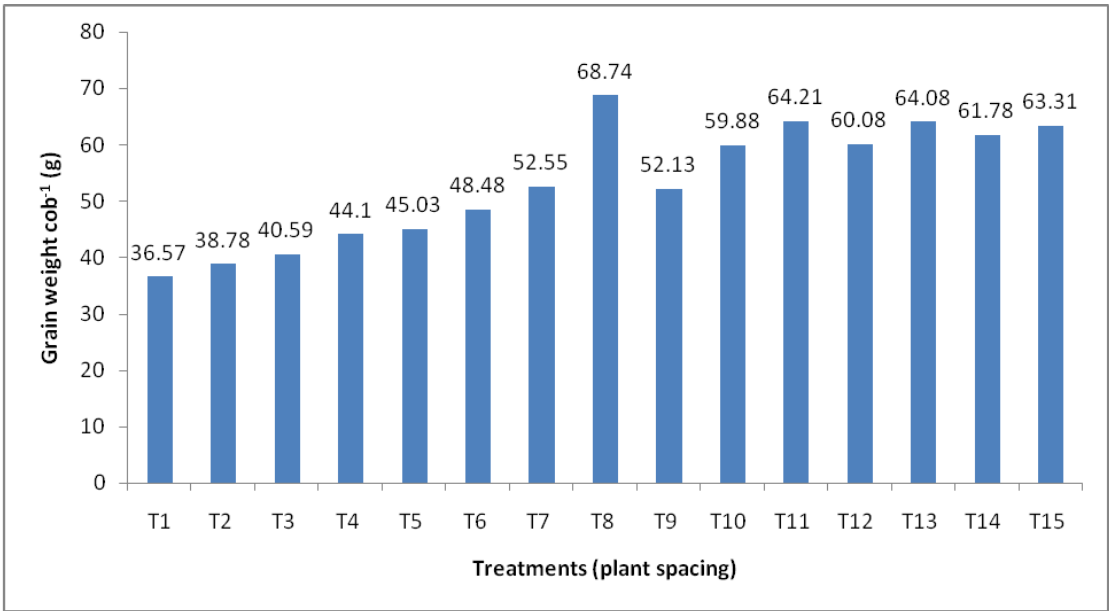

Fig. 6. Weight of grains cob^{-1} of maize as influenced by plant spacing ($LSD_{0.05}$ = 2.26)

4.2.6 Shell weight cob^{-1}

The recorded data on shell weight cob^{-1} was significantly influenced by different plant spacing (Table 6 and Appendix XI). Results exhibited that the highest shell weight cob^{-1} (16.68 g) was recorded from the plant spacing T_{13} which was significantly different from other treatments and followed by T_{14} whereas the lowest shell weight cob^{-1} (10.81 g) was recorded from the plant spacing T_1 which was significantly different from other treatments but statistically similar to T_2, T_3, T_5, T_6 and T_{11}.

4.2.7 Chaff weight cob^{-1}

Significant variation on chaff weight cob^{-1} was influenced by different plant spacing (Table 6 and Appendix XI). Results exhibited that the highest chaff weight cob^{-1} (8.81 g) was recorded from the plant spacing T_{13} which was significantly different from other treatments and followed by T_8 whereas the lowest chaff weight cob^{-1} (4.17 g) was recorded from the plant spacing T_1 which was significantly different from other treatments.

Table 6. Yield contributing parameters of maize as influenced by plant spacing

Treatment	Yield contributing parameters		
	100 grain weight (g)	Shell weight cob^{-1} (g)	Chaff weight cob^{-1} (g)
T_1	20.39 f	10.81 g	4.17 j
T_2	21.50 e	10.83 g	5.90 h
T_3	23.80 d	10.86 g	6.38 g
T_4	24.65 cd	13.06 de	5.56 i
T_5	25.74 bc	10.89 g	6.98 ef
T_6	25.67 bc	11.27 fg	6.17 gh
T_7	24.72 cd	12.37 ef	5.49 i
T_8	26.88 a	15.55 b	8.46 b
T_9	25.05 bc	13.79 cd	6.24 g
T_{10}	26.15 ab	14.56 bc	6.84 f
T_{11}	24.65 cd	11.91 fg	7.17 de
T_{12}	25.93 ab	13.69 cd	7.62 c
T_{13}	26.10 ab	16.68 a	8.81 a
T_{14}	23.71 d	15.41 b	7.41 cd
T_{15}	24.73 cd	14.13 cd	7.36 cd
$LSD_{0.05}$	1.003	1.051	0.292
CV(%)	7.71	7.91	8.74

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of significance .

4.3 Yield parameters

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

There was a significant variation on grain yield as influenced by different plant spacing (Fig. 7 and Appendix XII). Results exhibited that the highest grain yield (7.33 t ha^{-1}) was recorded from the plant spacing T_8 which was statistically similar to T_7 and T_{13} whereas the lowest grain yield (4.01 t ha^{-1}) was recorded from the plant spacing T_{12} which was statistically similar with T_9 (50 cm × 25 cm) and T_{15}. The result obtained from the present study was similar with the findings of Nand *et al*. (2018), Fromme *et al*. (2019), Shrestha and Yadav (2018), Golla and Chalchisa (2019), Hasan *et al*. (2018) and Rahman *et al*. (2016).

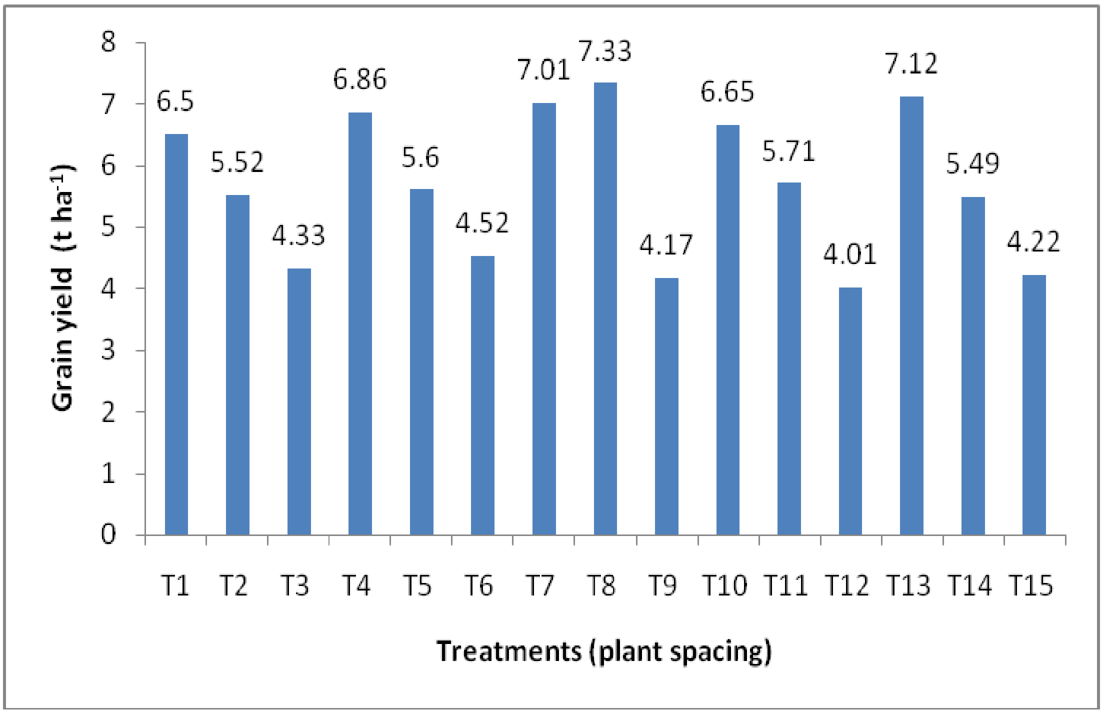

Fig. 7. Yield of maize as influenced by different plant spacing ($LSD_{0.05}$ = 0.21)

4.3.2 Stover yield

There was a significant variation on stover yield as influenced by different plant spacing (Fig. 8 and Appendix XII). Results exhibited that the highest stover yield (9.95 t ha^{-1}) was recorded from the plant spacing T_1 which was significantly different from other treatments and followed by T_4 whereas the lowest stover yield (4.49 t ha^{-1}) was recorded from the plant spacing T_{15} which was statistically similar to T_{12}. Hasan *et al.* (2018) also found similar result with the present study.

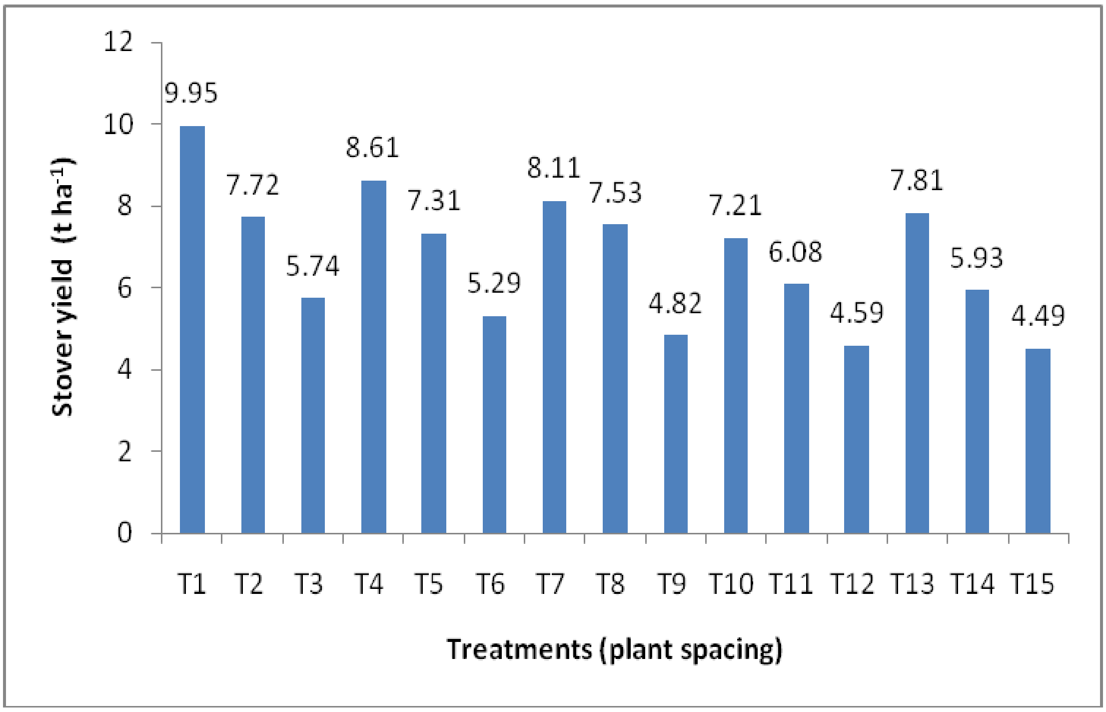

Fig. 8. Stover yield of maize as influenced by different plant spacing ($LSD_{0.05}$ = 0.37)

4.3.3 Biological yield

There was a significant variation on biological yield as influenced by different plant spacing (Fig. 9 and Appendix XII). Results indicated that the highest biological yield (16.45 t ha^{-1}) was recorded from the plant spacing T_1 which was significantly different from other treatments and followed by T_4 and T_7 whereas the lowest biological yield (8.59 t ha^{-1}) was recorded from the plant spacing T_{12} which was statistically similar to T_{15}.

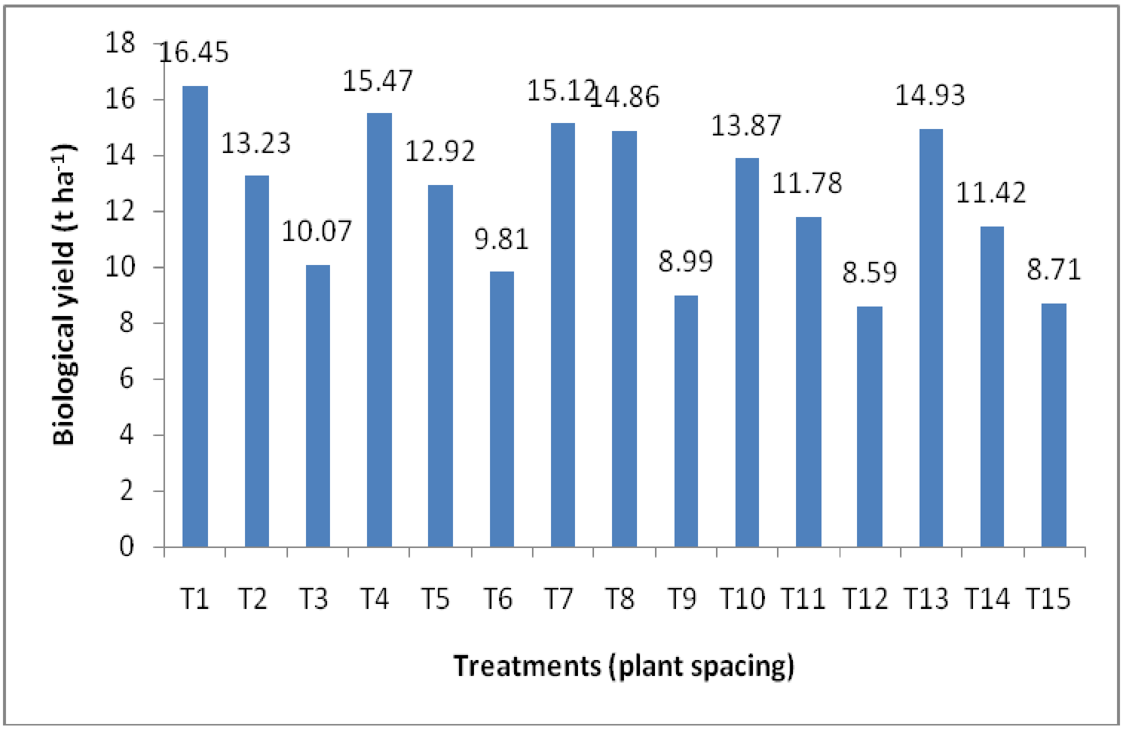

Fig. 9. Biological yield of maize as influenced by different plant spacing ($LSD_{0.05}$ = 0.41)

4.3.4 Harvest index

There was a significant variation on harvest index as influenced by different plant spacing (Fig. 10 and Appendix XII). Results indicated that the highest harvest index (49.33%) was recorded from the plant spacing T_8 which was similar to T_{11}, T_{15} and followed by T_{14} whereas the lowest harvest index (39.53%) was recorded from the plant spacing T_1 which was significantly different from other treatments. Zeleke *et al*. (2018) and Rahman *et al*. (2016) also found similar result with the present study.

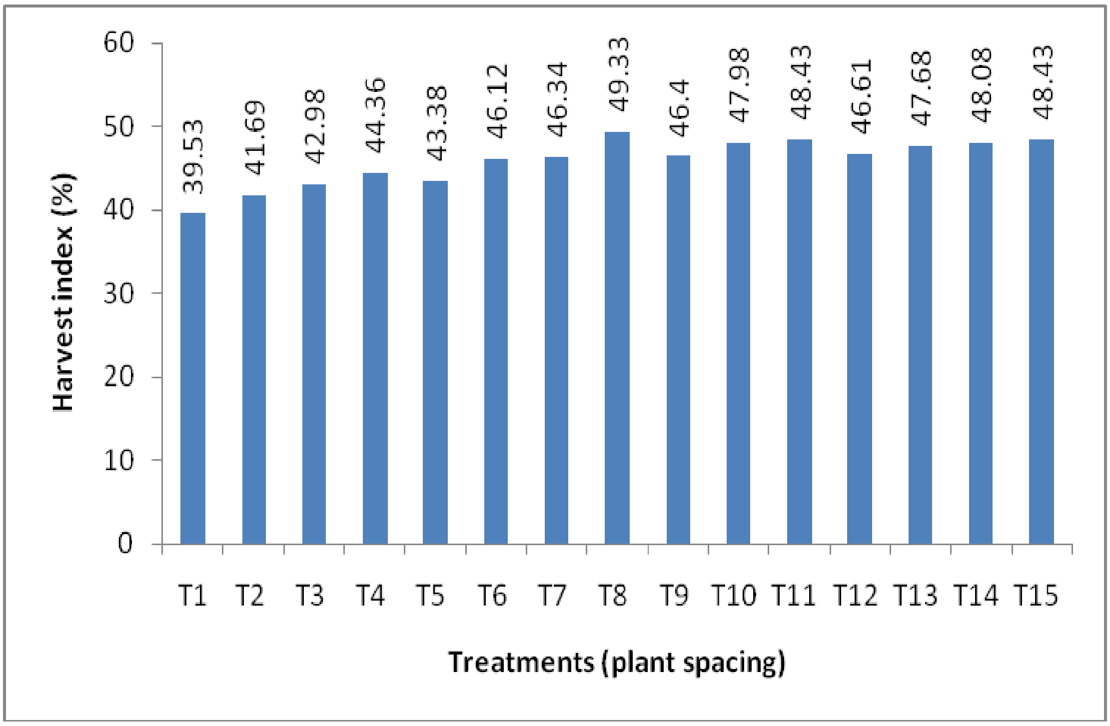

Fig. 10. Harvest index (%) of maize as influenced by different plant spacing ($LSD_{0.05}$ = 1.07)

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was conducted at the Agronomy Field of Sher-e-Bangla Agricultural University farm, in Kharif season during March to June, 2019 with a view to find out the growth and yield performance of a short stature early white maize under varying inter row and intra plant spacing.. The experiment was carried out in Randomized Complete Block Design (RCBD) with 3 replications having fifteen (15) plant spacings. The plant spacings were T_1 = 40 cm × 15 cm, T_2 = 40 cm × 20 cm, T_3 = 40 cm × 25 cm, T_4 = 45 cm × 15 cm, T_5 = 45 cm × 20 cm, T_6 = 45 cm × 25 cm, T_7 = 50 cm × 15 cm, T_8 = 50 cm × 20 cm, T_9 = 50 cm × 25 cm, T_{10} = 55 cm × 15 cm, T_{11} = 55 cm × 20 cm, T_{12} = 55 cm × 25 cm, T_{13} = 60 cm × 15 cm, T_{14} = 60 cm × 20 cm and T_{15} = 60 cm × 25 cm. The data on crop growth characters like plant height, number of leaves plant^{-1}, dry mater weight plant^{-1}, leaf length and breadth , tassel length etc. were recorded as well as yield contributing characters like number of grains cob^{-1}, cob length, cob diameter, number of grains cob^{-1}, 100-grain weight etc. and also yield and yield characters were recorded. Collected data were analyzed statistically using the MSTAT-C computer package program. The mean differences among the treatments were compared by DMRT at 5% level of significance. Different plant spacing showed significant variation on different growth, yield contributing characters and yield characters of the studied parameters.

In terms of growth parameters, results revealed that the highest plant height (182.40 cm) and tassel length (32.43 cm) at harvest were recorded from T_2 and T_8, respectively, whereas the lowest plant height (117.50 cm) and tassel length (24.27 cm) were found from T_{14} and T_1, respectively. Similarly, the highest average leaf length (71.56 cm), leaf breadth (6.59 cm) and leaf area plant^{-1} (365.10 cm^2) was recorded from T_{13} whereas the lowest average leaf length (39.60 cm), leaf breadth (4.69 cm) and leaf area plant^{-1} (207.80 cm^2) were recorded from T_1. Again, the highest cob leaf length (72.83 cm), cob leaf breadth (8.50 cm) and cob leaf area (676.00 cm^2) was recorded from T_{15} whereas the lowest cob leaf length (56.00 cm), cob leaf breadth (6.10 cm) and cob leaf area (343.30 cm^2) were recorded from the plant spacing T_1. Regarding dry matter content at vegetative stage, the highest at below cobs-node, cob-node and above cob-node (19.19, 13.57 and 10.41 g $plant^{-1}$, respectively) was recorded from the treatment T_8 whereas the lowest (10.79, 9.45 and 15.46 g $plant^{-1}$, respectively) was found from the treatment T_1. Similarly, dry matter content at harvest, the highest at below cobs-node, cob-node and above cob-node (21.12, 10.55 and 12.93 g $plant^{-1}$, respectively) was recorded from the treatment T_8 whereas the lowest (9.47, 5.87 and 7.61 g $plant^{-1}$, respectively) was found from the treatment T_1.

In case of yield contributing parameters, the highest cob length $plant^{-1}$ (14.00 cm), cob breadth $plant^{-1}$ (13.58 cm) and number of grains cob^{-1} (260.57 g) were recorded from the plant spacing T_{14} while the highest 100 grain weight (26.88 g) and grain weight cob^{-1} (68.74 g) were recorded from the plant spacing T_8 whereas the highest shell weight cob^{-1} (16.68 g) and chaff weight cob^{-1} (8.81 g) were recorded from the plant spacing T_{13}. On the other hand, the lowest cob length $plant^{-1}$ (11.80 cm), cob breadth $plant^{-1}$ (10.13 cm), 100 grain weight (20.39 g), grain weight cob^{-1} (36.57 g), shell weight cob^{-1} (10.81 g) and chaff weight cob^{-1} (4.17 g) were recorded from the plant spacing T_1 while the lowest number of grains cob^{-1} (170.55 g) was recorded from the plant spacing T_3.

In terms of yield parameters the highest grain yield (7.33 t ha^{-1}) and harvest index (49.33%) were recorded from the plant spacing T_8 but the highest stover yield (9.95 t ha^{-1}) and biological yield (16.45 t ha^{-1}) were recorded from the plant spacing T_1. On the other hand, the lowest grain yield (4.01 t ha^{-1}) and biological yield (8.59 t ha^{-1}) were recorded from T_{12} whereas the lowest stover yield (4.49 t ha^{-1}) and harvest index (39.53%) was recorded from T_{15} and T_1, respectively.

From the above result it can be summarized that closer spacing or higher planting density (lower number of plant population per unit area) showed better performance in terms of per plant yield and other growth parameters but at lower plant spacing (higher population density), ha^{-1} yield was better than higher spacing. With this respect, results showed that the highest number of grains cob^{-1} (260.57) was found from T_{14} while the highest grain weight cob^{-1} (68.74 g) and 100 seed weight (26.88 g) were found from T_8. Likewise, the lowest number of grains cob^{-1} (170.55) and grain weight cob^{-1} (36.57 g) was found from the treatment T_3 and T_1, respectively. Again, the highest grain yield (7.33 t ha^{-1}) was found from the plant spacing T_8 whereas the lowest grain yield (4.01 t ha^{-1}) was found from the treatment T_{12}. From the above findings, it can be concluded that the treatment T_8 showed highest grain yield (7.33 t ha^{-1}) and harvest index (49.33%).

So, this treatment T_8 (plant spacing) can be considered as the best compared to other plant spacing. This research work should be conducted to other cropping region of Bangladesh to choose optimum planting population , minimizing production cost and maximizing yield compared to yellow maize cultivation . Finally, it is recommended that all the research activities should be done considering the farmers financial condition and requirements .

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

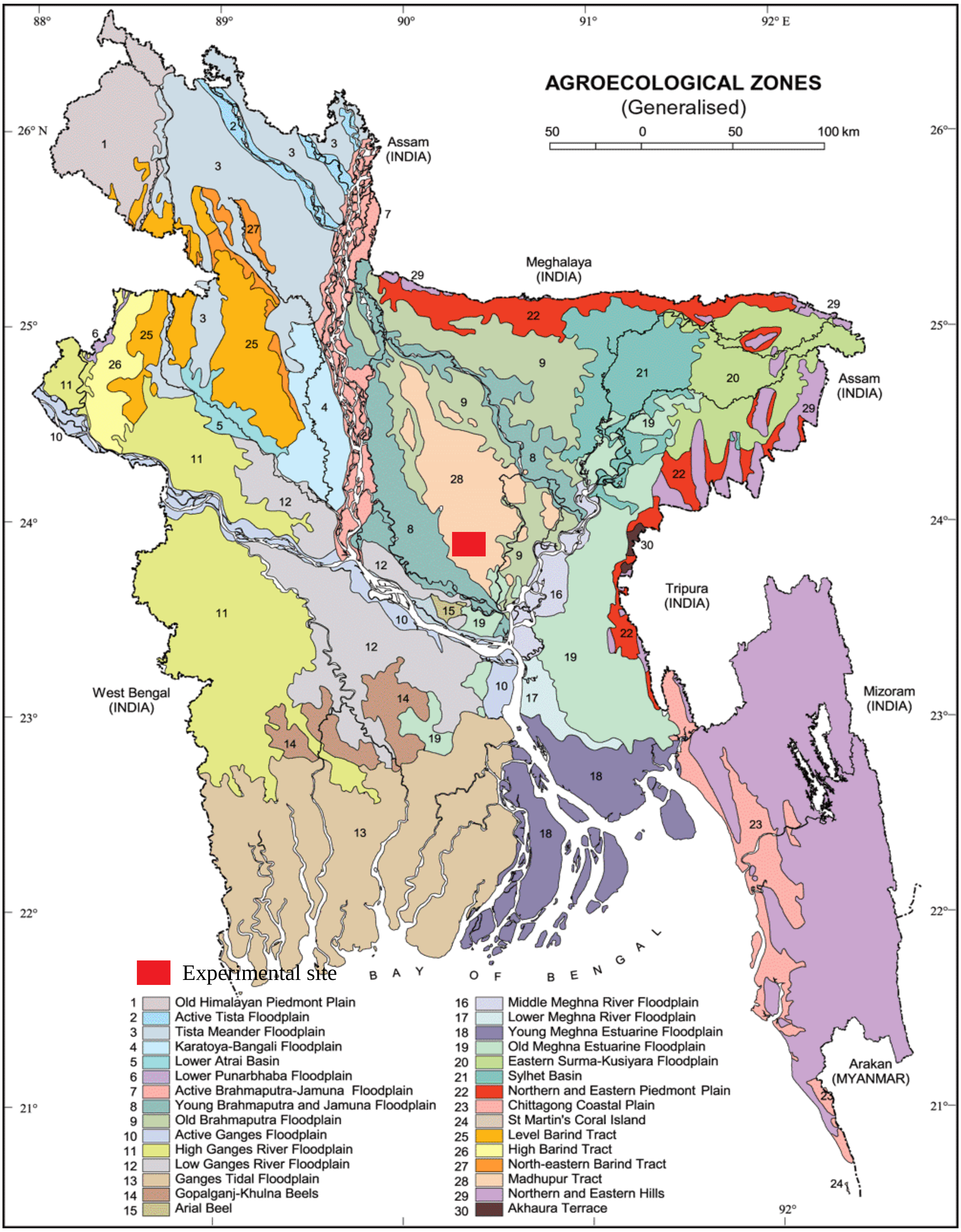


Fig. 11. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during March 2018 to June 2019.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2018	March	35.20	21.00	28.10	52.44	20.4
2018	April	34.70	24.60	29.65	65.40	165.0
2018	May	32.64	23.85	28.25	68.30	182.2
2018	June	27.40	23.44	25.42	71.28	190

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

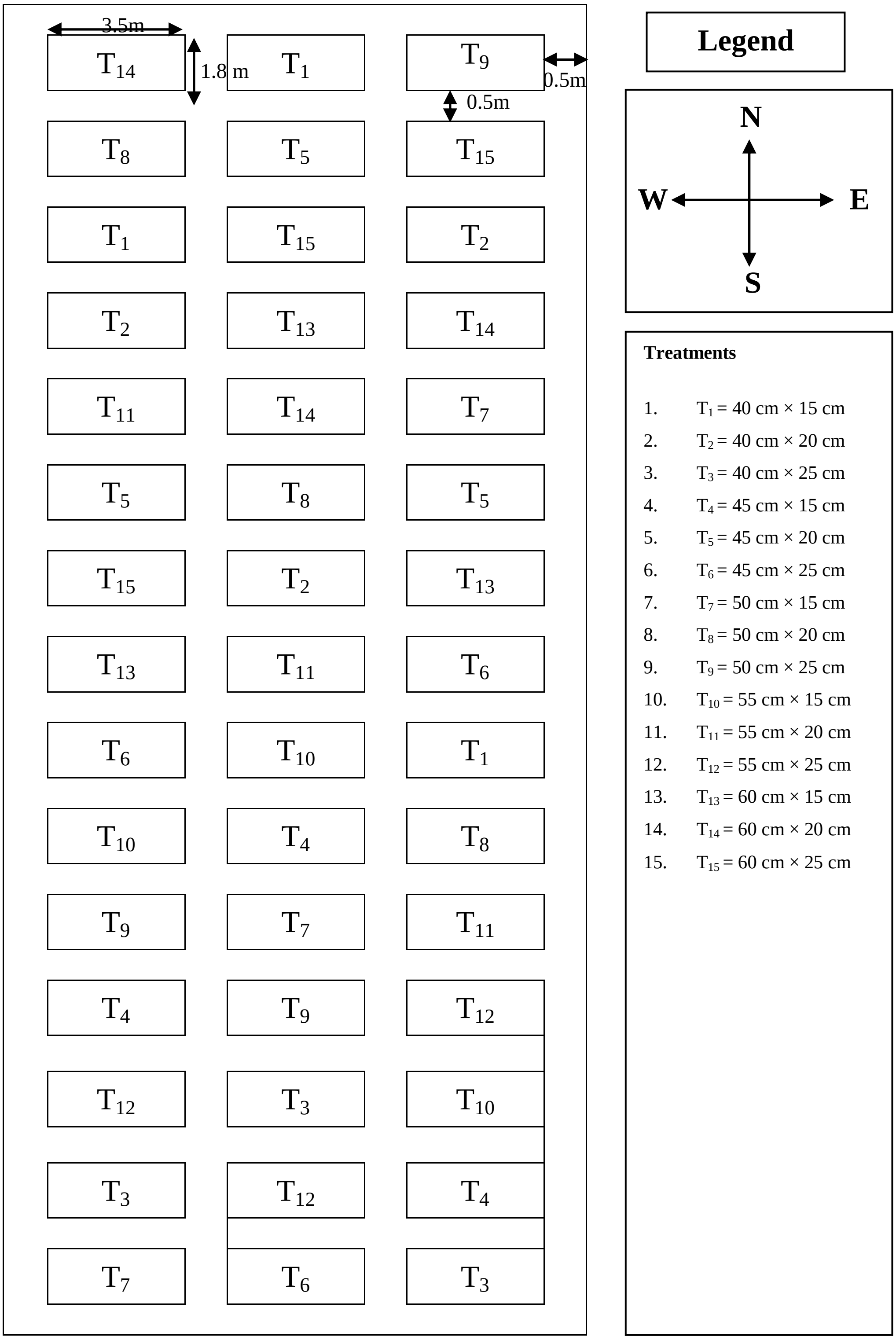
Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)



Treatments

1. T_1 = 40 cm × 15 cm
2. T_2 = 40 cm × 20 cm
3. T_3 = 40 cm × 25 cm
4. T_4 = 45 cm × 15 cm
5. T_5 = 45 cm × 20 cm
6. T_6 = 45 cm × 25 cm
7. T_7 = 50 cm × 15 cm
8. T_8 = 50 cm × 20 cm
9. T_9 = 50 cm × 25 cm
10. T_{10} = 55 cm × 15 cm
11. T_{11} = 55 cm × 20 cm
12. T_{12} = 55 cm × 25 cm
13. T_{13} = 60 cm × 15 cm
14. T_{14} = 60 cm × 20 cm
15. T_{15} = 60 cm × 25 cm

Appendix IV. Layout of the experimental plot

Appendix V. Plant height and tassel length of maize as influenced by different plant spacing

Sources of variation	Degrees of freedom		
		Plant height at harvest (cm)	Tassel length at harvest (cm)
Replication	2	10.065	4.035
Factor A	4	589.317*	14.888**
Error	14	16.838	5.790

NS = Non-significant * = Significant at 5% level of significance, ** = Significant at 1% level of significance

Appendix VI. Leaf length, breadth and area of maize as influenced by different plant spacing

Sources of variation	Degrees of freedom	Average Leaf length, breadth and area		
		Average leaf length plant^{-1} (cm)	Average leaf breadth plant^{-1} (cm)	Average leaf area plant^{-1} (cm)
Replication	2	3.021	3.196	16.102
Factor A	4	218.37*	0.937**	1523.95*
Error	14	10.316	0.656	24.121

NS = Non-significant * = Significant at 5% level of significance,**= Significant at 1% level of significance

Appendix VII. Cob leaf length, breadth and area of maize as influenced by different plant spacing

Sources of variation	Degrees of freedom	Cob leaf length, breadth and area		
		Cob leaf length (cm)	Cob leaf breadth (cm)	Cob leaf area (cm)
Replication	2	3.643	0.553	10.176
Factor A	4	92.48*	55.91 **	1636.72*
Error	14	6.842	1.910	16.190

NS = Non-significant * = Significant at 5% level of significance, **= Significant at 1% level of significance

Appendix VIII. Shoot dry weight plant^{-1} of maize at vegetative stage as influenced by different plant spacing

Sources of variation	Degrees of freedom	Shoot dry weight (g)		
		At lower unit	At cob unit	At upper unit
Replication	2	1.997	5.922	1.675
Factor A	4	23.63*	14.216**	13.166**
Error	14	0.949	7.459	0.184

NS = Non-significant * = Significant at 5% level of significance,**= Significant at 1% level of significance

Appendix IX. Dry weight plant^{-1} of maize as influenced by different plant spacing

Sources of variation	Degrees of freedom	Plant dry weight (g)		
		Plant dry weight at below cob unit	Plant dry weight at cob unit	Plant dry weight at upper cob unit
Replication	2	3.132	2.782	5.288
Factor A	4	28.286*	4.139**	7.410*
Error	14	3.580	1.911	4.861

NS = Non-significant * = Significant at 5% level of significance,**= Significant at 1% level of significance

Appendix X. Cob length and breadth of maize as influenced by plant spacing

Sources of variation	Degrees of freedom	Cob length and breadth	
		Cob length (cm)	Cob breadth (cm)
Replication	2	3.671	3.496
Factor A	4	78.529*	100.80**
Error	14	3.144	2.506

NS = Non-significant * = Significant at 5% level,**= Significant at 1% level

Appendix XI. Yield contributing parameters and yield of maize as influenced by plant spacing

Sources of variation	Degrees of freedom	Yield and yield contributing parameters				
		100 grain weight (g) 3	Number of gains per cob 7	Grain weight cob^{-1} (g) 4	Shell weight cob^{-1} (g) 5	Chaff weight cob^{-1} (g) 6
Replication	2	2.518	10.239	8.049	8.343	3.018
Factor A	4	9.228*	883.939*	184.171*	11.525*	4.294**
Error	14	1.056	12.578	10.808	4.495	2.749

NS = Non-significant * = Significant at 5% level of significance, ** = Significant at 1% level of significance

Appendix XII. Yield parameters of maize on grain yield ha^{-1}, stover yield ha^{-1}, biological yield ha^{-1} and harvest index as influenced by different plant spacing

Sources of variation	Degrees of freedom	Yield parameters			
		Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.114	0.237	0.471	0.386
Factor A	4	7.362*	10.369*	11.479*	13.052*
Error	14	1.056	1.133	1.089	0.756

NS = Non-significant * = Significant at 5% level of significance,** = Significant at 1% level of significance