GROWTH, YIELD ATTRIBUTES AND YIELD OF A MAIZE GENOTYPE SAUWMOP DT61G UNDER DIFFERENT PLANTING CONFIGURATIONS IN RABI SEASON

ESTIAK AHMMED

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

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BY
ESTIAK AHMMED

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Approved by:

Dr.Md.Jafar Ullah	**Dr.Tuhin Suvra Roy**
Professor	**Professor**
Supervisor	**Co-supervisor**

Prof. 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 thesis entitled "Growth, Yield Attributes and yield of a Maize Genotype SAUWMOP DT61G Under Different Planting Configurations in Rabi season "submitted to the 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 bona-fide research work carried out by* ***ESTIAK AHMMED*** *REGISTRATION no.* ***13-05433*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Date:
Place: Dhaka, Bangladesh

Dr.Md.Jafar Ullah
Professor
Department of Agronomy
Sher-e-Bangla Agricultural University,

Dhaka-1207

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GROWTH, YIELD ATTRIBUTES AND YIELD OF A MAIZE GENOTYPE SAUWMOP DT61G UNDER DIFFERENT PLANTING CONFIGURATIONS IN RABI SEASON

By

ESTIAK AHMMED

ABSTRACT

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2018 to February, 2019 in Rabi season. The white maize genotype SAUWMOP DT61G was examined under different planting configurations. The experiment comprised two factors, A: five levels of row spacing R1(40 cm), R2(45 cm), R3 (50 cm), R4(55 cm) and R5(60 cm) and B: three levels of plant-to-plant spacing in a row P1(15 cm, P2(20 cm), and P3(25 cm). The experiment was laid out in Randomized Complete Block Design (RCBD) and each treatment combination was tested using three replications. Both the row to spacing and plant-to-plant spacing along with their combination had significant effects on the plant attributes. The treatment combination 60 cm × 15 cm spacing (R5P1) showed the tallest plant (144.60 cm). The highest number of plant (16.62 m−2), maximum leaf area plant−1 (2345.00 cm2) and maximum biomass (18.59 t ha−1) was observed in 40 cm × 15 cm spacing (R1P1). The 60 cm × 25 cm combination treatment had the highest grain wt/ha (10.98) which was attributed to the highest values of no. of grain/cob (489.60), Wt./cob (104.60), grain wt./cob (78.40 g), cob length (16.55 cm), cob girth (15.00cm), cob dry wt./plant (89.92 g), stover dry wt./plant (64.00 g), root dry wt./plant (14.64 g) and total dry wt./plant (168.60 g) obtained from this treatment. However, the yield of the 60 cm × 20 cm combination treatment (10.64 t/ha) was not significantly lower than that of the 60 cm × 25 cm combination treatment. So, to reduce the seed cost, the combination treatments 60 cm × 25 cm may be used for higher profit.

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LIST OF ABBREVIATIONS

AEZ	Agro-Ecological Zone
Anon.	Anonymous
AIS	Agriculture Information Service
BARC	Bangladesh Agricultural Research Council
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BNNC	Bangladesh National Nutrition Council
BRRI	Bangladesh Rice Research Institute
CRRI	Central Rice Research Institute
CV %	Percent Coefficient of Variance
cv	Cultivar (s)
DAT	Days After Transplanting
DRR	Directorate of Rice Research
eds.	Editors
et al.	et alii (and others)
etc.	et cetera (and other similar things)
FAO	Food and Agricultural Organization
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
IRRI	International Rice Research Institute
L.	Linnaeus
LSD	Least Significant Difference
i.e.	id est (that is)
MoP	Muriate of Potash
NPTs	New Plant Types
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
TDM	Total Dry Matter
TSP	Triple Super Phosphate
UNDP	United Nations Development Programme
var.	Variety
viz.	Namely

CHAPTER I

INTRODUCTION

Maize (*Zea mays* L.) is the world's widely grown highland cereal and primary staple food crop in many developing countries (Kandil, 2013). It was originated in America and first cultivated in the area of Mexico more than 7,000 years ago, and spread throughout North and South America (Hailare, 2000). This cereal crop belongs to the family Poaceae. It is a typical monoecious plant highly cross-pollinated (95%), self-pollination may reach up to 5% (Poehlman and Sleper, 1995). It has very high yield potential, there is no cereal on the earth, which has so immense potentiality and that is why it is called "Queen of cereals" (FAO, 2002). It ranks 1^{st} in respect of yield per unit area, 2^{nd} in respect total production and 3^{rd} after wheat and rice in respect of acreage in cereal crops (Zamir *et al.*, 2013).

Maize is grown as a fodder, feed and food crop. It is also used as raw material for manufacturing pharmaceutical and industrial products. Wheat, rice and maize are the most important cereal crops in the world but maize is the most popular due to its high yielding, easy of processing, readily digested and costs less than other cereals (Jaliya *et al*., 2008). Because of its variable use in agro-industries, it is recognized as a leading commercial crop of great agro-economic value. Maize as a major source of carbohydrate is used as human food in different forms; in the textile industry. Maize grain contains 70% carbohydrate, 10% protein, 4% oil, 10.4% albumin, 2.3% crude fiber, 1.4% ash (Nasim *et al*., 2012). Moreover, it contains 90 mg carotene, 1.8 mg niacin, 0.8 mg thiamin and 0.1 mg riboflavin per 100 g grains (Chowdhury and Islam, 1993). In advanced countries, it is an important source of many industrial products such as corn sugar, corn oil, corn flour, starch, syrup, brewer's grit and alcohol (Dutt, 2005).Corn oil is used for salad, soap-making and lubrication. Maize oil is used as the best quality edible oil. So that it is more balanced nutritionally and agriculturally small quantity grains are currently used for livestock as well as poultry feed and this is expected to increase with the development of the livestock and poultry production enterprise in the country.Maize is a major component of livestock feed and it is palatable to poultry, cattle and pigs as it supplies them energy (Iken *et al*., 2001). The stalk, leaves, grain and immature ears are cherished by different species of livestock (Dutt, 2005).

Its world average yield is 27.80 q ha^{-1} maize ranks first among the cereals and is followed by rice, wheat, and millets, with average grain yield of 22.5, 16.3 and 6.6 q ha^{-1}, respectively (Nasim *et al*., 2012). Introduction of maize in Bangladesh as human food can be a viable alternative for sustaining food security as the productivity of maize much higher than riceand wheat (Ray *et al.*, 2013). It provides many of the B vitamins and essential minerals along with fibre, but lacks some other nutrients, such as vitamin $B_{12}$and vitamin C. People in many developed and developing countries produce and consume maize as staple food. Maize has been a recent introduction in Bangladesh. Rice maize cropping system has been expanded (Timsina *et al.*, 2010) rapidly in the northern districts of Bangladesh mainly in response to increasing demand for poultry feed (BBS, 2016). Maize production of Bangladesh increased from 3,000 tons in 1968 to 3.03 million tons in 2017growing at an average annual rate of 28.35 % (FAO, 2019).

There are two kinds of maize in respect of grain colour; yellow and white. Worldwide, the yellow maize is mainly used as fodder while the white ones are mainly consumed as human food (FAO, 2002). The currently grown maize in Bangladesh is yellow type, which is mainly adapted importing genetic materials from CIMMYT. Again, although there are some indigenous local maize in the southeast hills, those are not high yielding (Ullah *et al.*, 2016). World production of white maize is currently estimated to be around 65 to 70 million tons. Among the individual geographical regions of the developing countries, white maize production has a paramount importance in Bangladesh. The major producers are the United States, Brazil, France, India and Italy. The main white maize producers in Africa include Kenya, Tanzania, Zambia and Zimbabwe (Kidist, 2013).

Maize currently grown in Bangladesh is of yellow type and is used in the feed industry. White maize covers only 12% of the total acreage of the world, which is mostly used as human food (FAO-CIMMYT, 1997). During 1970s, the productivity of grown white maize was lower compared to those of yellow ones. With the advanced breeding approaches, worldwide, recent reports demonstrate that the yield productivity of white maize is almost at par with those of the yellow ones (Akbar *et al.*, 2016). Bangladesh Agricultural Research Institute (BARI) has developed seven open pollinated and 11 hybrid varieties whose yield potentials are 5.50–7.00 t ha^{-1} and 7.40–12.00 t ha^{-1}, respectively, which are well above the world average of 3.19 t ha^{-1} (Nasim *et al*., 2012).

In general, the yield productivity of any crop in this country is low which is generally attributed to the poor agronomic management. There are a number of well recognized biotic and abiotic factors like improved varieties, irrigation, sowing time, plant population and balanced use of fertilizers each has an effective role in enhancing the yield of crop. Among the agronomic managements, setting optimum population density using the correct planting configuration are important agronomic operations. Potential higher yields of modern hybrids obtainable with higher population encouraged planting maize at narrower spacing (Khan *et al.*, 2005). In Bangladesh, a population density of 83,000 planted in rows at 60 cm x 20 cm configuration gave the highest grain yield. Optimum plant density, however, depends largely on genotype, season, available growth resources and agronomic management conditions significantly (Khan *et al.*, 2005).

Plant density is one of the most important cultural practices determining grain yield, as well as other important agronomic attributes of this crop (Sangoi, 2001). Stand density affects plant architecture, alters growth and developmental patterns and influences carbohydrate production and partition (Casal, 1985).

Maize is more sensitive to variations in plant density than other members of the grass family (Almeida and Sangoi, 1996). This may be detrimental to final yield because it stimulates apical dominance, induces barrenness, and ultimately decreases the number of ears produced per plant and kernels set per ear (Sangoi and Salvador, 1998). Narrow rows make more efficient use of available light and shade the surface soil more completely during the early part of the season while the soil is still moist (Bullock *et al*., 1998). Maize grain yield declines when plant density is increased beyond the optimum plant density primarily because of decline in the harvest index and increased stem lodging (Tollenaar *et al*., 1997).

Such cases represent intense interplant competition for incident photosynthetic photon flux density, soil nutrients and soil water. The grain yield per plant is decreased in response to decreasing light and other environmental resources available to each plant (Ali *et al*., 2003). Stand density affects plant architecture, alters growth and developmental patterns and influences carbohydrate production. At low densities, many modern maize varieties do not tiller effectively and quite often produce only one ear per plant. Whereas, the use of high population increases interplant competition for light, water and nutrients, which may be detrimental to final yield because it stimulates apical dominance, induces barrenness, and ultimately decreases the number of ears produced per plant and kernels set per ear (Sangoi, 2001). In dense population most plants remain barren ear and ear size remain smaller, crop become susceptible to lodging, disease and pest, while plant population at sub-optimum level resulted lower yield per unit area (Nasir, 2000). High plant population leads to lodging of maize plants (Trenton and Joseph, 2007). In case of low plant density, yield per unit area is reduced because of lesser than optimum plants (Cardwell, 1982).This results in limited supplies of carbon and nitrogen and consequent increases in barrenness and decreases in kernel number per plant and kernel size (Lemcoff and Loomis, 1994). One of the major factors limiting optimum conversion of light energy to grain in maize grown at high plant densities is barrenness, the failure of plants to produce viable ears (Sangoi, 1996).

Vega *et al.* (2001) and (Luque *et al.*, 2006) reported that other member of the grass family, maize differs in its responses to plant density. Optimum plant population is the prerequisite for obtaining maximum yield (Trenton and Joseph 2007; Gustavo *et al*., 2006). Liu *et al*. (2004) also reported that maize yield differs significantly under varying plant density levels due to difference in genetic potential. Correspondingly, maize also responds differently in quality parameters like crude starch, protein and oil contents ingrains (Munamava *et al*., 2006). Plant populations affect most growth parameters of maize even under optimal growth conditions and therefore it is considered a major factor determining the degree of competition between plants (Sangakkara *et al*., 2004).

Plant population and row width determine light interception and consequently photosynthesis and yield (Stewart *et al*., 2003). Papadopoulos and Pararajasingham (1997) noted that it is possible to manipulate plant spacing to maximize light interception in any crop. Nafziger (2006) observed that, within the normal range of crop population, the increase in crop yield from increasing plant population is related to the increase in light interception. Zhang *et al*. (2008) reported that the best distribution of light is attained in systems with narrow strips and high plant densities. Increasing plant density through narrow row planting of maize could increase light interception and consequently increase grain yield. However, little attempt has been made to explain the relationship and interaction between these factors and the resulting effects on maize grain yield. Keeping this in view, the present study was formulated under following

Objectives:

1. To evaluate the growth and yield performance of white maize genotype SAUWMOP DT61G under varying row to row spacing

2. To evaluate the growth and yield performance of white maize genotype SAUWMOP DT61G under varying plant to plant spacing

3. To find out the optimum row to row and plant to plant spacing of white maize genotype SAUWMOP DT61G for obtaining the highest productivity

CHAPTER II

REVIEW OF LITERATURE

Plant spacing has a significant role to play for proper growth and yield of plant. From agronomic point of view, spacing for modern maize cultivation has become an important issue. An attempt was made in this section to collect and study relevant information available in the country and abroad to gather knowledge helpful in conducting the present research work and subsequently writing up the result and discussion. Some of the important and informative works and research findings so far been done at home and abroad on regarding the influence of planting configuration on the growth and yield of white maize have been reviewed in this chapter under the following headings and sub-headings:

2.1 Review of Planting Configuration

2.1.1 Review on Growth Parameters

2.1.1.1 Plant height

Ahmmed (2018) conducted an experiment to evaluate the performance of white maize variety under different spacings and integrated fertilizer management. The experiment comprised two different factors: (1) two different plant spacings viz. All chemical fertilizer (recommended dose), : maize straw compost + ½ of recommended dose, Cowdung + ½ of recommended dose and vermicompost + ½ of recommended dose. In respect of the spacing effect, the wider spacing showed the highest plant height.

Hasan *et al.* (2018) conducted an experiment to investigate the effect of variety and plant spacing on yield attributes and yield of maize. The experiment comprised of 5 varieties *viz.*, Khoibhutta, BARI hybrid maize 7, BARI hybrid

Ukonze *et al.* (2016) carried out a study to compare and analyse how spacing influenced the performance and yield of late maize. One maize variety was evaluated under three spacing for performance data such as plant heights, stem girths, number of leaves, number of nodes and leaf area and for the yield, data were collected on cob length, cob weight, cob + husk weight, cob circumference and 1000-grain weight (yield). The results obtained 56 days after planting (DAP) in the two years of study showed significant differences ($p < 0.05$) in plant height. morphological parameters.

Mechi (2015) conducted a field experiment to assess the response of maize hybrid variety “BH-661” to nitrogen (N) fertilizer and inter row spacing. The experiment comprised of two-factor *viz.*, four levels of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and four inter row spacing (55, 65, 75 and 85 cm). Result revealed that, the tallest plant (291.7 cm) was recorded from inter row spacing 85 cm and the shortest plant (240.7 cm) was recorded from inter row spacing 55 cm.

Enujeke (2013 a) carried out a field study to evaluate the effects of variety and spacing on growth characters of hybrid maize. Three hybrid maize varieties were evaluated under three different plant spacing for growth characters like plant height, number of leaves, leaf area and stem diameter. Result revealed that the tallest plant 176.7 cm was recorded from plants sown in and the shortest one 152.7 cm was recorded from plants sown in spacing.

Jula*et al*. (2013) conducted a field experiment to evaluate the effects of various intra-row spaces on the growth and yield of maize intercropped into ginger. The experiment consisted of six treatments.

Shafi *et al.* (2012) conducted an experiment to investigate the effect of planting density on plant growth and yield of maize varieties. The experiment consist of four maize varieties viz., Azam, Pahari, Jalal-2003 and Sarhad white as main plot factor and three plant densities of 45000, 55000 and 65000 plants ha^{-1} as sub-plot factor. Result showed that the tallest maize plant was recorded from the treatment of 65,000 plants ha^{-1}. The shortest plant was attained by 45,000 plants ha^{-1}.

Jiotode *et al.* (2002) conducted a field experiment with Maize cv. AMC-1 (Akola Maize Composite-1) to evaluate its growth responses and water use influenced under varying irrigation levels at 40, 60 or 80 mm CPE and irrigation as per the critical growth stages of the crop; and three row spacing of 30, 45 and 60 cm. Plant height was the highest at the 30-cm row spacing.

Asafu-Agyei (1990) conducted four field studies to determine the effect of seven planting densities on grain yield of three maize varieties differing in maturity: early, medium and full season.

2.1.1.2 Number of leaves plant^{-1}

Ahmmed (2018) conducted an experiment to evaluate the performance of white maize variety under different spacings and integrated fertilizer management. viz.: All chemical fertilizer (recommended dose), T_2: maize straw compost + ½ of recommended dose, T_3: Cowdung + ½ of recommended dose and T_4: vermicompost + ½ of recommended dose. In respect of the spacing effect, the wider spacing R_1 showed the highest number of leaves plant^{-1}.

Enujeke (2013) carried out a study to evaluate the effects of variety and spacing on growth characters of hybrid maize. Three hybrid maize varieties were evaluated under three different plant spacing for growth characters as plant height, number of leaves, leaf area and stem girth.

Jula*et al*. (2013) carried out a field experiment to evaluate the effects of various intra-row spacing on the growth and yield of maize intercropped into ginger.

Jiotode *et al.* (2002) conducted a field experiment with Maize cv. AMC-1 (Akola Maize Composite-1) to evaluate its growth responses and water use influenced under varying irrigation levels at 40, 60 or 80 mm CPE and irrigation as per the critical growth stages of the crop; and three row spacing of 30, 45 and 60 cm. A row spacing of 60 cm was recorded to provide the highest number of leaves per plant.

Dalvi (1984) conducted a field experiment to study the effect of various spacings and nitrogen levels on growth, yield and quality of two varieties of maize (*Zea mays* L.) during Rabi season.

2.1.1.3 Leaf area

Ukonze *et al.* (2016) carried out a study to compare and analyse how spacing influenced the performance and yield of late maize. One maize variety was evaluated under three spacing for performance data such as plant heights, stem girths, number of leaves, number of nodes and leaf area and for the yield, data were collected on cob length, cob weight, cob + husk weight, cob circumference and 1000-grain weight (yield). The results obtained 56 days after planting (DAP) in the two years of study showed significant differences ($p < 0.05$) in leaf area.

Mechi (2015) conducted a field experiment to assess the response of maize hybrid variety “BH-661” to nitrogen (N) fertilizer and inter row spacing. The experiment was arranged in a factorial combination of four levels of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and four inter row spacing . Result revealed that, the maximum leaf area index (LAI) (3.38) was recorded from inter row spacing 85 cm and the minimum LAI (2.85) was recorded from inter row spacing 55 cm.

Enujeke (2013 a) carried out a study to evaluate the effects of variety and spacing on growth characters of hybrid maize. Three hybrid maize varieties were evaluated under three different plant spacing for growth characters as plant height, number of leaves, leaf area and stem girth.

Jula*et al*. (2013) carried out a field experiment to evaluate the effects of various intra-row spacing on the growth and yield of maize intercropped into ginger.

Shafi *et al.* (2012) conducted an experiment to investigate the effect of planting density on plant growth and yield of maize varieties. The experiment consist of four maize varieties viz., Azam, Pahari, Jalal-2003 and Sarhad white as main plot factor and three plant densities of 45000, 55000 and 65000 plants ha^{-1} as sub-plot factor. Results indicated that highest leaf area index was observed in planting density of 65,000 plants ha^{-1} and the lowest LAI was observed in planting density of 45,000 plants ha^{-1}.

Abuzar*et al*. (2011) conducted a field experiment to determine the effect of plant population densities on maize. They reported that the treatments having plant population of 120,000 and 140,000 plants ha^{-1} produced higher LAI of 2.77 and 2.52, respectively. The lowest LAI was obtained with population of 40,000 plants ha^{-1}.

Jiotode *et al.* (2002) conducted a field experiment with Maize cv. AMC-1 (Akola Maize Composite-1) to evaluate its growth responses and water use influenced under varying irrigation levels at 40, 60 or 80 mm CPE and irrigation as per the critical growth stages of the crop; and three row spacing of 30, 45 and 60 cm. A row spacing of 60 cm was recorded to provide the highest leaf area per plant. Leaf area index was the maximum at the 30-cm row spacing.

Asafu-Agyei (1990) conducted four field studies to determine the effect of seven planting densities: plants ha^{-1} on grain yield of three maize varieties differing in maturity: early, medium and full season. Result revealed that, the maximum leaf area index (LAI) (3.00) was recorded from plants ha^{-1} and the minimum LAI (0.80) was from plants ha^{-1}.

2.1.1.4 Stem Diameter

Ukonze *et al.* (2016) carried out a study to compare and analyse how spacing influenced the performance and yield of late maize. One maize variety was evaluated under three spacing for performance data such as plant heights, stem girths, number of leaves, number of nodes and leaf area and for the yield, data were collected on cob length, cob weight, cob + husk weight, cob circumference and 1000-grain weight (yield). The results obtained 56 days after planting (DAP) in the two years of study showed significant differences ($p < 0.05$) in stem diameter.

Enujeke (2013 a) carried out a study to evaluate the effects of variety and spacing on growth characters of hybrid maize. Three maize hybrid varieties were evaluated under three different plant spacing for growth characters such as plant height, number of leaves, leaf area and stem diameter. Based on the findings of this study, it was recommended that spacing could be used to enhance increased stem girth and leaf area whose photosynthetic activities could positively influence maize yield.

2.1.1.5 Dry matter weight plant^{-1}

Jula *et al*. (2013) conducted a field experiment to evaluate the effects of various intra-row spacing on the growth and yield of maize intercropped into ginger.

Alvarez (2006) conducted a field experiment where the effects of row spacing (0.7 and 0.9 m) and plant density (55,000 and 75,000 plants ha^{-1}) on the performance of maize hybrids AG1051, AG9010 and DKB440 were determined. Dry matter weight increased with increasing sowing density and decreasing row spacing. The hybrid AG1051 was associated with the highest dry matter yield regardless of row spacing, whereas the hybrids AG9010 and DKB440 was associated with the highest grain yield regardless of planting density.

Jiotode *et al.* (2002) conducted a field experiment with Maize cv. AMC-1 (Akola Maize Composite-1) to evaluate its growth responses and water use influenced under varying irrigation levels at CPE and irrigation as per the critical growth stages of the crop; and three row spacing.

Dalvi (1984) conducted a field experiment to study the effect of various spacings and nitrogen levels on growth, yield and quality of two varieties of maize (*Zea mays* L.) during Rabi season.

2.1.1.6 Cob length

Ahmmed (2018) conducted an experiment to evaluate the performance of white maize variety under different spacings and integrated fertilizer management. In respect of the spacing effect, the wider spacing showed the highest cob length.

Nand (2015) conducted a field experiment to evaluate the effect of spacing and fertility levels on protein content and yield of hybrid and composite maize (*Zea mays* L.). Eighteen treatment combinations were involved. main plots were allotted to maize hybrid (DHM-117) and composite (Madhuri) along with three spacing. In addition, sub-plots were tested for three fertility levels *viz.*, F_1 - NPK and Zn of (120 : 60 : 40 and 15 kg ha^{-1}) F_2 - NPK and Zn of (160 : 80 : 60 and 20 kg ha^{-1}) and F_3 - NPK and Zn of (180 : 100 : 80 and 25 kg ha^{-1}).

Shafi *et al*. (2012) conducted a study to investigate the effect of planting density on plant growth and yield of maize varieties. The experiment consist of four maize varieties *viz*., Azam, Pahari, Jalal-2003 and Sarhad white with three plant densities of 45000, 55000 and 65000 plants ha^{-1}. Data indicated that planting density had a significant effect on cob length.

Fanadzo *et al.* (2010) conducted a study to determine the effects of inter-row spacing and plant population (40,000 and 60,000 plants ha^{-1})

on weed biomass and the yield of both green and grain materials of maize plants. Cob length decreased with increase in plant population and with wider rows.

Alvarez (2006) conducted a field experiment where the effects of row spacing (0.70 and 0.90 m) and plant density (55,000 and 75,000 plants ha^{-1}) on the performance of maize hybrids AG1051, AG9010 and DKB440 were determined. The hybrid AG1051 was associated with the maximum cob height regardless of row spacing treatments.

Sener (2004) conducted a two-year study to determine the optimum intra-row spacing for maize hybrids commercially grown in Eastern Mediterranean Region during 2000 and 2001 growing seasons. Maize hybrids reacted differently to various plant density and intra-row spacing. Main plots were assigned to maize hybrids *viz.*, Dracma, Pioneer 3223, Pioneer 3335, Dekalb 711 and Dekalb 626. Split-plots were assigned to intra-row spacing of 10.0, 12.5, 15.0, 17.5 and 20.0 cm. Hybrid × intra-row spacing interaction effects were significant in case of cob length.

Dalvi (1984) conducted a field experiment to study the effect of various spacings and nitrogen levels on growth, yield and quality of two varieties of maize (*Zea mays* L.) during Rabi season.

2.1.1.7 Cob Weight

Ukonze *et al.* (2016) carried out a study to compare and analyse how spacing influenced the performance and yield of late maize. One maize variety was evaluated under three spacing for performance data such as plant heights, stem girths, number of leaves, number of nodes and leaf area and for the yield, data were collected on cob length, cob weight, cob + husk weight, cob circumference and 1000-grain weight (yield). With regard to yield, 80 cm × 20 cm gave the highest average cob weight of 0.74 kg.

Nand (2015) conducted a field experiment to evaluate the effect of spacing and fertility levels on protein content and yield of hybrid and composite maize (*Zea mays* L.). Eighteen treatment combinations were involved. The main plots were allotted to maize hybrid (DHM-117) and composite (Madhuri) along with three spacing. In addition, sub-plots were tested for three fertility levels *viz.*, F_1 - NPK and Zn of (120 : 60 : 40 and 15 kg ha^{-1}) F_2 - NPK and Zn of (160 : 80 : 60 and 20 kg ha^{-1}) and F_3 - NPK and Zn of (180 : 100 : 80 and 25 kg ha^{-1}). The spacing of 60 cm × 20 cm significantly increased the cob weight (205.90 and 205.90 g) than the spacing respectively.

Fanadzo *et al.* (2010) conducted a study to determine the effects of inter-row spacing (45 and 90 cm) and plant population (40,000 and 60,000 plants ha^{-1}) on weed biomass and the yield of both green and grain materials of maize plants. Growing maize at 40,000 plants ha^{-1} resulted in similar green cob weight regardless of inter-row spacing.

2.1.1.8 Cob Circumference

Ahmmed (2018) conducted an experiment to evaluate the performance of white maize variety under different spacings and integrated fertilizer management.

Eyasu *et al.* (2018) conducted a field study with the objective of evaluating different varieties and row spacing on growth, yield and yield components of maize. Four plant row spacing and three maize varieties ('BH-540', Lemu 'P3812W' and Jabi 'PHB 3253') were tested. The results indicated that cob circumference was significantly influenced by the interaction effect of row spacing and varieties.

Hasan *et al.* (2018) conducted an experiment to investigate the effect of variety and plant spacing on yield attributes and yield of maize.

Nand (2015) conducted a field experiment to evaluate the effect of spacing and fertility levels on protein content and yield of hybrid and composite maize (*Zea mays* L.). In addition, sub-plots were tested for three fertility levels *viz.*, F_1 - NPK and Zn of (120 : 60 : 40 and 15 kg ha^{-1}) F_2 - NPK and Zn of (160 : 80 : 60 and 20 kg ha^{-1}) and F_3 - NPK and Zn of (180 : 100 : 80 and 25 kg ha^{-1}).

Dalvi (1984) conducted a field experiment to study the effect of various spacings and nitrogen levels on growth, yield and quality of two varieties of maize (*Zea mays* L.) during Rabi season.

2.1.1.9 Number of Cobs per Plant

Eyasu *et al.* (2018) conducted a field study with the objective of evaluating different varieties and row spacing on growth, yield and yield components of maize. Four plant row spacing (45 cm, 55 cm, 65 cm and 75 cm) and three maize varieties ('BH-540', Lemu 'P3812W' and Jabi 'PHB 3253') were tested. The results indicated that number of cobs per plant was significantly influenced by the interaction effect of row spacing and varieties.

Hasan *et al.* (2018) conducted an experiment to investigate the effect of variety and plant spacing on yield attributes and yield of maize. Results revealed that variety and plant spacing had significant effect on the studied crop characters and yield.

2.1.1.10 Number of rows cob^{-1}

Hossain (2015) carried out a research work to study the effect of planting configuration on the growth and yield of white maize.

Sharifai *et al*. (2012) conducted field trials to determine the performance of extra early maize (*Zea may*s L.) as affected by intra-row spacing, nitrogen and poultry manure rates. The treatments consisted of factorial combinations of three intra-row spacing (20, 25 and 30 cm), three rates of nitrogen (40, 80 and 120 kg ha^{-1}) and four rates of poultry manure (0, 2, 4 and 6 t ha^{-1}). The results showed that the highest number of rows cob^{-1} (14.14) was recorded from intra-row spacing of 30 cm whereas the lowest number of rows cob^{-1} (13.39) was found from intra-row spacing of 20 cm.

Abuzar *et al*. (2011) conducted a field experiment to determine the effect of plant population densities on maize. They reported that the treatments having plant population density of 60,000 and 80000 plants ha^{-1} produced the highest number of rows per cob of 15.44 each. While the lowest number of rows per cob (13.44) was recorded with 140,000 plants ha^{-1}.

2.1.1.11 Number of grains rows^{-1}

Eyasu *et al.* (2018) conducted a field study with the objective of evaluating different varieties and row spacing on growth, yield and yield components of maize.three maize varieties ('BH-540', Lemu 'P3812W' and Jabi 'PHB 3253') were tested. The results indicated that number of kernels per rows was significantly influenced by the interaction effect of row spacing and varieties.

Hossain (2015) carried out a research work to study the effect of planting configuration on the growth and yield of white maize.

Abuzar *et al*. (2011) carried out a field experiment to determine the effect of plant population densities on maize. The lowest number of grains per row (18.78) was recorded in T_6 (140,000 plants ha^{-1}), possibly due to less availability of nutrients for grain formation.

2.1.1.12 Number of grains cob^{-1}

Ahmmed (2018) conducted an experiment to evaluate the performance of white maize variety under different spacings and integrated fertilizer management. Results revealed that both the individual and the interaction treatments had significant effect on different growth and yield parameters of white maize.

Eyasu *et al.* (2018) conducted a field study with the objective of evaluating different varieties and row spacing on growth, yield and yield components of maize. The results indicated that number of grains per cob was significantly influenced by the interaction effect of row spacing and varieties.

Hasan *et al.* (2018) conducted an experiment to investigate the effect of variety and plant spacing on yield attributes and yield of maize. The experiment comprised of 5 varieties *viz.*

Akbar *et al.* (2016) conducted on-farm experiments to investigate the possibility of introducing white maize as human food evaluating seed yields under varying plant spacings. Yield response of two maize hybrids (PSC-121 and KS-510) planted in three different row arrangements was evaluated in the experiment. Planting in twin-rows produced higher number of grains per cob significantly compared with planting in single rows.

Hossain (2015) carried out a research work to study the effect of planting configuration on the growth and yield of white maize.

Mechi (2015) conducted a field experiment to assess the response of maize hybrid variety “BH-661” to nitrogen (N) fertilizer and inter row spacing. Results revealed that, the highest number of grains cob^{-1} (564.9) was recorded.

Enujeke (2013 b) carried out a study to evaluate the effects of variety and spacing on yield indices of Open-pollinated maize.
the lowest number of grains cob^{-1} (363.0) in 2008 and (369.0) in 2009.

Shafi *et al.* (2012) conducted an experiment to investigate the effect of planting density on plant growth and yield of maize varieties. The experiment consisted of four maize varieties viz., Azam, Pahari, Jalal-2003 and Sarhad white as main plot factor and three plant densities of 45000, 55000 and 65000 plants ha^{-1} as sub-plot factor. They reported that the highest plant density negatively affected number of grains cob^{-1}. With increasing plant population, number of grains cob^{-1} decreased in a linear manner. Maximum number of grains cob^{-1}was observed at plant density of 45,000 plants ha^{-1} when compared with other treatments.

Abuzar *et al.* (2011) carried out a field experiment to determine the effect of plant population densities on maize. Results revealed that the treatments with 40,000 plants ha^{-1} produced the highest number of grains per cob (447.3) followed by T_2 (400.8) having population of 60,000 plants ha^{-1}. The lowest number of grains per cob (253.1) was recorded in treatment having 140,000 plants ha^{-1}.

Dalvi (1984) conducted a field experiment to study the effect of various spacings and nitrogen levels on growth, yield and quality of two varieties of maize (*Zea mays* L.) during Rabi season.

2.1.1.13 Grain Weight per Cob

Nand (2015) conducted a field experiment to evaluate the effect of spacing and fertility levels on protein content and yield of hybrid and composite maize (*Zea mays* L.). Eighteen treatment combinations were involved. In addition, sub-plots were tested for three fertility levels *viz.*, F_1 - NPK and Zn of (120 : 60 : 40 and 15 kg ha^{-1}) F_2 - NPK and Zn of (160 : 80 : 60 and 20 kg ha^{-1}) and F_3 - NPK and Zn of (180 : 100 : 80 and 25 kg ha^{-1}).

Shafi *et al*. (2012) conducted a study to investigate the effect of planting density on plant growth and yield of maize varieties. The experiment consist of four maize varieties *viz*., Azam, Pahari, Jalal-2003 and Sarhad white with three plant densities of 45000, 55000 and 65000 plants ha^{-1}. Data indicated that planting density had a significant effect on grain weight cob^{-1}. The combined effect of Sarhad white with planting density of 65,000 plants ha^{-1} produced the highest grain weight cob^{-1}.

Dalvi (1984) conducted a field experiment to study the effect of various spacings and nitrogen levels on growth, yield and quality of two varieties of maize (*Zea mays* L.) during Rabi season.

2.1.1.14 1000-grain weight

Ahmmed (2018) conducted an experiment to evaluate the performance of white maize variety under different spacings and integrated fertilizer management.

Eyasu *et al.* (2018) conducted a field study with the objective of evaluating different varieties and row spacing on growth, yield and yield components of maize. The results indicated that 1000-grain weight was significantly influenced by the interaction effect of row spacing and varieties.

Hasan *et al.* (2018) conducted an experiment to investigate the effect of variety and plant spacing on yield attributes and yield of maize.

Ukonze *et al.* (2016) carried out a study to compare and analyse how spacing influenced the performance and yield of late maize. One maize variety was evaluated under three spacing for performance data such as plant heights, stem girths, number of leaves, number of nodes and leaf area and for the yield, data were collected on cob length, cob weight, cob + husk weight, cob circumference and 1000-grain weight (yield).

Hossain (2015) carried out a research work to study the effect of planting configuration on the growth and yield of white maize.

Mechi (2015) conducted a field experiment to assess the response of maize hybrid variety “BH-661” to nitrogen (N) fertilizer and inter row spacing.

Shafi *et al.* (2012) conducted an experiment to investigate the effect of planting density on plant growth and yield of maize varieties. The experiment consisted of four maize varieties viz., Azam, Pahari, Jalal-2003 and Sarhad white as main plot factor and three plant densities of 45000, 55000 and 65000 plants ha^{-1} as sub-plot factor. They reported that, increasing planting density had a negative impact on 1000-grain weight. Increasing plant population decreased 1000-grain weights. Maximum 1000-grain weight was produced by planting density of 45,000 plants ha^{-1} when compared with other treatments.

Sharifai *et al*. (2012) conducted field trials to determine the performance of extra early maize (*Zea may*s L.) as affected by intra-row spacing, nitrogen and poultry manure rates. The treatments consisted of factorial combinations of three intra-row spacing (20, 25 and 30 cm), three rates of nitrogen (40, 80 and 120 kg ha^{-1}) and four rates of poultry manure (0, 2, 4 and 6 t ha^{-1}). The results showed that the maximum 100-grain weight (20.51 g) was recorded from intra-row spacing 30 cm whereas the minimum 100-grain weight (19.64 g) was found from intra-row spacing 20 cm.

Abuzar *et al*. (2011) carried out a field experiment to determine the effect of plant population densities on maize. The lowest 1000-grain weight (166.7 g) was recorded in treatment having plant population of 140,000 plants ha^{-1}.

Dalvi (1984) conducted a field experiment to study the effect of various spacings and nitrogen levels on growth, yield and quality of two varieties of maize (*Zea mays* L.) during Rabi season.

2.1.2 Review on yield parameters

2.1.2.1 Grain yield

Ahmmed (2018) conducted an experiment to evaluate the performance of white maize variety under different spacings and integrated fertilizer management.

Results revealed that both the individual and the interaction treatments had significant effect on different growth and yield parameters of white maize. The highest seed yield was mostly attributed to the number of grains per cob (328–433) and 100 seeds weight (29.67–35.33 g).

Eyasu *et al.* (2018) conducted a field study with the objective of evaluating different varieties and row spacing on growth, yield and yield components of maize. Four plant row spacing and three maize varieties (‘BH-540’, Lemu ‘P3812W’ and Jabi ‘PHB 3253’) were tested. The results indicated that grain yield per hectare was significantly influenced by the interaction effect of row spacing and varieties. The lowest grain yield per hectare was recorded from variety Jabi grown at row spacing of . Based on these results, it can be concluded that under irrigated condition Lemu and BH-540 maize varieties at 65–75 cm row spacing resulted higher biomass and grain yield of maize.
Three intra-row spacing *viz.* 0, 23, 46, 69, 92 and 115 kg ha^{-1} were assigned to the experimental plot by factorial combinations. Based on the results, the maximum grain yield (10,207.8 kg ha^{-1}) was obtained when the hybrid was sown at the closest intra row spacing

with application of the highest rate of nitrogen (115 kg ha^{-1}). This result showed 8.90 % yield advantages compared to the standard check. However, statistically similar grain yield (9,887 kg ha^{-1}) was also obtained under application of 92 kg nitrogen ha^{-1} in the same intra spacing (20 cm). It was concluded that application of 115 kg N ha^{-1} on maize hybrid planted at 20 cm intra row spacing was the most profitable agronomic practice as compared to other combinations.

Hasan *et al.* (2018) conducted an experiment to investigate the effect of variety and plant spacing on yield attributes and yield of maize. Results revealed that variety and plant spacing had significant effect on the studied crop characters and yield.

Akbar *et al.* (2016) conducted on-farm experiments to investigate the possibility of introducing white maize as human food evaluating seed yields under varying plant spacings. Yield response of two maize hybrids (PSC-121 and KS-510) planted in three different row arrangements was evaluated in the experiment. Grain yield ranged between 7,103 kg and 10,126 kg per ha across hybrids and planting arrangements. Hybrid PSC-121 recorded 19 % more yield than KS-510. Generally, grain yield increased with increasing planting density. Planting in twin-rows giving 80,000 plants per ha and produced 17.7 % higher yield compared with planting in single rows 60 cm apart giving 66,667 plants ha^{-1}. Planting in twin-rows produced higher yield significantly compared with single rows. Increase in maize grain yield was associated with the number of grains per ear and individual grain weight.

Hossain (2015) carried out a research work to study the effect of planting configuration on the growth and yield of white maize.

Mechi (2015) conducted a field experiment to assess the response of maize hybrid variety “BH-661” to nitrogen (N) fertilizer and inter row spacing. The experiment was arranged in a factorial combination of four levels of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and four inter row spacing.

Nand (2015) conducted a field experiment to evaluate the effect of spacing and fertility levels on protein content and yield of hybrid and composite maize (*Zea mays* L.). In addition, sub-plots were tested for three fertility levels

viz., F_1 - NPK and Zn of (120 ∶ 60 ∶ 40 and 15 kg ha^{-1}) F_2 - NPK and Zn of (160 ∶ 80 ∶ 60 and 20 kg ha^{-1}) and F_3 - NPK and Zn of (180 ∶ 100 ∶ 80 and 25 kg ha^{-1}).
The interaction effect between variety × spacing was found significant ($P < 0.05$) on protein yield.

Enujeke (2013 a) carried out a study to evaluate the effects of variety and spacing on growth characters of hybrid maize. Three maize hybrid varieties were evaluated under three different plant spacing for growth characters as plant height, number of leaves, leaf area and stem girth. Results of interaction showed that variety and spacing were significantly ($P < 0.05$) different. Based on the findings of this study, it was recommended that (i) hybrid variety 9022-13 be grown to enhance growth characters which interplay to improve grain yield of maize be used to enhance increased stem girth and leaf area whose photosynthetic activities could positively influence maize yield.

Enujeke (2013 b) carried out a study to evaluate the effects of variety and spacing on yield indices of Open-pollinated maize.

Jula*et al*. (2013) conducted a field experiment to evaluate the effects of various intra-row spacing on the growth and yield of maize intercropped into ginger. The results indicated that, grain yield was the highest (3.98 t ha^{-1}) for maize intercrop

Sharifai *et al*. (2012) conducted field trials to determine the performance of extra early maize (*Zea may*s L.) as affected by intra-row spacing, nitrogen and poultry manure rates. The treatments consisted of factorial combinations of three intra-row spacing (20, 25 and 30 cm), three rates of nitrogen (40, 80 and 120 kg ha^{-1}) and four rates of poultry manure (0, 2, 4 and 6 t ha^{-1}). The results showed that the highest grain yield (2.32 t ha^{-1}) was recorded from intra-row spacing of 25 cm whereas the lowest grain yield (1.97 t ha^{-1}) was found from intra-row spacing of 30 cm.

Shafi *et al.* (2012) conducted an experiment to investigate the effect of planting density on plant growth and yield of maize varieties. The experiment consisted of four maize varieties viz., Azam, Pahari, Jalal-2003 and Sarhad white as main plot factor and three plant densities of 45000, 55000 and 65000 plants ha^{-1} as sub-plot factor. Data indicated that planting density had a significant effect on grain yield. They reported that, plant population of 65,000 plants ha^{-1} had significantly the highest yield whereas; the lowest yield was recorded from plant population of 55000 plants ha^{-1}.

Abuzar *et al*. (2011) carried out a field experiment to determine the effect of plant population densities on maize. The effect of six plant population densities i.e. T_1 (40,000 plants ha^{-1}), T_2 (60,000 plant ha^{-1}), T_3 (80,000 plants ha^{-1}), T_4 (100,000 plants ha^{-1}), T_5 (120,000 plants ha^{-1}) and T_6 (140,000 plants ha^{-1}) was investigated using maize variety Azam. Result revealed that the maximum grain yield (2604 kg ha^{-1}) was recorded in T_2 (60,000 plants ha^{-1}) followed by T_3 (80,000 plants ha^{-1}) which produced grain yield of 2346 kg ha^{-1}. The minimum grain yield of 746.3 kg ha^{-1} was recorded in T_6 having population of 140,000 plants ha^{-1}.

Fanadzo *et al.* (2010) conducted a study to determine the effects of inter-row spacing (45 and 90 cm) and plant population (40,000 and 60,000 plants ha^{-1}) on weed biomass and the yield of both green and grain materials of maize plants. 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%. Similar grain yield was obtained regardless of inter-row spacing when maize was grown at 40,000 plants ha^{-1}; but at 60,000 plants ha^{-1}, 45 cm wide rows resulted in 11 % higher grain yield than 90 cm rows. Increasing plant population from 40,000 to 60,000 plants ha^{-1} resulted in a 30 % grain yield increase. The study demonstrated that growers could obtain higher green plants and grain yield by increasing plant population from the current practice of 40,000 to 60,000 plants ha^{-1} and through use of narrow rows.

Alvarez (2006) conducted a field experiment where the effects of row spacing (0.7 and 0.9 m) and plant density (55,000 and 75,000 plants ha^{-1}) on the performance of maize hybrids AG1051, AG9010 and DKB440 were determined. Grain yield increased with increasing sowing density and decreasing row spacing. The hybrids AG9010 and DKB440 was associated with the highest grain yield regardless of planting density.

Muhammad *et al*. (2006) indicated that there was maximum grain yield of 6.6 t ha^{-1} of maize against the minimum of 3.28 t ha^{-1} at narrow spacing, although narrow plant spacing (10–15 cm) caused substantial reduction in yield components such as grain cob^{-1} and 1000-kernel weight compared to the wide plant spacing.

Sener (2004) conducted a two-year study to determine the optimum intra-row spacing for maize hybrids commercially grown in Eastern Mediterranean Region during 2000 and 2001 growing seasons. Maize hybrids reacted differently to various plant density and intra-row spacing. Main plots were assigned to maize hybrids *viz.*, Dracma, Pioneer 3223, Pioneer 3335, Dekalb 711 and Dekalb 626. Split-plots were assigned to intra-row spacing of 10.0, 12.5, 15.0, 17.5 and 20.0 cm. The effects of intra-row spacing on the grain yield was recorded to be statistically significant. Hybrid × intra-row spacing interaction effects were significant at grain yield. The highest grain yields were obtained from Pioneer 3223 and Dracma at 15.0 cm intra-row spacing (11,718 and 11,180 kg ha^{-1}, respectively).

Gardner (1985) found that kernel yield per unit area increased to a maximum yield of 1080 g m^{-2} at the density of about 10 plants m^{-2}, whereas total dry matter yield asymptotically increased up to 12.5 plants m^{-2}.

2.1.2.2 Stover yield

Hasan *et al.* (2018) conducted an experiment to investigate the effect of variety and plant spacing on yield attributes and yield of maize. The maximum stover

Hossain (2015) carried out a research work to study the effect of planting configuration on the growth and yield of white maize.

Mechi (2015) conducted a field experiment to assess the response of maize hybrid variety “BH-661” to nitrogen (N) fertilizer and inter row spacing. The experiment was arranged in a factorial combination of four levels of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and four inter row spacing.Result revealed that, the highest stover yield (15.50 t ha^{-1}) was recorded from inter row spacing of 65 cm and the lowest stover yield (14.33 t ha^{-1}) was obtained from inter row spacing of 55 cm.

Shafi *et al.* (2012) conducted an experiment to investigate the effect of planting density on plant growth and yield of maize varieties. The experiment consisted of four maize varieties viz., Azam, Pahari, Jalal-2003 and Sarhad white as main plot factor and three plant densities of 45000, 55000 and 65000 plants ha^{-1} as sub-plot factor. They reported that highest stover yield was recorded from the treatment of 65,000 plants ha^{-1} and lowest from the treatment of 45,000 plants ha^{-1}.

Abuzar *et al.* (2011) carried out a field experiment to determine the effect of plant population densities on maize.

(100,000 plants ha^{-1}), T_5 (120,000 plants ha^{-1}) and T_6 (140,000 plants ha^{-1}) was investigated using maize variety Azam. Results showed that treatments having population of 60,000 and 80,000 plants ha^{-1} produced the maximum biomass yield of 16,890 kg ha^{-1} each, while the lowest biomass yield (13,330 kg ha^{-1}) was recorded with population of 140,000 plants ha^{-1}.

2.1.2.3 Biological yield

Hossain (2015) carried out a research work to study the effect of planting configuration on the growth and yield of white maize.

Shafi *et al.* (2012) conducted an experiment to investigate the effect of planting density on plant growth and yield of maize varieties. The experiment consisted of four maize varieties viz., Azam, Pahari, Jalal-2003 and Sarhad white as main plot factor and three plant densities of 45000, 55000 and 65000 plants ha^{-1} as sub-plot factor. Data indicated that planting density had a significant effect on biological yield. They reported that, the highest biological yield was recorded from the treatment of 65,000 plants ha^{-1} and the lowest biological yield was recorded from plant population of 45,000 plants ha^{-1}.

2.1.2.4 Shelling Percentage

Ahmmed (2018) conducted an experiment to evaluate the performance of white maize variety under different spacings and integrated fertilizer management. Results revealed that both the individual and the interaction treatments had significant effect on different growth and yield parameters of white maize.

2.1.2.5 Harvest index

Ahmmed (2018) conducted an experiment to evaluate the performance of white maize variety under different spacings and integrated fertilizer management.

Hossain (2015) carried out a research work to study the effect of planting configuration on the growth and yield of white maize.

Mechi (2015) conducted a field experiment to assess the response of maize hybrid variety “BH-661” to nitrogen (N) fertilizer and inter row spacing. The experiment was arranged in a factorial combination of four levels of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and four inter row spacing (55, 65, 75 and 85 cm). Results indicated that, the highest harvest index (53.16 %) was recorded from inter row spacing of 85 cm and the lowest harvest index (42.91 %) was obtained from inter row spacing of 55 cm.

Shafi *et al.* (2012) conducted an experiment to investigate the effect of planting density on plant growth and yield of maize varieties. The experiment consisted of four maize varieties viz., Azam, Pahari, Jalal-2003 and Sarhad white as main plot factor and three plant densities of 45000, 55000 and 65000 plants ha^{-1} as sub-plot factor. They reported that, the highest harvest index was observed in the treatment of 65,000 plants ha^{-1} and the lowest in 45,000 plants ha^{-1}.

Ma *et al*. (2003) conducted field experiments to evaluate maize response to row spacing and N fertility over a 4-yr period (1997–2000). Row spacing of 0.51 m, 0.76 m and 0.76 m paired row alone or in combination with hybrid were tested in the sub-plot whereas combination of fertilizer N by population density (1997 and 1998) or N alone was assigned to the main plot. In 1997 and 1998, combinations of N by density consisted of 0, 60, 120, 180 and 240 kg N ha^{-1} at 89,000 plants ha^{-1} and 60 and 180 kg N ha^{-1} at 69,000 plants ha^{-1} using a single hybrid, Pioneer 3893. In 1999 and 2000, N fertility levels of 0, 80 and 180 kg N ha^{-1} were the main plots and six combinations of hybrids (Pioneer 3893 and Pioneer 38P06 Bt) by row spacing were grown in the sub-plots at 69,000 plants ha^{-1}. They found that, harvest index was significantly higher under the 0.51 m spacing than the other spacing treatments.

CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design, crop growing procedure, intercultural operations, data collection and statistical analyses.

3.1 Experimental period

The experiment was conducted during the period from 22 October 2018 to 22 February 2019 in Rabi season.

3.2 Site description

3.2.1 Geographical location

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level.

3.2.2 Agro-Ecological Zone

The experimental field belongs to the Agro-ecological zone (AEZ) of “The Madhupur Tract”, AEZ-28. This was a region of complex relief and soils developed over the Madhupur clay, where floodplain sediments buried the dissected edges of the Madhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain. For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.3 Climate

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Meteorological data related to the temperature, relative humidity and rainfall during the experiment period of was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix- III.

3.4 Soil

The soil of the experimental field belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Soil pH ranges from 5.4–5.6 (Anon., 1989). The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0–15 cm depths were collected from the experimental field. The soil analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix II.

3.5 Planting materials

In this research work, "SAUWMOP DT61G" variety of white maize was used as plant materials, which were collected from Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.

3.6 Description of the variety

The genotype of white maize SAUWMOP DT61Gwas used as planting material for the present study. These varieties are recommended for Rabi and kharif season. The feature of these varieties is presented below:

Name of Variety	:	SAUWMOP DT61G
Identifying character	:	Bold grain quality and drought tolerant
Type	:	Medium duration, Open pollinated
Height	:	180–200 cm
Crop duration	:	110–120 days
Leaf colour at Maturity	:	Stay green at maturity
Suitable area	:	All over Bangladesh
Number of cobs plant^{-1}	:	Mainly one

Grain colour	:	White
Yield	:	8.20–10.50 t ha^{-1}
Source	:	Personal Communication: Prof. Dr. Md. Jafar Ullah, Dept. Of Agronomy, SAU, Dhaka.

Major diseases and Management

Diseases: No specific disease was observed, minor leaf blight.

Management: Clean cultivation with timely sowing and balance fertilizer application. Seed treatment with vitavax- 200 @ 2.50 g kg^{-1} seed, spraying with Tilt or Folicure @ 0.5% and burning of crop residues.

Major insect/pest and Management

Insect pests: Armyworm attack along with some other insect attack may be at vegetative stage of maize as well as Earworm attack in cob at reproductive stage in maize.

Management

For cutworm: The larvae were killed after collecting from soil near the cut plants in morning. Dursban or Pyrifos 20 EC 5 ml $liter^{-1}$ water sprayed especially at the base of plants to control cutworms.

For earworm: The larvae are killed after collecting from the infested cobs. Cypermethrin (Ripcord 10 EC/Cymbush 10 EC) @ 2 ml $litre^{-1}$ water sprayed to control this pest.

For stem borer: Marshall 20 EC or Diazinon 60 EC @ 2 ml $litre^{-1}$ water sprayed properly to control the pest. Furadan 5 G or Carbofuran 5 G @ 20kg ha^{-1} applied on top of the plants in such a way so that the granules stay between the stem and leaf base. Such type of application of insecticides is known as whorl application.

3.7 Experimental details

Sowing Date: 22 October, 2018

Silking Date: 21 December 2018

Harvesting Date: 22 February 2019.

3.8 Experimentaltreatments

There were two sets of treatments in the experiment. The treatments were row-to-row spacing and plant-to-plant spacing. Those are shown below:

Factor A: Row to row spacing (five levels)

i. R_1 – 40 cm,

ii. R_2 – 45 cm,

iii. R_3 – 50 cm,

iv. R_4 – 55 cm and

v. R_5 – 60 cm.

Factor B: Plant to plant spacing (three levels)

i. P_1 – 15 cm,

ii. P_2 – 20 cm and

iii. P_3 – 25 cm.

3.8.1 Treatment combinations

This two factor experiments were included 15 treatment combinations.

R_1P_1 : 40 cm × 15 cm

R_1P_2 : 40 cm × 20 cm

R_1P_3 : 40 cm × 25 cm

R_2P_1 : 45 cm × 15 cm

R_2P_2 : 45 cm × 20 cm

R_2P_3 : 45 cm × 25 cm

R_3P_1 : 50 cm × 15 cm

R_3P_2 : 50 cm × 20 cm

R_3P_3 : 50 cm × 25 cm

R_4P_1 : 55 cm × 15 cm

R_4P_2 : 55 cm × 20 cm

R_4P_3 : 55 cm × 25 cm

R_5P_1 : 60 cm × 15 cm

R_5P_2 : 60 cm × 20 cm

R_5P_3 : 60 cm × 25 cm

3.8.2 Experimental design

The experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications. The field was divided into 3 blocks to represent 3 replications. Total 45 unit plots was made for the experiment with 15 treatments. The size of each unit plot was 6.30 m^2 (3.50 m × 1.80 m). Distance maintained between replication and plots were 1.0 m and 0.75 m, respectively. The treatments were assigned in plot at random.

3.9 Detail of experimental preparation

3.9.1 Preparation of experimental land

A pre-sowing irrigation was given on 10 October 2018. The land was opened with the help of a tractor drawn disc harrow on 17 October, 2018 and then ploughed with rotary plough twice followed by laddering to achieve a medium tilth required for the crop under consideration. All weeds and other plant residues of previous crop were removed from the field. Immediately after final land preparation, the field layout was made on 19 October 2018 according to experimental specification. Individual plots were cleaned and finally the plot were prepared.

3.9.2 Fertilizer application

Doses of vermicompost was used @ 2 t ha^{-1} before final land preparation. The field was fertilized with nitrogen, phosphate, potash, sulphur, zinc and boron at the rate of 500-250-200-250-15-5 kg ha^{-1} of urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid, respectively (BARI, 2014). The whole amounts of fertilizers were applied as basal doses except Urea. Only one-third Urea was applied as basal doses and the rest amount was applied at 15 DAS interval for three instalments.

3.9.3 Seed sowing

The white maize seeds were sown in lines maintaining row-to-row distance and plant to plant distance as per treatments having 2 seeds $hole^{-1}$ under direct sowing in the well prepared plot on 22 October 2018.

3.10 Intercultural operations

After raising seedlings, various intercultural operations such as irrigation, weeding, gap filling and thinning, drainage, pest and disease control etc. were accomplished for better growth and development of the maize seedlings.

3.10.1 Gap filling and thinning

Gap filling was done on 30 October 2018, which was 10 days after sowing (DAS). During plant growth period. Thinning was done on 6 November 2018, which was 15 days after sowing.

3.10.2 Weeding

The hand weeding was done as when necessary to keep the plot free from weeds. During plant growth period two weeding were done. The weeding was done on 16 November 2018 and 6 December 2018, which was 25 and 45 days after sowing, respectively.

3.10.3 Earthing up

Earthing up was done on 21 November 2018 which was 30 days after sowing. It was done to protect the plant from lodging and for better irrigation management and nutrition uptake.

3.10.4 Application of irrigation water

Irrigation water was added to each plot, first irrigation was done as pre-sowing and other four were given at 20, 40,65 and 85 days after sowing (DAS). First irrigation was given on 11 November 2018, which was 20 days after sowing. Second irrigation was given on 1 December 2018, which was 40 days after sowing. Third irrigation was given on 26 December 2018, which was 65 days after sowing, and fourth irrigation was given on, 15 January 2019, which was 85 days after sowing.

3.10.5 Drainage

There were heavy rainfalls during the experimental period. Drainage channels were properly prepared to easy and quick drained out of excess water.

3.10.6 Pest and disease control

As described in section 3.6.

3.10.7 General observations of the experimental site

Regular observations were made to see the growth stages of the crop. In general, the plot looked nice with normal green plants, which were vigorous and luxuriant.

3.11 Harvesting, threshing and cleaning

The mature cobs were harvested when the husk cover was completely dried and black coloration was found in the grain base (black band).The cobs of five randomly selected plants of each plot were separately harvested for recording yield attributes and other data. Harvesting was done on 22 February 2019.

3.12 Drying

The harvested products were taken on the threshing floor and it was dried for about 3–4 days.

3.13 Crop sampling

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

3.14 Collection of data

Data were collected on the following parameters-

A. Crop growth characters

1. Plant height (cm)
2. Plant density (No. m^{-2})
3. Leaf area $plant^{-1}$ (cm^2)
4. Cob dry matter $plant^{-1}$ (g)
5. Stover dry matter $plant^{-1}$ (g)
6. Root dry matter $plant^{-1}$ (g)
7. Total dry matter $plant^{-1}$ (g)

B. Yield contributing characters

1. Cob length (cm)
2. Cob breadth (cm)
3. Grain weight $plant^{-1}$ (g)
4. Shell weight $plant^{-1}$ (g)
5. Chaff weight $plant^{-1}$ (g)
6. Total cob weight $plant^{-1}$ (g)
7. Number of rows cob^{-1} (no.)

8. Number of grain rows cob^{-1} (no.)

9. Number of grains cob^{-1} (no.)

C. Yield characters

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

2. Biomass (t ha^{-1})

3. Harvest index (%)

3.15 Procedure of recording data

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

3.15.1 Plant height (cm)

The height of plant was recorded in centimetre (cm) at harvest. Data were recorded as the average of five plants selected from the inner rows of each plot. The height was measured from the ground level to the tip of the plant.

3.15.2 Plant density (No. m^{-2})

Data on plant density were collected from each plot at harvesting time of the white maize plants. Plants grown in the quadrate (1 m × 1 m) were identified and the quadrate was placed randomly at three places in each plot as following by Cruz *et al*. (1986) method. The plants within the quadrate were counted and converted to number m^{-2} by the average number of two samples.

$$\text{Plant density (Number m}^{-2}\text{)} = \frac{\text{Total number of plants}}{\text{Total surveyed unit area}}$$

3.15.3 Leaf area $plant^{-1}$ (cm^2)

Leaf area was estimated manually by counting the total number of leaves $plant^{-1}$ and measuring the length and average width of leaf and multiplying by a factor of 0.70 (Keulen and Wolf, 1986). It was done at harvest. Dried leaves at the harvesting was not included while monitoring the leaf area.

$$\text{Leaf area plant}^{-1} = \frac{\text{Surface area of leaf sample } (\text{cm}^2) \times \text{No. of leaves plant}^{-1} \times \text{Correlation factor}}{\text{No. of leaves sampled}}$$

3.15.4 Cob dry weight plant^{-1} (g)

Cob dry weight plant^{-1} was collected at harvest. From each plot, five plants were uprooted randomly. Then the stem, leaves, cob and roots were separated. The cob sample was sliced into very thin pieces and put into envelop and placed in oven maintaining 70°C for 72 hours. Then the cob sample was transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken.

3.15.5 Stover dry weight plant^{-1} (g)

Stover dry weight plant^{-1} was collected at harvest. From each plot, five plants were uprooted randomly. Then the stem, leaves, cob and roots were separated. The stover sample (stem and leaves) was sliced into very thin pieces and put into envelop and placed in oven maintaining 70°C for 72 hours. Then the stover sample was transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken.

3.15.6 Root dry weight plant^{-1} (g)

Root dry weight plant^{-1}was collected at harvest. From each plot, five plants were uprooted randomly. Then the stem, leaves, cob and roots were separated. The root sample was sliced into very thin pieces and put into envelop and placed in oven maintaining 70°C for 72 hours. Then the root sample was transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken.

3.15.7 Total dry weight plant^{-1} (g)

Dry weight plant^{-1}was collected at harvest. From each plot, five plants were uprooted randomly. Then the stem, leaves, cob and roots were separated. The all sample was sliced into very thin pieces and put into envelop and placed in oven maintaining 70°C for 72 hours. Then the all sample was transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken by the following formula:

Total dry weight plant^{-1} (g) = Cob dry weight + Stover dry weight + Root dry weight

3.15.8 Cob length (cm)

Cob length was measured in centimetre from the base to the tip of the ear of five corn from the five selected plants in each plot with the help of a centimetre scale then average data were recorded.

3.15.9 Cob breadth (cm)

Five cobs were randomly selected plot^{-1} and the circumference was taken from each cob. Then average result was recorded in cm.

3.15.10 Grain weight plant^{-1} (g)

Whole grains of five cobs were randomly taken from each plot and the weight was taken in an electrical balance. The average chaff weight was recorded in gram.

3.15.11 Shell weight plant^{-1} (g)

Total husk of five cobs were randomly taken from each plot and the weight was taken in an electrical balance. The average chaff weight was recorded in gram.

3.15.12 Chaff weight plant^{-1} (g)

Whole chaff without grains of five cobs were randomly taken from each plot and the weight was taken in an electrical balance. The average chaff weight was recorded in gram.

3.15.13 Total cob weight plant^{-1} (g)

Cob weight with husk of five randomly selected cobs from the five selected plants in each plot was taken and the average weight was recorded in gram.

3.15.14 Number of rows cob^{-1} (no.)

Row number of five randomly selected cobs from the five selected plants plot^{-1}werecounted and finally averaged.

3.15.15 Number of grain rows cob^{-1} (no.)

Five cobs from each plot were selected randomly and the number of grain rows was counted and then the average result was recorded.

3.15.16 Number of grains cob^{-1} (no.)

The numbers of grains cob^{-1} was measured from the base to tip of the ear collected from five randomly selected cobs of each plot and finally averaged.

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

Final grain yield was adjusted at 14% moisture. The grain yield t ha^{-1} was measured by the following formula:

$$\text{Grain yield (t ha}^{-1}\text{)} = \frac{\text{Grain yield per meter sqare (kg)} \times 10000}{1000}$$

3.15.18 Biomass (t ha^{-1})

Final grain yield was adjusted at 14% moisture. Grain yield together with stover yield was regarded as biological yield and calculated with the following formula:

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

3.15.19 Harvest Index (%)

Harvest Index denotes the ratio of economic yield to biological yield and was calculated with the following formula:

$$\text{Harvest Index (\%)} = \frac{\text{Economic Yield (Grain weight)}}{\text{Biomass (Total weight)}} \times 100$$

3.16 Statistical analysis

The collected data were compiled and analysed following the analysis of variance (ANOVA) techniques by Randomized Completely Block Design (RCBD) to find out the statistical significance of experimental results. The collected data were analysed by computer package program MSTAT-C software (Russell. 1986). The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Crop Growth Parameters

4.1.1 Plant height (cm)

4.1.1.1 Effect of row spacing

Plant height is an important morphological character that acts as a potent indicator of availability of growth resources in its vicinity. Row spacing showed significant variation on plant height of white maize at harvesting stage (Figure 1 and Appendix IV). The figure exhibits that row spacing was increased, and then plant height increased. row spacing. This finding was clearly supported by those of Tahmina (2018) and Nand (2015) who reported maximum plant height within 60 cm row spacing. Dutta *et al*. (2015) and Paulpandi *et al*. (1998) reported that, wider row spacing had taller plants due to better availability of resources. Wider space availability between the rows and closer intra-rows might have increased the root spread, which eventually utilized the resources such as water, nutrients, CO_2 and light very effectively. Bairagi *et al*. (2015) and Jiotode *et al*. (2002) also reported that, better plant height at wider spacing could be assigned to the fact that with more available area per plant, energy was always harvested better. However, Dar *et al*. (2014), Sarjamei *et al.* (2014), Demotsmainard and Pellerin (1992) found dissimilar results reporting that, high plant population resulted in enhancing plant height. Plant competition for light is the main reason for higher plants at dense populations (Muchow *et al*., 1990).

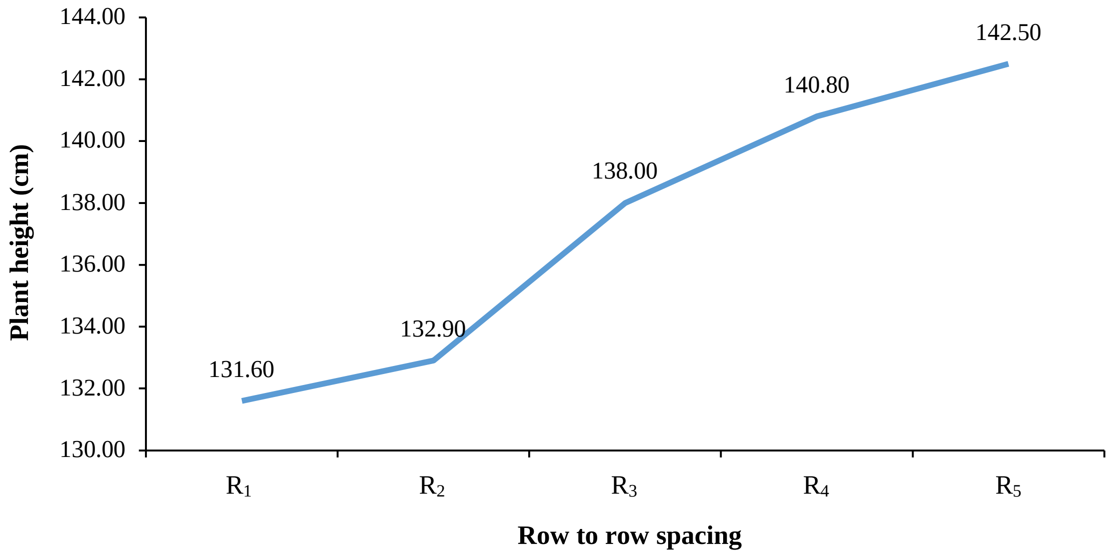

Figure 1: Effect of row to row spacing on plant height (cm) of white maize (LSD value = 1.31 at harvesting time)

4.1.1.2 Effect of plant spacing

Effect of plant spacing showed a significant variation on plant height of white maize at harvesting stage (Figure 2 and Appendix IV). The figure exhibits that when the plant spacing was increased, then plant height decreased. The tallest plant (140.80 cm) was obtained from 15 cm (P_1) plant spacing and the shortest plant (132.00 cm) was obtained from 25 cm (P_3) plant spacing. The second tallest plant (138.70 cm) was obtained from 20 cm (P_2) plant spacing. This result also collaborate the findings of Hasan *et al.* (2018), Ukonze *et al.* (2016) and Enujeke (2013a). Enujeke (2013b) and Ibeawuchi *et al.* (2008) found that the different plant spacing with different plant densities generally influenced maize plant height. Close spacing causes competition and removal of nutrients for growth and genetic makeup either for tallest or shortness for the particular plant.

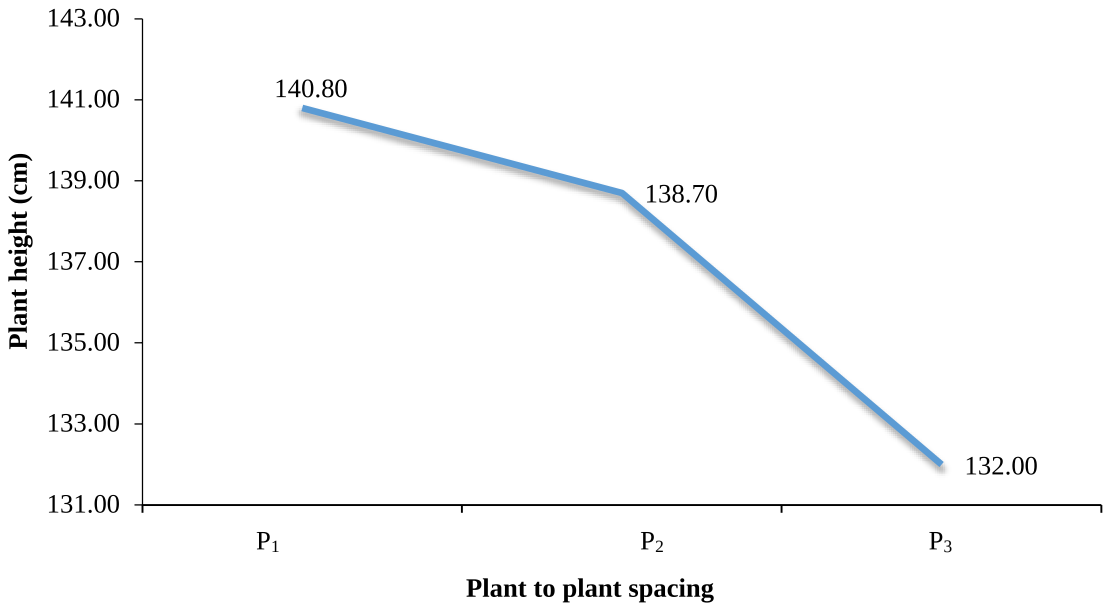

Figure 2: Effect of plant-to-plant spacing on plant height (cm) of white maize (LSD value = 1.01 at harvesting time)

4.1.1.3 Interaction effect of row spacing and plant spacing

Plant height was influenced by the combined effect of different row spacing and plant spacing at harvesting stage of white maize (Table 1). Interaction of row spacing and plant spacing had significant effect on plant height (Appendix IV). This agrees well to the findings of Ibrahim *et al.* (2000) and Majambu *et al.* (1996) that attributed the differences in growth indices of crops to genetic constitution. Dalley *et al.* (2006); Widdicombe and Thelen (2002); Teasdale (1995) who attributed the increased growth rates and earlier canopy closure of narrow row spaced crops to quest for increased light interception as well as increased availability of soil moisture because of equidistant distribution of crop plants.

Table 1: Interaction effect of row-to-row spacing and plant-to-plant spacing on plant height (cm) of white maize

Treatment combination	Plant height (cm)
40 cm × 15 cm	136.00 e
40 cm × 20 cm	135.30 ef
40 cm × 25 cm	123.50 g
45 cm × 15 cm	137.30 de
45 cm × 20 cm	135.90 e
45 cm × 25 cm	125.50 g
50 cm × 15 cm	142.30 b
50 cm × 20 cm	138.40 cd
50 cm × 25 cm	133.30 f
55 cm × 15 cm	143.80 ab
55 cm × 20 cm	140.00 c
55 cm × 25 cm	138.50 cd
60 cm × 15 cm	144.60 a
60 cm × 20 cm	143.80 ab
60 cm × 25 cm	139.00 cd
$LSD_{(0.05)}$	**2.18**
CV (%)	**7.95**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

4.1.2 Plant density (No. m^{-2})

4.1.2.1 Effect of row spacing

Significant difference was observed on plant density (no. m^{-2}) of white maize at harvest stages (Appendix IV). The figure 3 exhibits that the decreasing of row spacing enhance plant density. Among the row spacing, 40 cm (R_1) showed the highest number of plant density (13.06 m^{-2}). On the other hand, 60 cm (R_5) showed the lowest number of plant density (8.70 m^{-2}). This is similar to the findings of Tahmina (2018).

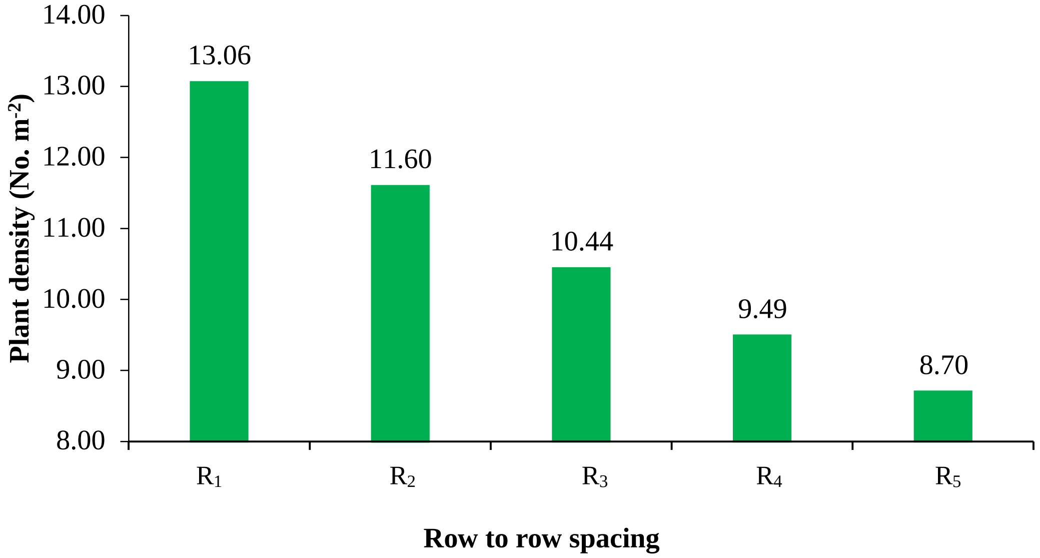

Figure 3: Effect of row-to-row spacing on plant density (no. m^{-2}) of white maize (LSD value = 0.22 at harvesting time)

4.1.2.2 Effect of plant spacing

Plant spacing showed a significant effect on plant density (no. m^{-2}) of white maize (Appendix IV). The figure 4 exhibits that the decreasing of plant spacing enhanced plant density. At harvesting stage, 15 cm plant spacing (P_1) showed the highest number of plant density (13.61 m^{-2}); whereas plant spacing 25 cm (P_3) showed the lowest number of plant density (8.17 m^{-2}). This is similar to the findings of Enujeke (2013 a).

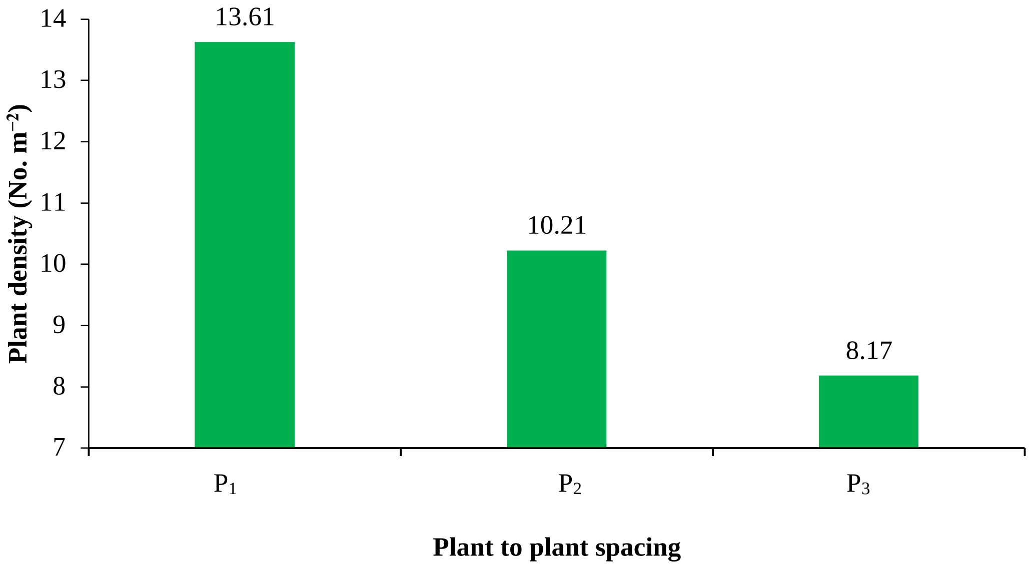

Figure 4: Effect of plant-to-plant spacing on plant density (no. m^{-2}) of white maize (LSD value = 0.17 at harvesting time)

4.1.2.3 Interaction effect of row spacing and plant spacing

Interaction of row spacing and plant spacing showed a decreasing trend with increase spacing in respect of plant density (Table 2 and Appendix IV).

Table 2: Interaction effect of row-to-row spacing and plant-to-plant spacing on plant density (no. m^{-2}) of white maize

Treatment combination	Plant density (No. m^{-2})
40 cm × 15 cm	16.67 a
40 cm × 20 cm	12.50 d
40 cm × 25 cm	10.00 g
45 cm × 15 cm	14.81 b
45 cm × 20 cm	11.11 f
45 cm × 25 cm	8.89 h
50 cm × 15 cm	13.33 c
50 cm × 20 cm	10.00 g
50 cm × 25 cm	8.00 j
55 cm × 15 cm	12.12 e
55 cm × 20 cm	9.09 h
55 cm × 25 cm	7.27 k
60 cm × 15 cm	11.11 f
60 cm × 20 cm	8.33 i
60 cm × 25 cm	6.67 l
$LSD_{(0.05)}$	**0.22**
CV (%)	**8.23**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

4.1.3 Leaf area plant^{-1} (cm^2)

4.1.3.1 Effect of row spacing

Row spacing showed a significant variation on leaf area plant^{-1} (cm^2) of white maize (Figure 5 and Appendix IV). Decreased spacing resulted in larger leaf area possibly because there was a reduction in competition for space, sunlight and nutrients within the wider spaced plants. This is similar to the findings of Ali *et al*. (2003) who reported that competition between maize plants for light, soil fertility and other environmental factors were markedly increased with highest population but decreased with lower plant population.

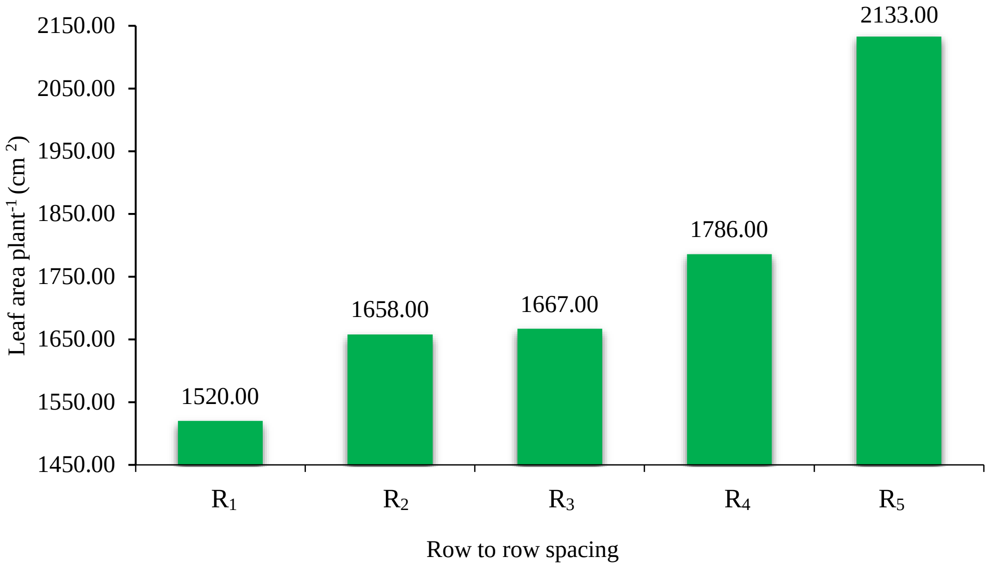

Figure 5: Effect of row-to-row spacing on leaf area plant^{-1} (cm^{2}) of white maize (LSD value = 31.92 at harvesting time)

4.1.3.2 Effect of plant spacing

Plant spacing showed a significant variation on leaf area plant^{-1} (cm^2) of white maize at harvesting stage (Figure 6 and Appendix IV). The result under the present study was in conformity with Nand (2015) and Jiotode *et al.* (2002).

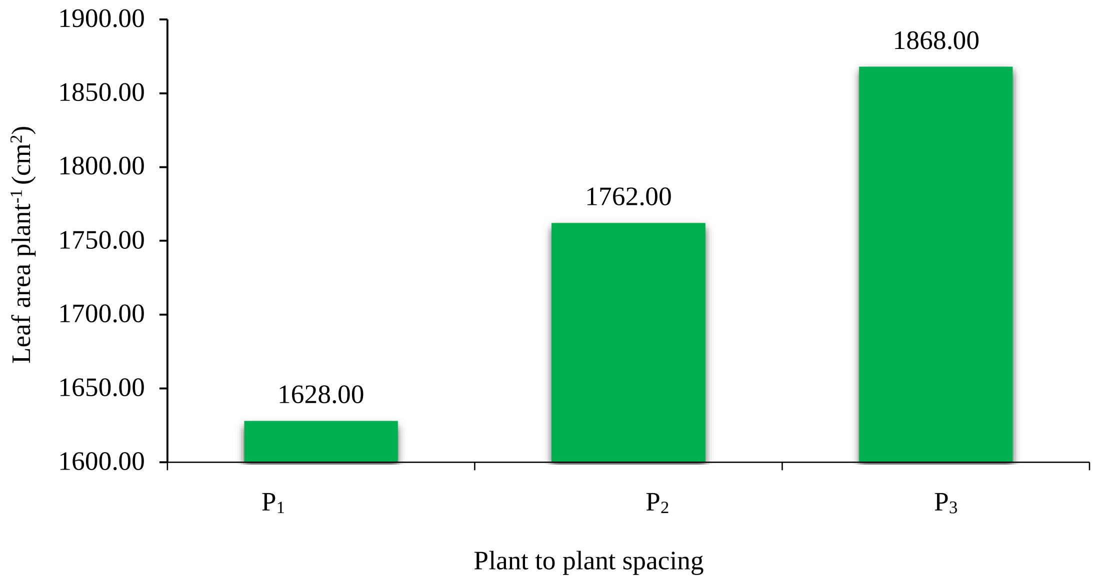

Figure 6: Effect of plant-to-plant spacing on leaf area plant^{-1} (cm^2) of white maize (LSD value = 24.73 at harvesting time)

4.1.3.3 Interaction effect of row spacing and plant spacing

Leaf area plant^{-1} (cm^2) was influenced by the combined effect of row spacing and plant spacing of white maize variety (Table 3 and Appendix IV).

Table 3: Interaction effect of row-to-row spacing and plant-to-plant spacing on leaf area plant^{-1} (cm^2) of white maize

Treatment combination	Leaf area plant^{-1} (cm^2)
40 cm × 15 cm	1377.00 k
40 cm × 20 cm	1484.00 j
40 cm × 25 cm	1552.00 i
45 cm × 15 cm	1562.00 i
45 cm × 20 cm	1621.00 h
45 cm × 25 cm	1675.00 g
50 cm × 15 cm	1724.00 ef
50 cm × 20 cm	1747.00 e
50 cm × 25 cm	1792.00 d
55 cm × 15 cm	1710.00 f
55 cm × 20 cm	1813.00 cd
55 cm × 25 cm	1835.00 c
60 cm × 15 cm	2017.00 b
60 cm × 20 cm	2037.00 b
60 cm × 25 cm	2345.00 a
LSD$_{(0.05)}$	**31.92**
CV (%)	**8.09**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

4.1.4 Cob dry weight plant^{-1} (g)

4.1.4.1 Effect of row spacing

4.1.4.2 Effect of plant spacing

Plant spacing showed a significant variation of cob dry weight plant^{-1} of white maize (Figure 8 and Appendix V).

4.1.4.3 Interaction effect of row spacing and plant spacing

Interaction of row spacing and plant spacing showed significant variation of cob dry weight plant^{-1} (Table 4 and Appendix V).

4.1.5 Stover dry weight plant^{-1} (g)

4.1.5.1 Effect of row spacing

Stover dry weight plant^{-1} (g) of white maize significantly differed due to different row spacing throughout the harvesting stage (Figure 7 and Appendix V).

treatment which was statistically similar (52.80 g) with (45 cm row spacing) treatment.

4.1.5.2 Effect of plant spacing

Stover dry weight plant^{-1} (g) of white maize significantly differed due to different plant spacing throughout the harvesting stage (Figure 8 and Appendix V).

4.1.5.3 Interaction effect of row spacing and plant spacing

Interaction effect of row spacing and plant spacing significantly influenced the stover dry matter weight plant^{-1} of white maize throughout the growing period (Table 4 and Appendix V).

4.1.6 Root dry weight plant^{-1} (g)

4.1.6.1 Effect of row spacing

Row spacing showed a significant variation of root dry weight plant^{-1} of white maize (Figure 7 and Appendix V).

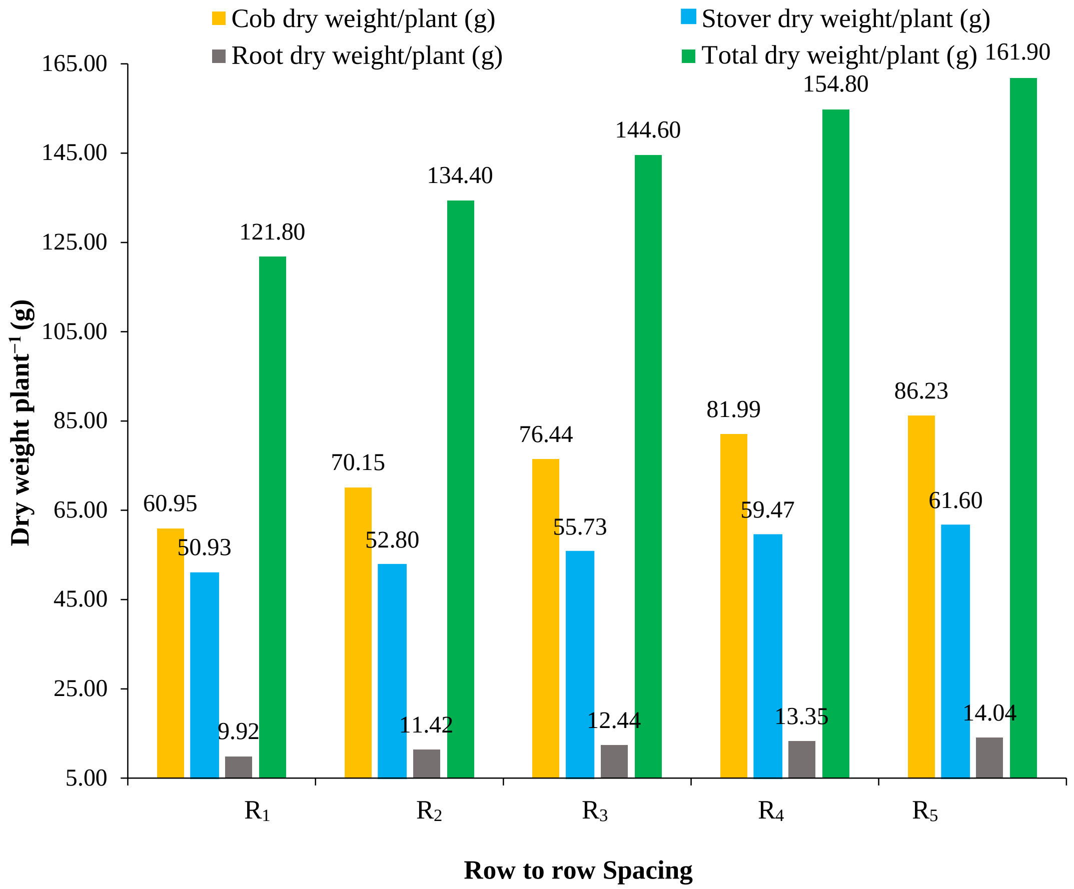

Figure 7: Effect of row-to-row spacing on cob dry weight plant^{-1} (g), stover dry weight plant^{-1} (g), root dry weight plant^{-1} (g) and total dry weight plant^{-1} (g) of white Maize (LSD value = 1.31, 1.95, 0.22 and 2.08, respectively)

4.1.6.2 Effect of plant spacing

Plant spacing showed a significant variation of root dry weight plant^{-1} of white maize (Figure 8 and Appendix V). At harvest stage, 25 cm plant spacing (P_3) showed the maximum root dry weight plant^{-1} (13.02 g); whereas plant spacing 15 cm (P_1) showed the minimum root dry weight plant^{-1} (11.42 g).

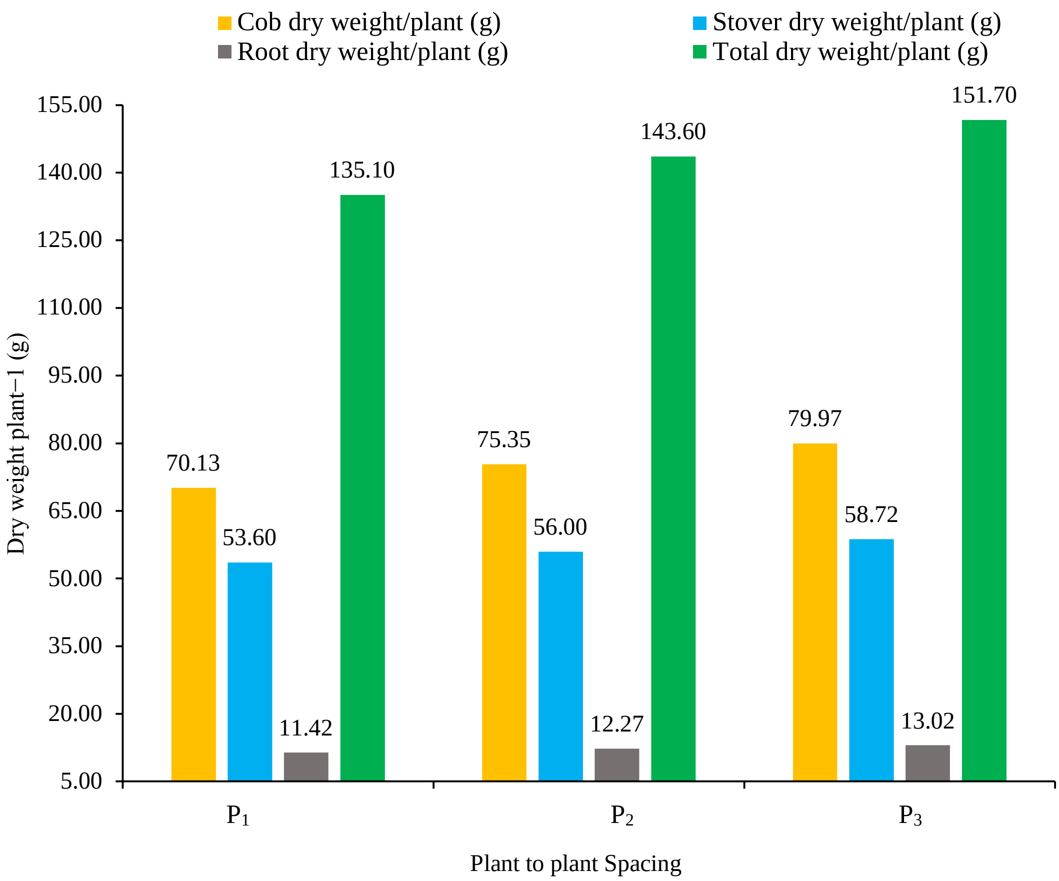

Figure 8: Effect of plant-to-plant spacing on cob dry weight plant^{-1} (g), stover dry weight plant^{-1} (g), root dry weight plant^{-1} (g) and total dry weight plant^{-1} (g) of white maize (LSD value = 1.01, 1.51, 0.17 and 1.61, respectively)

4.1.6.3 Interaction effect of row spacing and plant spacing

Interaction of row spacing and plant spacing showed significant variation of root dry weight plant^{-1} (Table 4 and Appendix V).

4.1.7 Total dry weight plant^{-1} (g)

4.1.7.1 Effect of row spacing

Total dry weight plant^{-1} (g) of white maize significantly differed due to different row spacing throughout the harvesting stage (Figure 7 and Appendix V). Result showed that, the maximum total dry weight plant^{-1} (161.90 g) was produced by R_5 (60 cm row spacing) which was statistically second maximum (154.80 g) with R_4 (55 cm row spacing) treatment. On the other hand, the minimum total dry weight plant^{-1} (121.80 g) was produced by R_1 (40 cm row spacing) which was statistically second minimum (134.40 g) with R_2 (45 cm row spacing) treatment. This result was conformity with the results of Dutta *et al*. (2015) and Jiotode *et al*. (2002) who revealed that, higher dry matter plant^{-1} (DMP) accumulation was found at wider plant spacing. Higher DMP at wider spacing can be attributed to more dry matter accumulation per plant at wider spacing. At wider spacing there was less intra plant competition for light, water and nutrient elements which ensure better growth and development of crop plant and accumulation of more dry matter than the narrower plant spacing. Similar results were also reported by Archana and Bai (2016) and Golada *et al.* (2013).

4.1.7.2 Effect of plant spacing

Total dry weight plant^{-1} (g) of white maize significantly altered due to different plant spacing throughout the harvesting stage (Figure 8 and Appendix V). Zarapkar (2006) also found that dry matter accumulation per plant was higher in case of wider spacings compared to closer spacings. Similar results were also observed by Bairagi *et al*. (2015) and Chamroy *et al*. (2017).

4.1.7.3 Interaction effect of row spacing and plant spacing

Interaction effect of row spacing and plant spacing significantly influenced the total dry matter weight plant^{-1} of white maize throughout the growing period (Table 4 and Appendix V). A plant forms adequate number of leaves and branches when it has adequate supplies of light, nutrients and water. Closer spacing in a cropped field, may lead to greater reduction in dry matter accumulation because of competition for nutrients and other growth factors. Earlier reports of Makinde and Alabi (2002) and Sterner (1984) support this observation.

Table 4: Interaction effect of row-to-row spacing and plant-to-plant spacing on cob dry weight plant^{-1} (g), stover dry weight plant^{-1} (g), root dry weight plant^{-1} (g) and total dry weight plant^{-1} (g) of white maize

Treatment combination	Cob dry weight plant^{-1} (g)	Stover dry weight plant^{-1} (g)	Root dry weight plant^{-1} (g)	Total dry weight plant^{-1} (g)
40 cm × 15 cm	53.57 k	48.00 i	8.72 l	110.30 k
40 cm × 20 cm	61.28 j	50.40 h	9.98 k	121.70 j
40 cm × 25 cm	68.00 h	54.40 e-g	11.07 i	133.50 h
45 cm × 15 cm	64.52 i	50.40 h	10.50 j	125.40 i
45 cm × 20 cm	68.97 h	52.80 g	11.23 i	133.00 h
45 cm × 25 cm	76.95 f	55.20 ef	12.53 g	144.70 f
50 cm × 15 cm	72.10 g	53.60 fg	11.74 h	137.40 g
50 cm × 20 cm	76.44 f	56.00 de	12.44 g	144.90 f
50 cm × 25 cm	80.77 d	57.60 d	13.15 e	151.50 d
55 cm × 15 cm	78.50 e	56.00 de	12.78 f	147.30 e
55 cm × 20 cm	83.25 c	60.00 c	13.55 cd	156.80 c
55 cm × 25 cm	84.21 c	62.40 ab	13.71 c	160.30 b
60 cm × 15 cm	81.94 d	60.00 c	13.34 de	155.30 c
60 cm × 20 cm	86.83 b	60.80 bc	14.13 b	161.80 b
60 cm × 25 cm	89.92 a	64.00 a	14.64 a	168.60 a
$LSD_{(0.05)}$	**1.31**	**1.95**	**0.22**	**2.08**
CV (%)	**9.04**	**10.08**	**9.08**	**8.87**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

4.2 Yield contributing characters

4.2.1 Cob length (cm)

4.2.1.1 Effect of row spacing

Different row spacing had significant effect on cob length of white maize (Appendix VI). This finding was directly related with Nand (2015) who reported longest cob observed in R_1 (60 cm). This result also collaborate the findings of Hasan *et al.* (2018), Chamroy *et al.* (2017), Bairagi *et al.* (2015), Ukonze *et al.* (2016), Fanadzo *et al.* (2010), Kunjir *et al.* (2007) and Ramchandrappa *et al.* (2004).

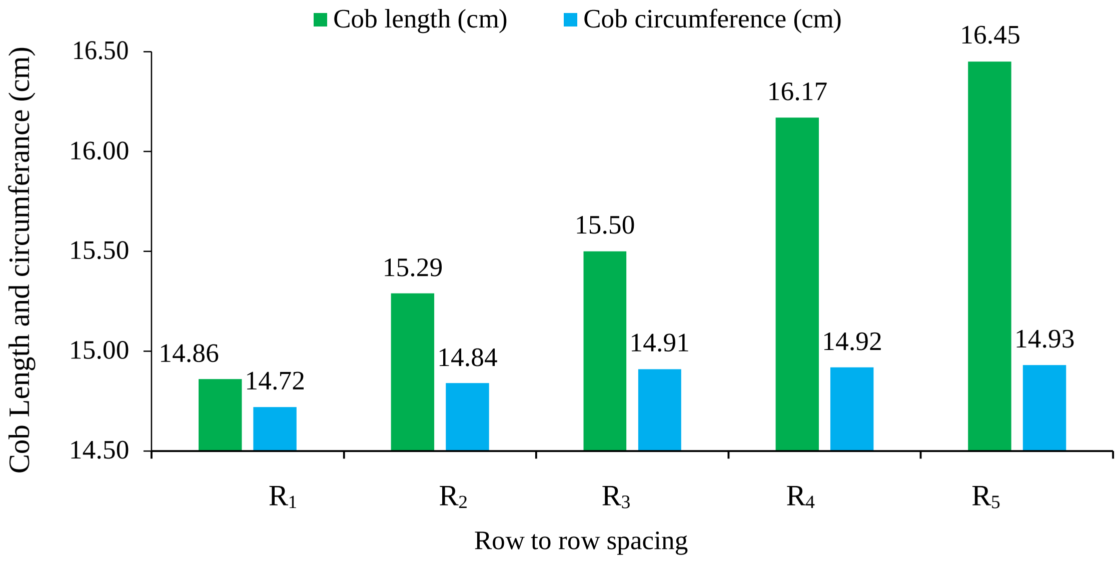

Figure 9: Effect of row to row spacing on cob length (cm) and cob circumference (cm) of white maize (LSD value = 0.31 and NS, respectively)

4.2.1.2 Effect of plant spacing

Different plant spacing had significant effect on cob length of white maize (Appendix VI). Results represented in Figure 10 indicated that the longest cob (15.92 cm) was attained with P_3 (25 cm plant spacing) which was statistically similar (15.69 g) with P_2 (20 cm plant spacing) where the shortest cob (15.36 cm) was with P_1 (15 cm plant spacing). This result was consistent with the findings of Imran *et al.* (2015), Sarjamei *et al.* (2014) and Zhang *et al.* (2006) who reported that cob length significantly varied for plant spacing and cob length reduced by higher plant densities. This might be due to the effect of interplant competition for light, soil water and nutrients (Lashkari *et al.*, 2011).

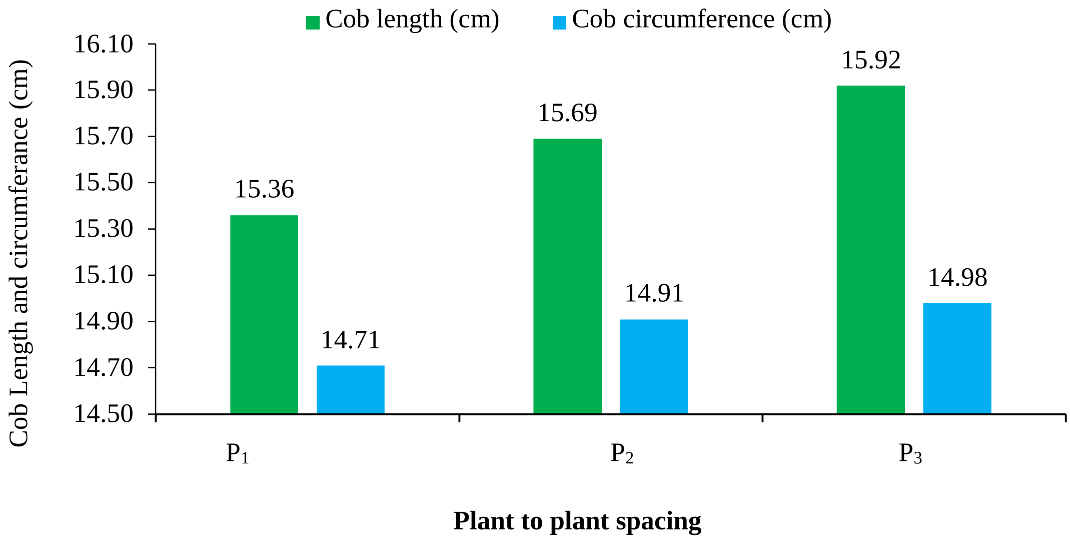

Figure 10: Effect of plant to plant spacing on cob length (cm) and cob circumference (cm) of white maize (LSD value = 0.24 and NS, respectively)

4.2.1.3 Interaction effect of row spacing and plant spacing

Interaction effect of row spacing and plant spacing determined the cob length of white maize (Appendix VI).

4.2.2 Cob circumference (cm)

4.2.2.1 Effect of row spacing

Different row spacing had no significant effect on cob circumference of white maize (Figure 9 and Appendix VI).

4.2.2.2 Effect of plant spacing

Different plant spacing had no significant effect on cob circumference of white maize (Figure 9 and Appendix VI).

4.2.2.3 Interaction effect of row spacing and plant spacing

Interaction effect of row spacing and plant spacing was not influenced the cob circumference of white maize (Appendix VI).

Table 5: Interaction effect of row to row spacing and plant to plant spacing on cob length (cm) and cob circumference (cm) of white maize

Treatment combination	Cob length (cm)	Cob circumference (cm)
40 cm × 15 cm	14.21 g	14.40
40 cm × 20 cm	15.00 f	14.87
40 cm × 25 cm	15.38 e	14.90
45 cm × 15 cm	15.00 f	14.70
45 cm × 20 cm	15.30 ef	14.83
45 cm × 25 cm	15.58 de	15.00
50 cm × 15 cm	15.40 e	14.80
50 cm × 20 cm	15.50 e	14.93
50 cm × 25 cm	15.61 de	15.00
55 cm × 15 cm	15.89 cd	14.86
55 cm × 20 cm	16.12 bc	14.90
55 cm × 25 cm	16.50 a	15.00
60 cm × 15 cm	16.30 ab	14.80
60 cm × 20 cm	16.51 a	15.00
60 cm × 25 cm	16.55 a	15.00
$LSD_{(0.05)}$	**0.32**	**NS**
CV (%)	**6.20**	**8.67**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

4.2.3 Grain weight plant^{-1} (g)

4.2.3.1 Effect of row spacing

Different row spacing had significant effect on grain weight plant^{-1} of white maize (Appendix VIIThe grain weight plant^{-1} range from 54.13 g to 75.47 g.

4.2.3.2 Effect of plant spacing

Different plant spacing had significant effect on grain weight plant^{-1} of white maize (Appendix VII). The grain weight plant^{-1} range from 60.80 g to 69.44 g.

4.2.3.3 Interaction effect of row spacing and plant spacing

Interaction effect of row spacing and plant spacing determined the grain weight plant^{-1} of white maize (Appendix VII).

4.2.4 Shell weight plant^{-1} (g)

4.2.4.1 Effect of row spacing

Shell weight plant^{-1} was significantly affected by different row spacing of white maize (Figure 11 and Appendix VII).

4.2.4.2 Effect of plant spacing

Shell weight plant^{-1} was significantly affected by different plant spacing of white maize (Figure 12 and Appendix VII).

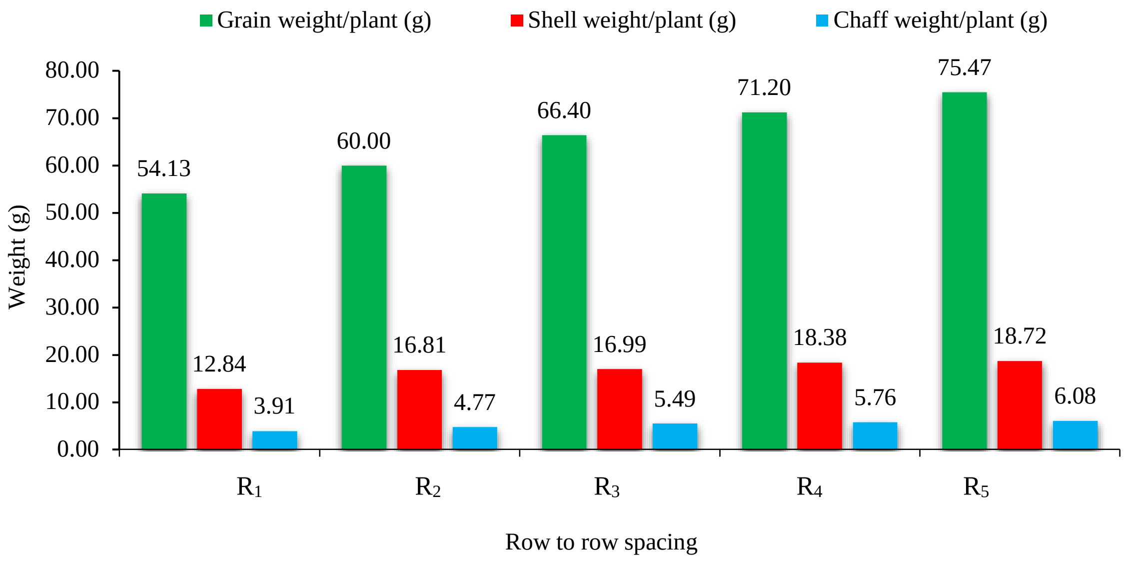

Figure 11: Effect of row-to-row spacing on grain weight plant^{-1} (g), shell weight plant^{-1} (g) and chaff weight plant^{-1} (g) of white maize (LSD value = 1.45, 0.44, 0.43 and 2.25, respectively)

4.2.4.3 Interaction effect of row spacing and plant spacing

Combined effect of row spacing and plant spacing showed significant variation in respect of shell weight plant^{-1} of white maize (Table 6 and Appendix VII).

4.2.5 Chaff weight plant^{-1} (g)

4.2.5.1 Effect of row spacing

Different row spacing had significant effect on chaff weight plant^{-1} of white maize (Appendix VII). Results represented in Figure 11 indicated that the highest chaff weight plant^{-1} (6.08 g) was attained with R_5 (60 cm spacing) which was statistically similar with R_4 (5.76 g) and R_3 (5.49 g) whereas, the lowest chaff weight plant^{-1} (3.91 g) was with R_1 (40 cm spacing) followed by R_2 (45 cm spacing).

4.2.5.2 Effect of plant spacing

Different plant spacing had significant effect on chaff weight plant^{-1} of white maize (Appendix VII). Results represented in Figure 12 indicated that the highest chaff weight plant^{-1} (5.66 g) was attained with P_3 (25 cm spacing) whereas, the lowest chaff weight plant^{-1} (4.94 g) was with P_1 (15 cm spacing) which was statistically similar with P_2 (5.00 g).

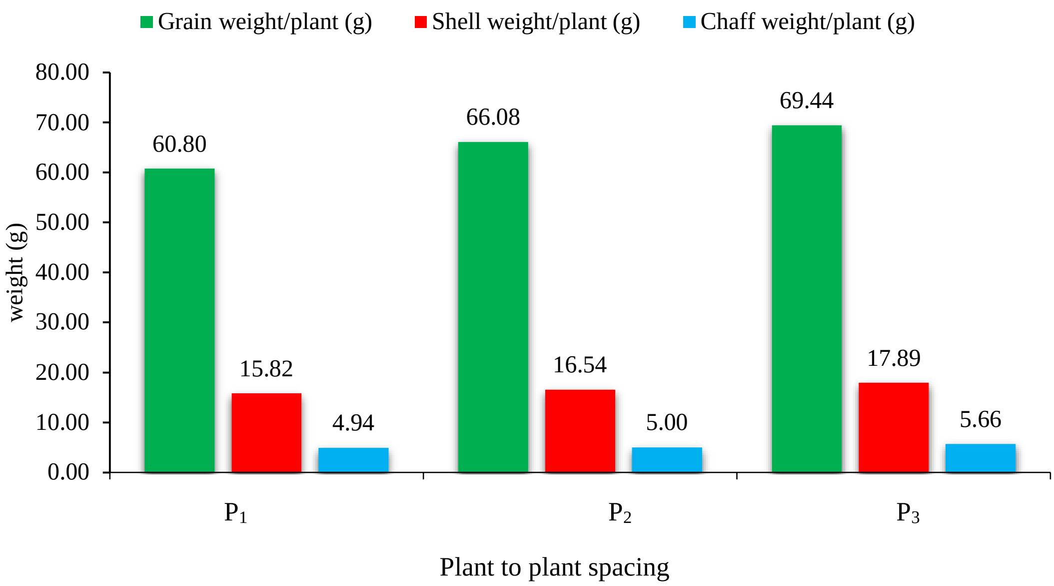

Figure 12: Effect of plant-to-plant spacing on grain weight plant^{-1} (g), shell weight plant^{-1} (g) and chaff weight plant^{-1} (g) of white maize (LSD value = 1.13, 0.34, 0.34 and 1.75, respectively)

Table 6: Interaction effect of row to row spacing and plant to plant spacing on grain weight plant^{-1} (g), shell weight plant^{-1} (g) and chaff weight plant^{-1} (g) of white maize

Treatment combination	Grain weight plant^{-1} (g)	Shell weight plant^{-1} (g)	Chaff weight plant^{-1} (g)
40 cm × 15 cm	46.40 k	11.48 i	4.45 cd
40 cm × 20 cm	56.00 j	12.49 h	2.77 e
40 cm × 25 cm	60.00 h	14.56 g	4.50 cd
45 cm × 15 cm	55.20 j	15.60 f	4.27 d
45 cm × 20 cm	58.40 i	17.16 d	4.64 cd
45 cm × 25 cm	66.40 f	17.68 c	5.40 b
50 cm × 15 cm	62.40 g	16.64 e	4.80 c
50 cm × 20 cm	68.00 e	15.60 f	5.28 b
50 cm × 25 cm	68.80 e	18.72 b	6.40 a
55 cm × 15 cm	68.00 e	17.68 c	5.60 b
55 cm × 20 cm	72.00 d	18.72 b	6.08 a
55 cm × 25 cm	73.60 c	18.74 b	5.60 b
60 cm × 15 cm	72.00 d	17.68 c	5.60 b
60 cm × 20 cm	76.00 b	18.72 b	6.24 a
60 cm × 25 cm	78.40 a	19.75 a	6.40 a
$LSD_{(0.05)}$	**1.45**	**0.44**	**0.43**
CV (%)	**6.33**	**6.56**	**9.98**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.2.5.3 Interaction effect of row spacing and plant spacing

Interaction effect of row spacing and plant spacing determined the chaff weight plant^{-1} of white maize (Appendix VII).

4.2.6 Number of rows cob^{-1}

4.2.6.1 Effect of row spacing

Significant influence was noted on number of rows cob^{-1} affected by different row spacing (Table 7 and Appendix VIII). The number of rows cob^{-1} range from 12.47 to 14.00. Abuzar *et al.* (2011) and Kunjir *et al*. (2007) found similar result on number of rows cob^{-1}.

4.2.6.2 Effect of plant spacing

Significant influence was noted on number of rows cob^{-1} affected by different plant spacing (Table 8 and Appendix VIII). The number of rows cob^{-1} range from 12.72 to 13.92. This is similar to the findings of Sharifai *et al*. (2012) and Abuzar *et al.* (2011) who reported that the treatments having less population produced the highest number of rows cob^{-1}.

4.2.6.3 Interaction effect of row spacing and plant spacing

Number of rows cob^{-1} was found to be significantly influenced by the treatment combination of row spacing and plant spacing (Table 9 and Appendix VIII).

Table 7: Effect of row-to-row spacing on no. of rows cob^{-1}, no. of grain rows cob^{-1} and no. of grains cob^{-1} of white maize

Treatments	No. of rows cob^{-1}	No. of grain rows cob^{-1}	No. of grains cob^{-1}
40 cm	12.47 d	22.80 d	285.40 d
45 cm	13.00 c	24.47 c	320.00 c
50 cm	13.47 bc	30.27 b	408.10 b
55 cm	13.60 ab	31.60 a	430.70 ab
60 cm	14.00 a	31.51 a	442.40 a
$LSD_{(0.05)}$	**0.48**	**1.20**	**23.16**
CV (%)	**9.16**	**9.55**	**10.67**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.2.7 Number of grain rows cob^{-1}

4.2.7.1 Effect of row spacing

Row spacing showed a significant variation in respect of the no. of grain rows cob^{-1} (22.80) which was statistically different from others. This is similar to the findings of Abuzar *et al.* (2011) who reported that the highest plant density negatively affected number of grain rows cob^{-1}.

4.2.7.2 Effect of plant spacing

Plant spacing showed a significant variation in respect of the no. of grain rows cob^{-1} (Table 8 and Appendix VIII).

4.2.7.3 Interaction effect of row spacing and plant spacing

Interaction of row spacing and plant spacing showed significant variation in respect of the no. of grain rows cob^{-1} (Table 9 and Appendix VIII).

Table 8: Effect of plant-to-plant spacing on no. of rows cob^{-1}, no. of grain rows cob^{-1} and no. of grains cob^{-1} of white maize

Treatments	No. of rows cob^{-1}	No. of grain rows cob^{-1}	No. of grains cob^{-1}
15 cm	12.72 c	24.87 c	318.30 c
20 cm	13.28 b	29.12 b	389.30 b
25 cm	13.92 a	30.40 a	424.30 a
LSD$_{(0.05)}$	**0.37**	**0.93**	**17.94**
CV (%)	**9.16**	**9.55**	**10.67**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.2.8 Number of grains cob^{-1}

4.2.8.1 Effect of row spacing

Different row spacing had significant effect on no. of grains cob^{-1} of white maize (Table 7 and Appendix VIII). The number of grains cob^{-1} range from 285.40 to 442.40. This result also collaborate the findings of Akbar *et al*. (2016) and Hasan *et al.* (2018). This is similar to the findings of Mechi (2015), Enujeke (2013b), Shafi *et al.* (2012) and Abuzar *et al.* (2011) who reported that the highest plant density negatively affected number of grains cob^{-1}.

4.2.8.2 Effect of plant spacing

Different plant spacing had significant effect on no. of grains cob^{-1} of white maize (Table 8 and Appendix VIII). The number of grains cob^{-1} range from 318.30 to 424.30. Results represented in Table 8 indicated that the increasing plant population, number of grains cob^{-1} decreased in a linear manner.

4.2.8.3 Interaction effect of row spacing and plant spacing

Table 9 and Appendix VIII represent the result of interaction effect of row spacing and plant spacing on number of grains cob^{-1} of white maize.

Table 9: Interaction effect of row-to-row spacing and plant-to-plant spacing on no. of rows cob^{-1}, no. of grain rows cob^{-1} and no. of grains cob^{-1} of white maize

Treatment combination	No. of rows cob^{-1}	No. of grain rows cob^{-1}	No. of grains cob^{-1}
40 cm × 15 cm	12.00 d	19.00 i	228.00 h
40 cm × 20 cm	12.20 d	24.00 g	292.80 f
40 cm × 25 cm	13.20 bc	25.40 f	335.30 e
45 cm × 15 cm	12.20 d	20.80 h	253.90 g
45 cm × 20 cm	12.80 c	25.40 f	325.30 e
45 cm × 25 cm	14.00 a	27.20 e	380.80 d
50 cm × 15 cm	13.20 bc	27.20 e	359.00 d
50 cm × 20 cm	13.20 bc	31.60 c	417.10 c
50 cm × 25 cm	14.00 a	32.00 c	448.00 b
55 cm × 15 cm	12.80 c	29.40 d	376.50 d
55 cm × 20 cm	14.00 a	32.00 c	448.00 b
55 cm × 25 cm	14.00 a	33.40 ab	467.60 ab
60 cm × 15 cm	13.40 b	27.93 e	374.20 d
60 cm × 20 cm	14.20 a	32.60 bc	463.30 b
60 cm × 25 cm	14.40 a	34.00 a	489.60 a
$LSD_{(0.05)}$	**0.48**	**1.20**	**23.16**
CV (%)	**9.16**	**9.55**	**10.67**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

4.3 Yield characters

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

4.3.1.1 Effect of row spacing

Different row spacing significantly affected the result of grain yield of white maize (Appendix IX). Generally, grain yield increased with increasing planting density (Akbar *et al.*, 2016). This finding was directly related with Nand (2015) who reported maximum grain yield observed in 60 cm spacing. This result also related with the findings of Golla *et al.* (2018); Hasan *et al.* (2018) and Fanadzo *et al.* (2010).

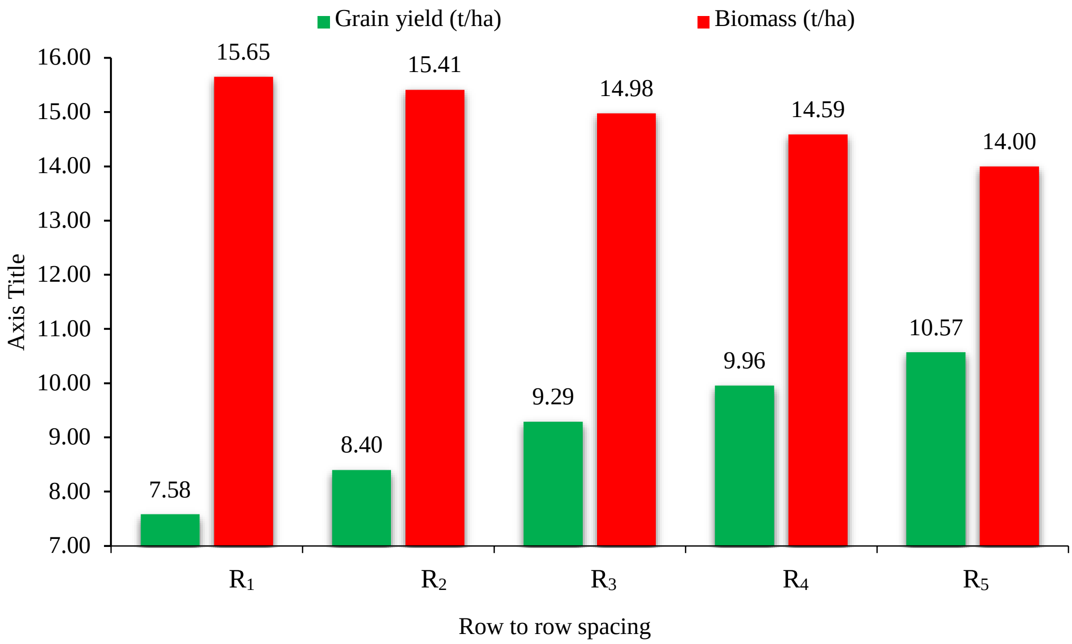

Figure 13: Effect of row-to-row spacing on grain yield (t ha^{-1}) and biomass (t ha^{-1}) of white maize (LSD value = 0.36 and 0.31, respectively)

4.3.1.2 Effect of plant spacing

Different plant spacing significantly affected the result of grain yield of white maize (Appendix IX). Increasing plant population decreased the production of grain due to the competition for nutrients and other growth factors. The result obtained from the present study was similar with the findings of Kunjir (2007), Golada *et al*. (2013) and Bairagi *et al*. (2015).

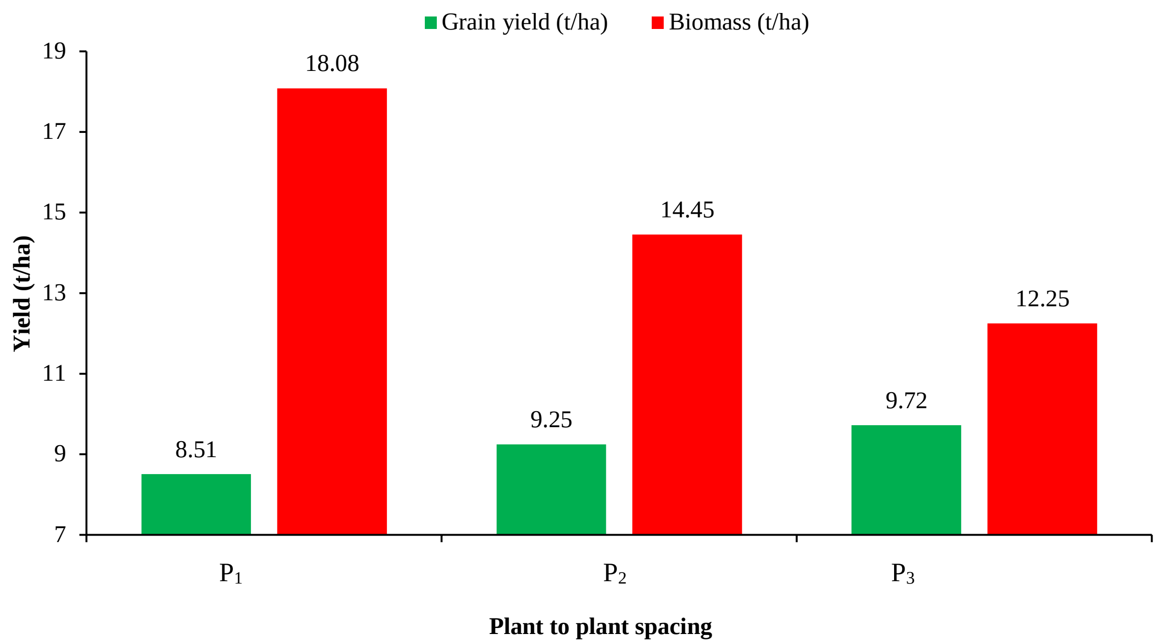

Figure 14: Effect of plant-to-plant spacing on grain yield (t ha^{-1}) and biomass (t ha^{-1}) of white maize (LSD value = 0.28 and 0.24, respectively)

4.3.1.3 Interaction effect of row spacing and plant spacing

Interaction effect of row spacing and plant spacing influenced significantly the grain yield of white maize (Appendix IX).

4.3.2 Biomass (t ha^{-1})

4.3.2.1 Effect of row spacing

Row spacing showed a significant variation in respect of biomass of white maize (Figure 13 and Appendix IX). Increasing plant population increased the biomass due to the competition for nutrients and other growth factors. The result obtained by Hasan *et al.* (2018) and Tahmina (2018) was similar with the present findings.

4.3.2.2 Effect of plant spacing

Plant spacing showed a significant variation in respect of biomass of white maize (Figure 14 and Appendix IX). This is similar to the findings of Mechi (2015), Shafi *et al.* (2012) and Abuzar *et al.* (2011) who reported that the increasing planting density had a positive impact on biomass.

4.3.2.3 Interaction effect of row spacing and plant spacing

Combination effect of row spacing and plant spacing showed significant variation in respect of biomass of white maize (Table 10 and Appendix IX). Similar findings were achieved by Kunjir (2007), Golada *et al*. (2013) and Bairagi *et al*. (2015).

Table 10: Interaction effect of row to row spacing and plant to plant spacing on grain yield (t ha^{-1}) and biomass (t ha^{-1}) of white maize

Treatment combination	Grain yield (t ha^{-1})	Biomass (t ha^{-1})
40 cm × 15 cm	6.50 i	18.59 a
40 cm × 20 cm	7.84 gh	15.21 d
40 cm × 25 cm	8.40 ef	13.35 g
45 cm × 15 cm	7.73 h	18.38 a
45 cm × 20 cm	8.18 fg	14.78 e
45 cm × 25 cm	9.30 d	12.86 h
50 cm × 15 cm	8.74 e	18.33 a
50 cm × 20 cm	9.51 d	14.50 ef
50 cm × 25 cm	9.63 d	12.12 i
55 cm × 15 cm	9.51 d	17.85 b
55 cm × 20 cm	10.08 c	14.25 f
55 cm × 25 cm	10.30 bc	11.66 j
60 cm × 15 cm	10.08 c	17.25 c
60 cm × 20 cm	10.64 ab	13.49 g
60 cm × 25 cm	10.98 a	11.25 k
LSD$_{(0.05)}$	**0.36**	**0.31**
CV (%)	**7.36**	**6.23**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.3.3 Harvest index (%)

4.3.3.1 Effect of row spacing

Harvest index was significantly affected by different row spacing of white maize (Figure 15 and Appendix IX). Shafi *et al*. (2012) found similar result, which supported the present study.

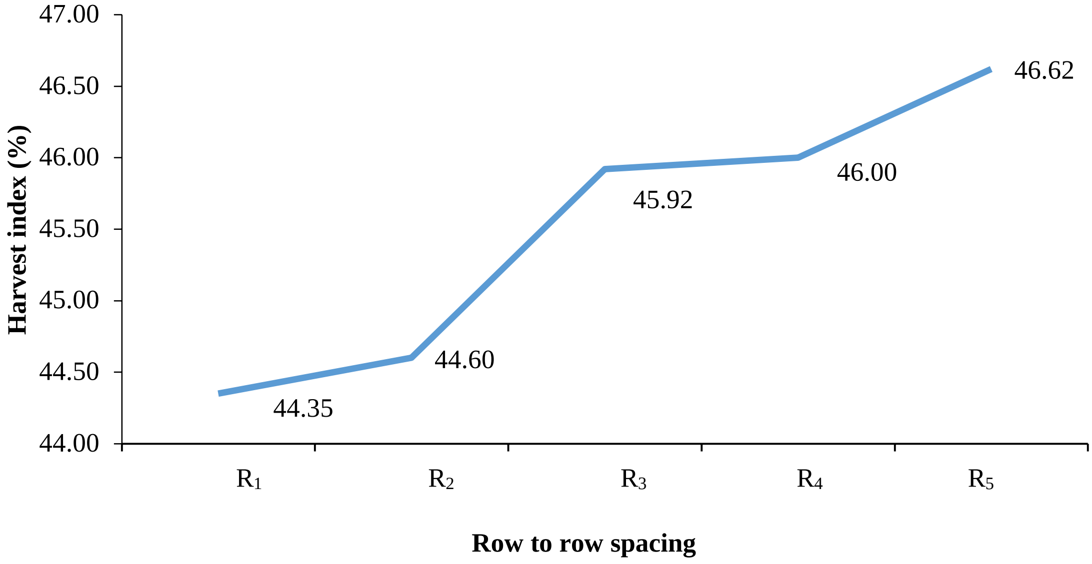

Figure 15: Effect of row-to-row spacing on harvest index (%) of white maize (LSD value =1.87 at harvesting time)

4.3.3.2 Effect of plant spacing

Harvest index was not significantly affected by different plant spacing of baby corn (Figure 16 and Appendix IX)

This is similar to the findings of Mechi (2015).

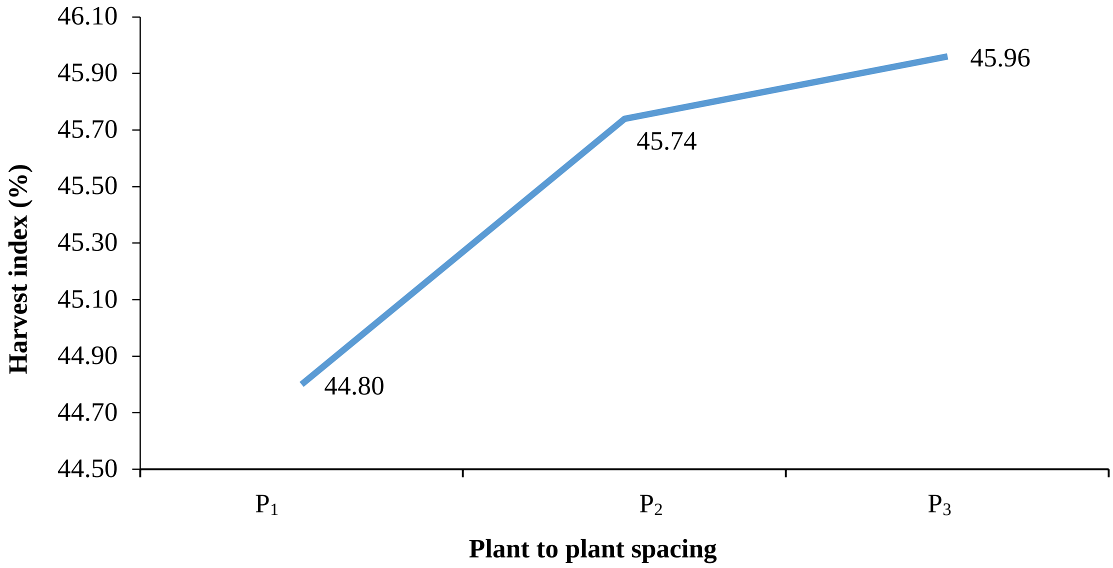

Figure 16: Effect of plant-to-plant spacing on harvest index (%) of white maize (LSD value = NS at harvesting time)

4.3.3.3 Interaction effect of row spacing and plant spacing

Interaction effect of row spacing and plant spacing on harvest index of white maize is presented in Table 11 and Appendix IX.

Table 11: Interaction effect of row-to-row spacing and plant-to-plant spacing on harvest index (%) of white maize

Treatment combination	**Harvest index (%)**
40 cm × 15 cm	42.07 d
40 cm × 20 cm	46.03 ab
40 cm × 25 cm	44.96 bc
45 cm × 15 cm	44.00 c
45 cm × 20 cm	43.91 cd
45 cm × 25 cm	45.89 ab
50 cm × 15 cm	45.40 a-c
50 cm × 20 cm	46.94 a
50 cm × 25 cm	45.41 a-c
55 cm × 15 cm	46.17 ab
55 cm × 20 cm	45.92 ab
55 cm × 25 cm	45.91 ab
60 cm × 15 cm	46.37 ab
60 cm × 20 cm	46.98 a
60 cm × 25 cm	46.51 ab
$LSD_{(0.05)}$	1.87
CV (%)	7.45

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

CHAPTER V

SUMMARY AND CONCLUSIONS

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from October, 2018 to February 2019 in Rabi season to study the growth, phenology and yield attributes and yield of a maize genotype SAUWMOP DT61G different planting configuration in Rabi season. The experimental field belongs to the Agro-ecological zone (AEZ) of “The Madhupur Tract”, AEZ-28. The soil of the experimental field belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. The planting materials was SAUD 18-3-3. It was the white maize. The seeds were collected from the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh. October 2018 was sowing date and 22 February 2019 was harvesting date.

The experiment comprised of two factors, Factor A: five levels of row spacing and Factor B: three levels of plant spacing. This two factor experiments were included 15 treatment combinations. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Total 45 unit plots were made for the experiment with 15 treatments. Vermicompost was used @ 2 t ha^{-1} before final land preparation. The field was fertilized with nitrogen, phosphate, potash, sulphur, zinc and boron at the rate of 500-250-200-250−15-5 kg ha^{-1} of urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid.

Data were collected on the following parameters-plant height (cm), plant density (No. m^{-2}), leaf area $plant^{-1}$ (cm^2), cob dry matter $plant^{-1}$ (g), stover dry matter $plant^{-1}$ (g), root dry matter $plant^{-1}$ (g), total dry matter $plant^{-1}$ (g), cob length (cm), cob breadth (cm), grain weight $plant^{-1}$ (g), shell weight $plant^{-1}$ (g), chaff weight $plant^{-1}$ (g), total cob weight $plant^{-1}$ (g), number of rows cob^{-1} (no.), number of grain rows cob^{-1} (no.), number of grains cob^{-1} (no.), grain yield (t ha^{-1}), biomass (t ha^{-1}) and harvest index (%). The collected data were analysed by computer package program MSTAT-C software. The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability.

Effect of row spacing showed significant variation on plant height, plant density, leaf area plant^{-1}, cob dry matter plant^{-1}, stover dry matter plant^{-1}, root dry matter plant^{-1}, total dry matter plant^{-1}, cob length, grain weight plant^{-1}, shell weight plant^{-1}, chaff weight plant^{-1}, total cob weight plant^{-1}, number of rows cob^{-1}, number of grain rows cob^{-1}, number of grains cob^{-1},grain yield, biomass and harvest index for harvesting stages of white maize except cob breadth.60 cm row spacing (R_5) showed the tallest plant (142.50 cm), highest cob dry weight plant^{-1} (86.23 g),highest stover dry weight plant^{-1} (61.60 g),maximum root dry weight plant^{-1} (14.04 g), maximum total dry weight plant^{-1} (161.90 g),longest cob length (16.45 cm),maximum cob breadth (14.93 cm), highest grain weight plant^{-1} (75.47 g),maximum shell weight plant^{-1} (18.72 g), highest chaff weight plant^{-1} (6.08 g), maximum total cob weight plant^{-1} (100.30 g),maximum number of rows cob^{-1} (14.00), maximum no. of grain rows cob^{-1} (31.60),height no. of grains cob^{-1} (442.40), highest grain yield (10.57 t ha^{-1}) and maximum harvest index (46.62 %). On the other hand, 40 cm row spacing (R_1) showed the shortest plant (131.60 cm), lowest cob dry weight plant^{-1} (60.95 g), lowest stover dry weight plant^{-1} (50.93 g),minimum root dry weight plant^{-1} (9.92 g),minimum total dry weight plant^{-1} (121.80 g),shortest cob length (14.86 cm),minimum cob breadth (14.72 cm),lowest grain weight plant^{-1} (54.13 g),minimum shell weight plant^{-1} (12.84 g),lowest chaff weight plant^{-1} (3.91 g), minimum total cob weight plant^{-1} (70.88 g), least number of rows cob^{-1} (12.47), minimum no. of grain rows cob^{-1} (22.80),lowest no. of grains cob^{-1} (285.400), lowest grain yield(7.58 t ha^{-1}) and minimum harvest index (44.35 %). 40 cm (R_1) showed the highest number of plant density (13.06 m^{-2}), maximum leaf area plant^{-1} (2133.00 cm^2) and maximum biomass (15.65 t ha^{-1}) whereas, 60 cm (R_5) showed the lowest number of plant density (8.70 m^{-2}), minimum leaf area $plant^{-1}$ (1520.00 cm^2) and minimum biomass (14.00 t ha^{-1}).

Effect of plant spacing showed significant variation on plant height, plant density, leaf area $plant^{-1}$, cob dry matter $plant^{-1}$, stover dry matter $plant^{-1}$, root dry matter $plant^{-1}$, total dry matter $plant^{-1}$, cob length, grain weight $plant^{-1}$, shell weight $plant^{-1}$, chaff weight $plant^{-1}$, total cob weight $plant^{-1}$, number of rows cob^{-1}, number of grain rows cob^{-1}, number of grains cob^{-1},grain yield and biomass for harvesting stages of white maize except cob breadth and harvest index.15 cm plant spacing showed the tallest plant (140.80 cm), highest number of plant density (13.61 m^{-2}),maximum leaf area $plant^{-1}$ (1868.00 cm^2) and maximum biomass (18.08 t ha^{-1}); whereas plant spacing 25 cm showed the shortest plant (132.00 cm), lowest number of plant density (8.17 m^{-2}),minimum leaf area $plant^{-1}$ (1628.00 cm^2) and minimum biomass (12.25 t ha^{-1}).25 cm plant spacing (P_3) showed the highest cob dry weight $plant^{-1}$ (79.97 g), highest stover dry weight $plant^{-1}$ (58.72 g), maximum root dry weight $plant^{-1}$ (13.02 g), maximum total dry weight $plant^{-1}$ (151.70 g), longest cob length (15.92 cm),maximum cob breadth (14.98 cm), highest grain weight $plant^{-1}$ (69.44 g),maximum shell weight $plant^{-1}$ (17.89 g), highest chaff weight $plant^{-1}$ (5.66 g), maximum total cob weight $plant^{-1}$ (92.99 g), maximum number of rows cob^{-1} (13.92), maximum no. of grain rows cob^{-1} (30.40), height no. of grains cob^{-1} (424.30), highest grain yield (9.72 t ha^{-1}) and maximum harvest index (45.96 %); whereas plant spacing 15 cm showed the lowest cob dry weight $plant^{-1}$ (70.13 g), lowest stover dry weight $plant^{-1}$ (53.60 g),minimum root dry weight $plant^{-1}$ (11.42 g),minimum total dry weight $plant^{-1}$ (135.10 g),shortest cob length (15.36 cm),minimum cob breadth (14.71 cm),lowest grain weight $plant^{-1}$ (60.80 g),minimum shell weight $plant^{-1}$ (15.82 g), lowest chaff weight $plant^{-1}$ (4.94 g), minimum total cob weight $plant^{-1}$ (81.58 g), least number of rows cob^{-1} (12.72), minimum no. of grain rows cob^{-1} (24.87), lowest no. of grains cob^{-1} (318.30), lowest grain yield (8.51 t ha^{-1}) and minimum harvest index (44.80%).

Interaction effect of different row spacing and plant spacing showed significant results plant height, plant density, leaf area plant^{-1}, cob dry matter plant^{-1}, stover dry matter plant^{-1}, root dry matter plant^{-1}, total dry matter plant^{-1}, cob length, grain weight plant^{-1}, shell weight plant^{-1}, chaff weight plant^{-1}, total cob weight plant^{-1}, number of rows cob^{-1}, number of grain rows cob^{-1}, number of grains cob^{-1} ,grain yield, biomass and harvest index for harvesting stages of white maize except cob breadth. On the other hand, the lowest cob dry matter weight plant^{-1} (53.57 g), lowest stover dry matter weight plant^{-1} (48.00 g), minimum root dry matter weight plant^{-1} (8.72 g), minimum total dry matter weight plant^{-1} (110.30 g), shortest cob length (14.21 cm),minimum cob breadth (14.40 cm), lowest grain weight plant^{-1} (46.40 g),minimum shell weight plant^{-1} (11.48 g), lowest chaff weight plant^{-1} (2.77 g), minimum total cob weight plant^{-1} (62.33 g), least number of rows cob^{-1} (12.00), minimum no.

cm). The results obtained from all other treatments showed intermediate results compared to the highest and the lowest value of all growth and yield parameters.

Conclusion

The combination treatment had the highest grain wt/ha (10.98) which was attributed to the highest values of No. of grain/cob (489.60), Wt/cob (104.60), grain wt./cob (78.40 g), cob length (16.55 cm), cob girth (15.00cm), cob dry wt/plant (89.92 g), stover dry wt/plant (64.00 g), root dry wt./plant (14.64 g) and total dry wt./plant (168.60 g) obtained from this treatment.

However, the yield of the combination treatment (10.64 t/ha) was not significantly lower than that of the combination treatment.

Therefore, to reduce the seed cost the combination treatments may be used for higher profit.

Recommendations

The present experiment was conducted in only one season using a single location. Therefore, it is difficult to recommend this finding without further study. By considering the results of the present experiment, further studies in the following areas are suggested below:

1. Studies of similar nature could be carried out in different Agro Ecological Zones (AEZ) in different seasons of Bangladesh for the evaluation of zonal adaptability.

2. Some wider and narrower spacings may be included in further studies to optimize the population density.

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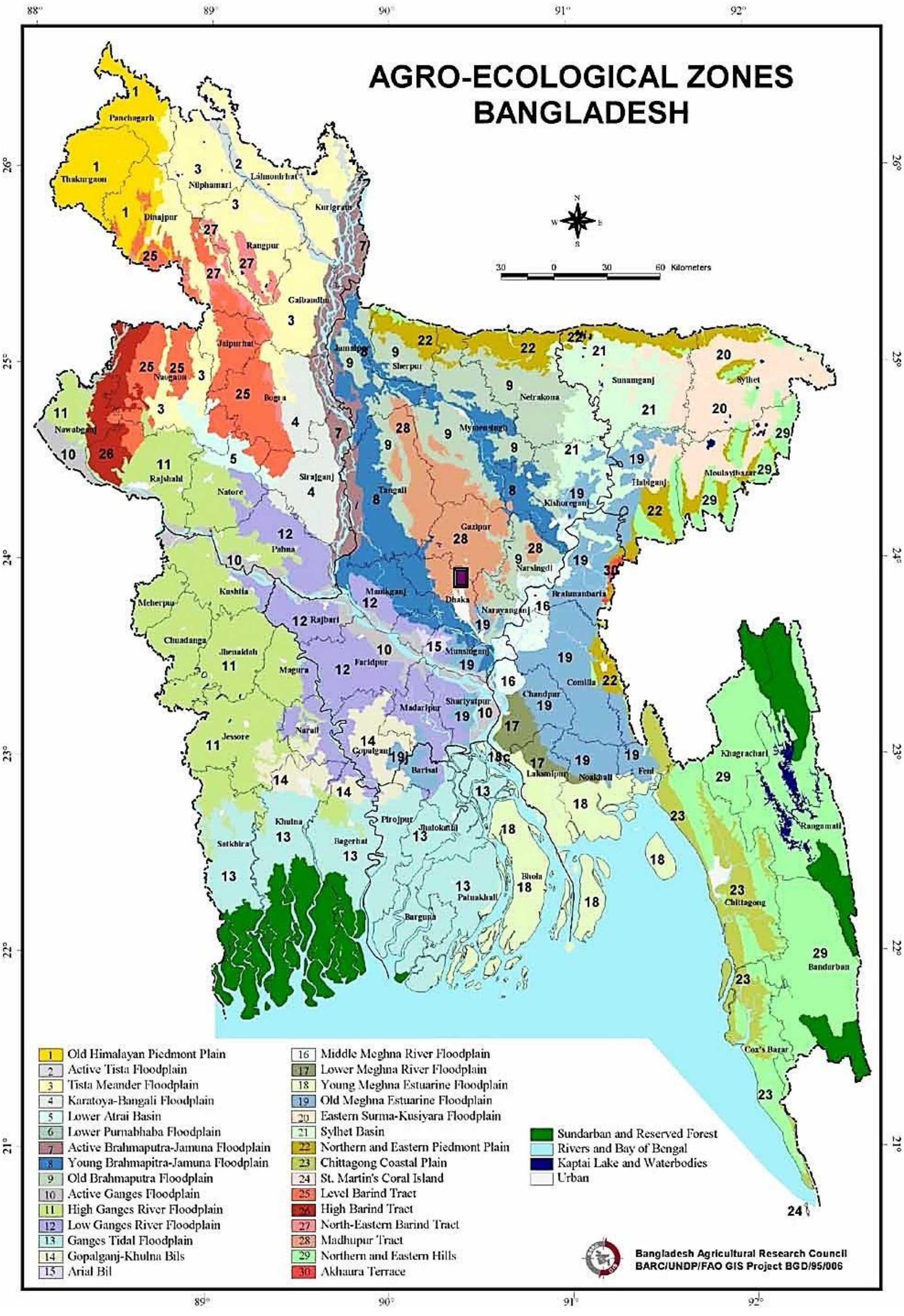
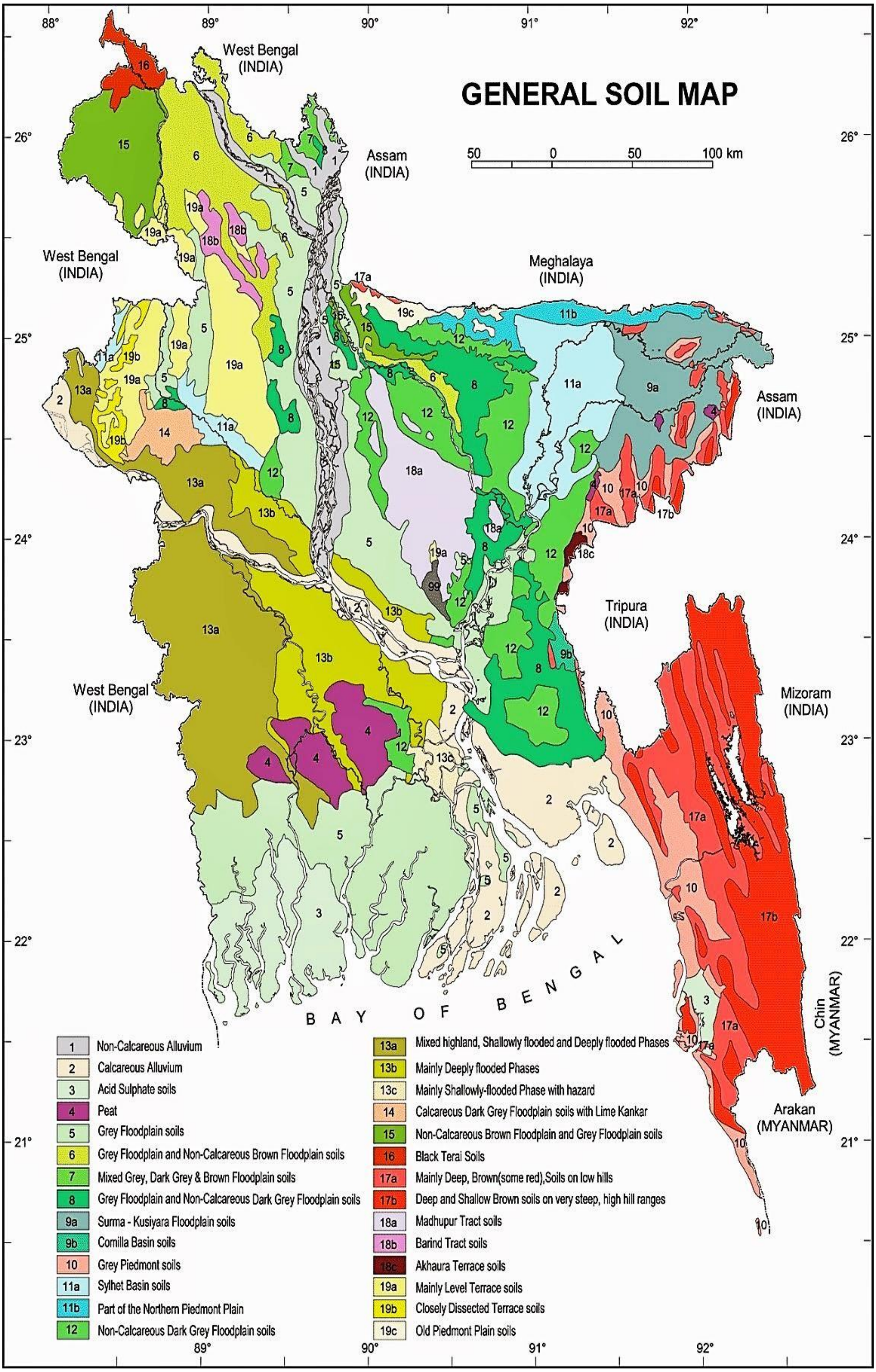
APPENDICES

Appendix I: (A) Map showing the experimental sites under study



The experimental site under study

Appendix I (B): Map showing the general soil sites under study



Appendix II: Characteristics of Agronomy Farm soil is analysed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly levelled
Flood level	Above flood level
Drainage	Well drained
Cropping Pattern	Maize mono cropping

B. Physical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30

C. Chemical properties of the initial soil

Characteristics	Value
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (mel 1.00 g soil)	0.10
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI), 2018.

Appendix III: Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from July to October 2018

Month	Air temperature (^{0}C)		R. H. (%)	Total rainfall (mm)
	Maximum	Minimum		
July, 2018	36.20	23.25	87	145
August, 2018	36.42	25.50	81	121
September, 2018	32.60	21.42	72	98
October, 2018	27.26	16.30	64	43

Source: Bangladesh Metrological Department (Climate and weather division) Agargaon, Dhaka.

Appendix IV: Analysis of variance (ANOVA) of data on plant height, plant density (No. m^{-2}) and Leaf area $plant^{-1}$ of white maize

Source of variation	df	Plant height	Plant density	Leaf area/plant
Replication	2	6.667	0.058	2181.533
Row to Row spacing (A)	4	204.330	26.709	486622.957
Plant to plant spacing (B)	2	320.701	113.376	217171.364
A × B	8	15.988	0.594	13561.168
Error	28	1.703	0.017	364.249

*Significant at 5% level of probability
** Significant at 1% level of probability

Appendix V: Analysis of variance (ANOVA) of data on cob dry weight plant^{-1} , stover dry weight plant^{-1}, root dry weight plant^{1} and total dry weight plant^{-1} of white maize

Source of variation	df	Cob dry weight plant^{-1}	Stover dry weight plant^{-1}	Root dry weight plant^{-1}	Total dry weight plant^{-1}
Replication	2	2.061	8.971	0.048	21.624
Row to Row spacing (A)	4	895.129	178.432	23.696	2295.806
Plant to plant spacing (B)	2	363.859	98.432	9.651	1029.391
A × B	8	11.135	1.792	0.295	18.380
Error	28	0.611	1.365	0.018	1.546

*Significant at 5% level of probability
** Significant at 1% level of probability

Appendix VI: Analysis of variance (ANOVA) of data on cob length and cob breadth of white maize

Source of variation	df	Cob length	Cob breadth
Replication	2	0.248	1.350
Row to Row spacing (A)	4	3.787	0.068
Plant to plant spacing (B)	2	1.203	0.287
A × B	8	0.123	0.026
Error	28	0.035	0.157

*Significant at 5% level of probability

** Significant at 1% level of probability

Appendix VII: Analysis of variance (ANOVA) of data on grain plant^{-1}, shell weight plant^{-1}, chaff weight plant^{-1} and total cob weight plant^{-1} of white maize

Source of variation	df	Grain weight plant^{-1}	Shell weight plant^{-1}	Chaff weight plant^{-1}	Total cob weight plant^{-1}
Replication	2	4.704	0.527	0.353	12.460
Row to Row spacing (A)	4	657.152	49.126	6.821	1211.430
Plant to plant spacing (B)	2	284.544	16.613	2.372	488.588
A × B	8	13.664	1.543	1.081	14.964
Error	28	0.755	0.068	0.067	1.816

*Significant at 5% level of probability

** Significant at 1% level of probability

Appendix VIII: Analysis of variance (ANOVA) of data on no. of rows cob^{-1}, no. of grain rows cob^{-1} and no. of grains cob^{-1} of white maize

Source of variation	df	No. of rows cob^{-1}	No. of grain rows cob^{-1}	No. of grains cob^{-1}
Replication	2	0.523	0.985	1142.511
Row to Row spacing (A)	4	3.132	157.201	44475.739
Plant to plant spacing (B)	2	5.408	125.868	43699.940
A × B	8	0.318	1.171	297.227
Error	28	0.083	0.516	191.744

*Significant at 5% level of probability

** Significant at 1% level of probability

Appendix IX: Analysis of variance (ANOVA) of data on grain yield, biomass and harvest Index of white maize

Source of variation	df	Grain yield	Biomass	Harvest Index
Replication	2	0.444	0.394	2.739
Row to Row spacing (A)	4	12.845	3.905	8.556
Plant to plant spacing (B)	2	5.584	130.150	5.631
A × B	8	0.264	0.204	3.359
Error	28	0.047	0.034	1.245

*Significant at 5% level of probability

** Significant at 1% level of probability

Plate 1: Photograph showing general view of experimental plot with signboard

Plate 2: Photograph showing view of experimental plot at reproductive stage