EFFECT OF LEAF CLIPPING ON PRODUCTIVITY UNDER DIFFERENT POPULATION DENSITIES OF HYBRID MAIZE

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CERTIFICATE

*This is to certify that the thesis entitled **"EFFECT OF LEAF CLIPPING ON PRODUCTIVITY UNDER DIFFERENT POPULATION DENSITIES OF HYBRID MAIZE"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (MS) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **EVANTA AFROZ,** Registration no. **15-06845** 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.

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Dedicated to

My

Beloved Parents

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The Author

EFFECT OF LEAF CLIPPING ON PRODUCTIVITY UNDER DIFFERENT POPULATION DENSITIES OF HYBRID MAIZE

ABSTRACT

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from October-2021 to February-2022 in Rabi season, to study the effect of leaf clipping at reproductive stage on productivity under different population densities of hybrid maize. The experiment consisted of two factors, and followed Randomized Complete Block Design (RCBD) with three replications. Factor A: Population density (4 levels) *viz:* P_1 = 60 cm × 15 cm (1,10,000 plants ha^{-1}), P_2 = 60 cm × 20 cm (83,000 plants ha^{-1}), P_3 = 60 cm × 25 cm (66,500 plants ha^{-1}) and P_4 = 60 cm × 30 cm (55,500 plants ha^{-1}) and Factor B: Leaf clipping (4 levels) *viz:* C_1 = Control (no clipping), C_2 = Clipping of uppermost 2 leaves, C_3 = Clipping of uppermost 4 leaves and C_4 = Clipping of uppermost 6 leaves. Experimental result revealed that, in case of different population densities of maize, the cob length (15.64 cm), cob diameter (4.82 cm), number of rows cob^{-1} (4.82), number of grains cob^{-1} (385.04), grain weight $plant^{-1}$ (107.07 g) and 100-grain weight (22.45 g) of maize were observed in P_4 (55,500 plants ha^{-1}) treatment. However, the highest grain yield of maize (8.27 t ha^{-1}) was observed in P_2 (83,000 plants ha^{-1}) treatment. Growth and yield of maize were significantly influenced due to the effect of leaf clipping at reproductive stage on maize. The highest cob length (15.02 cm), cob diameter (4.69 cm), number of rows cob^{-1} (14.33), number of grains cob^{-1} (352.65), grain weight $plant^{-1}$ (98.00 g), 100-grain weight (21.97 g) and grain yield (7.44 t ha^{-1}) were observed in C_1 (no clipping) treatment. In case of combination, the P_2C_1 combination treatment gave the highest grain yield of maize (8.53 t ha^{-1}). Based on the above findings, experimental results revealed that different population densities and leaf clipping on maize at reproductive stage significantly influenced the growth and yield of maize. Therefore, it was suggested that planting 83,000 plants ha^{-1} along with no leaf clipping (P_2C_1) combination treatment would help to influence plant growth and increase its ability to give better yield production of maize.

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ABBREVIATIONS

Full word	Abbreviations
Agriculture	Agri.
Agro-Ecological Zone	AEZ
Bangladesh Bureau of Statistics	BBS
Biology	Biol.
Biotechnology	Biotechnol.
Botany	Bot.
Cultivar	Cv.
Cumulative pan evaporation	CPE
Days after sowing	DAS
Dry weight	DW
Editors	Eds.
Emulsifiable concentrate	EC
Entomology	Entomol.
Environments	Environ.
Food and Agriculture Organization	FAO
Fresh weight	FW
International	Intl.
Irrigation water	IW
Journal	J.
Least Significant Difference	LSD
Liter	L
Triple super phosphate	TSP
Science	Sci.
Soil Resource Development Institute	SRDI
Technology	Technol.
Serial	Sl.
Water Use Efficiency	WUE

CHAPTER I

INTRODUCTION

Maize (*Zea mays* L.) is the most important cereal crop in Bangladesh after rice and wheat. It has potential nutritional values i.e., 100 grams of mature maize seeds contain 9.42 g of protein, 74.26 g carbohydrates, 0.64 g sugar, 7.3 g dietary fiber, 365 kcal energy (Islam and Hoshain, 2022). At present, the annual demand for maize in Bangladesh is around two million tons, but production is 4,700 thousand tonnes (BBS, 2021) which is a big gap between demand and production. To fulfil the demand, huge amount of money drains to import maize seeds and products. The consumption of maize in Bangladesh both as human food, livestock and poultry feed overall in all the segments will be increased in the future. In addition, maize has a potential prospect in Bangladesh and annual average weather had a positive effect on maize production in Bangladesh.

Maize has a wide genetic variability and able to grow successfully in any environment in Bangladesh. It generally grows both in winter and summer time in Bangladesh and shows potential yield. Recently, the yield of maize has experienced explosive growth in Bangladesh. Maize has now positioned itself as the first among the cereals in terms of yield (6.15 t ha^{-1}) as compared to boro rice (3.90 t ha^{-1}) and wheat (2.60 t ha^{-1}) (BBS, 2020).

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 consumed as human food (Revilla *et al*., 2022). The currently grown maize in this country is yellow type, which is mainly adapted importing genetic materials from CIMMYT. Again, although there are some indigenous local maize in the south east hills those have also not improved for having higher yields (Ullah *et al.*, 2016). Maize currently grown in Bangladesh is of yellow type and is used in the feed industry. Hybrid maize cultivation area has increased at the rate of about 20-25% per year since nineties as the yield potential of hybrid maize is greater than those of local races (Shompa *et al*., 2020). Now-a-days, there are many government and non-government organizations are working for increasing maize production in Bangladesh.

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). Different varieties respond differently to input supply, cultivation practices and prevailing environment etc. during the growing season (Bithy and Ahamed, 2018). The low productivity of maize is attributed to many factors like decline of soil fertility, poor agronomic practices (such as proper management of planting configuration, irrigation interval, fertilizer managements, weeding, thinning, earthing up, clipping etc.), and limited use of input, insufficient technology generation, poor seed quality, disease, insect, pest and weeds (Ullah *et al.*, 2017).

Increasing planting density has proven to be an effective agronomic practice for improving grain yield of maize and resource use efficiency worldwide (Fahad *et al*., 2020). However, only a few studies have explored how changes in the absorption and utilization of radiation, nutrients, and water caused by increasing planting density improve crop growth, development, and grain yield. Planting density affects the absorption and utilization of radiation, water, and nutrients in plants by changing the canopy and/or root system architecture (Du *et al*., 2021).

Increased planting density improves the intercepted photosynthetically active radiation (IPAR) by rapid canopy closure and increases the leaf area index (LAI) (Hernández *et al*., 2020). It is well-known that biomass yield is the production of IPAR, which ultimately converts into yield, and maize grain yield is determined by the product of total biomass (Du *et al*., 2021). Increasing planting density increases IPAR, but it also increases competition among plants for light, water, and nutrients (Rossini *et al*., 2011), causing abiotic stress in plants, which is often visually apparent in maize via the reduction in leaf area, leaf chlorophyll content, and grain biomass (Osakabe *et al*., 2014). Such phenomena decrease plant light interception and photoassimilate production, thereby decreasing crop productivity and resource use efficiency (Zhang *et al*., 2019).

Under abiotic stress conditions, dry matter allocation to reproductive organs declines, leading to lower grain yield, yield components (i.e., kernel number and weight), and harvest index (HI) (Mylonas *et al*., 2020). Therefore optimum plant population is vital for maintaining to exploit maximum natural resources such as nutrient, sunlight, soil moisture and to ensure maximum economic grain yield per production area.

Maize produces a greater quantity of epigeous mass than other cereals, so it can be used as fodder. Depending on the variety, a maize plant produces 15 to 20 leaves (Rokon *et al*., 2019) during its life cycle. Canopy structure of maize is such that adjoining leaves overlap one another and develop mutual shading. Crop canopy structure may be modified by partially removing vegetative organs to increase energy-use efficiency, especially that of solar radiation, and thus maximize yield (Chen *et al*., 2018). Decreasing the LAI of densely planted maize can change the canopy structure, increase both the light intensity in the canopy and the photosynthetic capacity of the leaves, and thus increase the grain yield (Liu *et al*., 2017). Changes in production capacity of source during grain filling are frequently accompanied by a marked change in stem weight as the supply of assimilates temporarily stored in the stem buffers the plant’s demand for assimilates from the sink, which changes the source-sink ratio and the grain yield (Liu *et al*., 2015).

The source-sink ratio was defined as the aboveground biomass increase per kernel during a given period, and optimal reduction of leaf area can increase post-silking source sink ratio and yield (Liu *et al*., 2015). For example, Hao *et al.* (2010) demonstrated that excising either 1/4 or 1/2 of all leaves on maize plants allowed more light into the field’s canopy, thus allowing increased net photosynthesis and stomatal conductance in the remaining leaves at ear level. Some studies also reported that removal of the two uppermost leaves of maize plants increased grain yield (Liu *et al*., 2017). Also, maize planted at a density of 10.0 plants m^{-2}, showed significantly increased grain yield when the LAI was reduced from 8.2 to 5.5 following leaf removal (Liu *et al*., 2009). While Liu *et al*. (2015) discovered that at 10.0 plants m^{-2} removing the upper leaves reduced grain yield. This showed that reducing the LAI of closely planted maize by leaf clipping increased light intensity in the canopy and the photosynthetic capacity of the leaves. However, the changes not only increased stalk dry matter accumulation and stalk lodging resistance, but also grain yield.

In Bangladesh few studies have been conducted with leaf clipping and high population densities of hybrid maize. Research work on the combined effect of population densities and leaf clipping is limited. Considering the above facts the present study was undertaken to find out the effect of leaf clipping at reproductive stage on productivity under high population densities of hybrid maize with the following objectives:

i. To explore the effects of planting density on growth and yield attributes of maize.
ii. To investigate the effect of leaf clipping on growth and yield of maize.
iii. To find out the interaction effects of planting density and leaf clipping on growth and yield of maize.

CHAPTER II

REVIEW OF LITERATURE

The relevant literature pertaining to the effect of leaf clipping on productivity under different population densities of hybrid maize were collected and reviewed under the following headings-

2.1 Effect of plant density

Djaman *et al.* (2022) conducted a field experiment at NMSU Agricultural Science Center in Farmington to evaluate six plant densities (54,700; 64,600; 74,600, 88,000; 101,700; and 120,100 plants ha^{-1}) under seven planting dates (from April 23 to June 5 in 2019 and from April 21 to June 10 in 2020) to determine the planting window and the optimum density. The results showed that crop height and leaf area index varied with plant density and planting date. Grain yield also varied with plant density and planting date. The highest grain yield (16.8 Mg ha^{-1}) was observed under the density 101,700 plants ha^{-1} which showed statistically similar yield as the density 88,000 plants ha^{-1} and the first planting trended to provide the best grain yield in 2019. In 2020, the highest grain yield (17 Mg ha^{-1}) was obtained under the density 88,000 plants ha^{-1} on May 18 planting date. Plant density 88,000 plants ha^{-1} was revealed as the optimum density that maximized grain yield and WUE and maize planting after May 25 is not recommended.

Mian *et al*. (2021) conducted a field experiment on hybrid maize with different plant population density at the Agronomy field of BARI, Joydebpur, Gazipur during the consecutive rabi season of 2019-2020 and 2020-2021. Five plant population density viz; T_1 = 66666 plants ha^{-1} (75 cm × 20 cm spacing: 6.67 plants m^{-2}), T_2 = 83333 plants ha^{-1} (60 cm × 20 cm spacing: 8.33 plants m^{-2}), T_3 =100000 plants ha^{-1} (50 cm × 20 cm spacing: 10 plants m^{-2}), T_4 = 125000 plants ha^{-1} (40 cm × 20 cm spacing: 12.5 plants m^{-2}) and T_5 = 166666 plants ha^{-1} (30 cm × 20 cm spacing: 16.67 plants m^{-2}) were used in the experiment. Experimental result showed that LAI (leaf area index) and TDM (total dry matter) increased with the increase of plant population, influencing grain yield of maize. The highest grain yield (10.12-10.78 t ha^{-1}) was recorded in T_3 (100000 plants ha^{-1}) and the lowest (5.02-5.33 t ha^{-1}) in T_5 (166666 plants ha^{-1}) treatment.

Acharya *et al*. (2020) conducted a study was on farmer's field of Khajura, Banke, during 2014 -2015 to identify the effect of plant population on maize hybrids under different sowing dates in winter season. Three plant densities (83333 plants ha^{-1}, 66666 plants ha^{-1} and 55555 plants ha^{-1}) were used in the study. Experimental result showed that plant population 83333 plants ha^{-1} (6.9 Mt ha^{-1}) and 66666 plants ha^{-1} (6.8 Mt ha^{-1}) produced higher grain yield than (6.4 Mt ha^{-1}) at 55555 plants ha^{-1}.

Gurmu and EshetuYadete (2020) reported that increasing plant density intensifies competition between adjacent plants and leads to shorter cob production in the plant, thus reducing the length of each row of cob seeds and consequently the number of seeds per row of cobs.

Worku and Derebe (2020) reviled that stover and grain yields were significantly increased with increasing plant density from 53,333 to 90,900 plants ha^{-1}.

Haarhoff and Swanepoel (2019) reported that maize yield response to plant density is season dependent with more impact during the driest season while grain yield is not affected by plant density during a season with the highest early season rainfall.

Reddy *et al.* (2018) conducted a field experiment during rabi 2016-2017 on silty loam soils at Agronomy Research Farm, Narendra Deva University of Agriculture & Technology, Narendra Nagar (Kumargunj), Faizabad (U.P.) to study the yield attributes of rabi maize as influenced by planting geometry and moisture regimes. The experiment was laid out in split plot design with four planting geometries viz., 60× 10 cm, 60 × 15 cm, 60 × 20 cm, 60 × 25 cm and four moisture regimes viz., 0.6 IW/CPE ratio, 0.9 IW/CPE ratio, 1.2 IW/CPE ratio, 0.9 IW/CPE ratio up to silking and 1.2 IW/CPE ratio for rest of the crop season which were replicated thrice. Results showed that higher length of cob, no. of grain rows per cob, no. of grains per row, no. of grains per cob, weight of cob, weight of grains per cob, girth of cob, test weight, shelling percentage, grain yield and stover yield was found in 60 × 25 cm spacing and 1.2 IW/CPE ratio.

Shrestha *et al.* (2018) reported that although yield components such as the number of seeds cob^{-1} and 1000-seed weight decreased with increasing plant density, increasing the number of plants ha^{-1} from 55,000 to 85,000 was able to compensate for the low plant yield and increase yield ha^{-1}.

Kandil *et al*. (2017) investigated the effect of hill spacing (15, 20, 25 and up to 30 cm) on grain yield and its attributes of maize. They found that sown maize plants in hills, 30 cm apart gave the highest values of ear diameter, kernel weight ear^{-1}, shelling percentage and 100-kernel weight. However, the longest ears were recorded due to sown maize plants at hill spacing of 25 cm apart. On the other side, sown maize plants at 15 cm apart produced the highest value for each of number of rows ear^{-1}, number of kernels row^{-1} and grain yield ha^{-1}.

Kareem *et al*. (2017) studied the effect of two population densities (95,556 and 53,333 plants ha^{-1}) on growth and yield of two maize cultivars. They found that increasing plant density from 53,333 to 95,556 plants ha^{-1} led to significant increase in grain yield ha^{-1}. On the other hand, number of kernels row^{-1}, number of kernels ear^{-1}, 100-kernel weight and shelling percentage were significantly decreased due to increasing plant density.

Revathi *et al.* (2017) found that lower planting density of 66,666 plants ha^{-1} recorded the maximum ear length and number of kernels ear^{-1} than 83,333 and 100,000 plants ha^{-1}, while, maximum grain yield ha^{-1} was recorded with 83,333 plants ha^{-1} and stover yield ha^{-1} was recorded with 100,000 plants ha^{-1}. On the other direction, weight of kernels ear^{-1}, number of rows ear^{-1} and 100-kernel weight were not significantly influenced by planting density.

Yan *et al*. (2017) reported that a high plant density of 9.0 plants m^{-2} decreased the post-silking N accumulation, leaf N concentration and net photosynthesis, which reduced the post-silking dry matter production, resulting in a low yield and NUE. Although a relatively low grain yield was observed at a density of 9.0 plants m^{-2}.

Manan *et al.* (2016) Conducted an experiment including two hybrids (PMH 1 and DKC 9125) at 3 plant population densities comprising of 55,555, 83,333 and 1,11,111 plants ha^{-1} with the objective of observing the effect of plant spacing on yield attributes and yield of maize hybrids and found that contrary to DKC 9125, in case of PMH 1 grain yield of 68.83 q ha^{-1} and 69.50 q ha^{-1} was obtained at plant population 1,11,111 plants

ha^{-1} (15 cm) and 83,333 plants ha^{-1} (20 cm), respectively. In case of DKC 9125 maximum cob yield (94.2) and grain yield (74.96) was found at closer plant spacing i.e. at 15 cm (1,11,111 plants ha^{-1}).

Nwogboduhu (2016), studied the response of three maize cultivars to planting densities (20000, 40000, 60000 and up to 80000 plants ha^{-1}) and found that plant density of 60,000 plants ha^{-1}, produced the highest grain yield and also was statistically similar with all other plant densities in ear weight and number of kernels ear^{-1}.

Rahmani *et al*. (2016) carried out an experiment to investigate the effect of planting date and plant densities on yield and yield components of sweet corn at agricultural and resources research center of Razavi Khorasan, Iran during 2009 growing season. A split plot experiment, based on randomized complete block design with four replications performed using SC 403 cultivar. The main plots belonged to three planting dates (D_1: May 15, D_2: July 4, D_3: July 25) while subplots belonged to different plant densities (P_1: 66600, P_2: 83300 and P_3: 111000 plants ha^{-1}). There was significant difference between different plant densities in respect of ear yield, de-husked ear yield and fresh forage yield. The highest (8.86 t ha^{-1}) and lowest (7.69 t ha^{-1}) grain yield observed for P_3 and P_1 respectively.

Qian *et al.* (2016) showed that with each increase of 10,000 plants ha^{-1}, the weight of 1000 corn grains decreases by 6 to 9 grams. Also, with increasing density, the number of cobs per plant decreases but the number of grains produced ha^{-1} increases.

El-Kholy *et al.* (2015) studied the effect of three plant densities (24000, 28000 and 32000 plants ha^{-1}) on yield and its attributes of yellow maize and reported that the low and moderate densities significantly increased kernel yield ha^{-1}.

Li *et al.* (2015) conducted a study to analyze changes in density independence with plant density based on the response of grain yield (GY), dry matter (DM) accumulation, and the harvest index (HI) to changes in plant density. Two modern cultivars, ZhengDan958 and ZhongDan909, were planted at 12 densities ranging from 1.5 to 18 plants m^{-2}. The experiment was conducted for 3 years with drip irrigation and plastic mulching, at the 71 Group and Qitai Farms located in Xinjiang, China. With increased plant density, dry matter (DM) accumulation per area increased logarithmically, the harvest index (HI) decreased according to a cubic curve, and grain yield (GY) per area increased quadratically; the optimum density was 10.57 plants m^{-2}. Further analysis showed that the response of GY per area, DM per area, and the HI to changes in plant density could be divided into four density ranges: Range I (≤4.7 plants m^{-2}), in which DM per area, the HI, and GY per area were significantly affected by density; Range II (4.7–8.3 plants m^{-2}), in which the HI was unaffected by density but DM per area and GY per area were significantly affected; Range III (8.3–10.75 plants m^{-2}), in which GY per area was unaffected by density but DM per area and the HI were significantly affected; and Range IV (≥10.7 plants m^{-2}), in which DM per area was unaffected by density but the HI and GY per area were significantly affected. These results indicated that Range II is a density-independent range and Range III is a GY-stable range.

Sorkhi and Fateh (2014) carried out an experiment at Research Station of Islamic Azad University of Miandoab in 2012 to study the effect of density on grain yield, biological yield and harvest index on corn hybrids of SC301 and SC 320. The result of the experiment showed that the highest and lowest grain yield was observed in 80 and 60 thousand plants ha^{-1} respectively. Density of 90 thousand plants ha^{-1} had the highest biological yield. The highest harvest index was observed in 80 thousand plants ha^{-1}.

Prasad and Ana (2012) conducted an experiment on maize with three levels of plant densities 66,666, 80,000 and 100,000 plants ha^{-1}. Results concluded that plant density of 80,000 plants ha^{-1} gave a maximum cob yield of 14,159 kg ha^{-1} while 100,000 plants ha^{-1} produced highest green fodder yield of 18,532 kg ha^{-1}.

Abuzar *et al*. (2011) conducted a field experiment to determine the effect of plant population densities on maize at the Agricultural Research Institute, Dera Ismail Khan, in mid July 2009. 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. Results showed that plant population of 40,000 $ha^{–1}$ produced maximum number of grains per row (32.33) and grains per ear (447.3). However, 60,000 plants ha^{-1} produced the maximum number of ears per plant (1.33), number of grain rows per ear (15.44), biomass yield (16,890 kg ha^{-1}) and grain yield (2,604 kg ha^{-1}).

Mashiqa *et al.* (2011) carried out a study to know the effect of plant density on yield and yield components of maize in Botswana and found that the cob length and diameter were more in lower plant densities.

Van Roekel and Coulter (2011) from their three years of field study on silty clay loam soil reported the quadratic plateau response of grain yield to plant density with kernel yield maximized at 81700 plants ha^{-1}. Yield attributes viz. cob length, number of kernels cob^{-1}, kernel weight cob^{-1} and shelling percentage were significantly higher at lower planting density but kernel (80.5 q ha^{-1}) and stover yield (100.8 q ha^{-1}) were significantly higher at 100000 plants ha^{-1} than that recorded with 67000 plants ha^{-1} under no-till conditions.

Zamir *et al.* (2011) reported that the lower grain weight in higher plant population density was occurred probably due to less availability of photosynthates for grain development on account of high inter-plant competition which resulted in low rate of photosynthesis and high rate of respiration as a result of enhanced mutual shading.

Reddy *et al.* (2010) conducted an experiment on clay loam soils at Warangal (A.P.) during rabi season and observed that sowing of maize under no-till condition at wider spacing of 60 cm × 25 cm (66666 plants ha^{-1}) resulted in significantly higher yield attributes (such as number of kernels cob^{-1} and 100-kernel weight) and grain yield over the other two spacing tested, 50 cm × 25 cm (80000 plants ha^{-1}) and 40 cm × 25 cm (100000 plants ha^{-1}).

Suryavanshi *et al.* (2009) revealed that spacing of 60 cm × 30 cm was significantly superior to spacing of 60 cm × 20 cm in increasing the leaf area, and total dry matter production of maize on clay soils of Parbhani (Maharashtra). Plant height, dry matter accumulation and per cent barrenness were increased with increase in planting densities and the highest values of these parameters were recorded at higher planting density of 133333 plants ha^{-1} on clay loam soil and 100000 plants ha^{-1} on sandy clam loam soils at Bapatla.

Hussein *et al.* (2008) reported that the higher values of number of grains cob^{-1}, ear length, ear weight, and grain weight cob^{-1} and grain index were recorded when maize plants were sown at wider spacing, and attributed the results obtained to possible decrease in intra-specific competition for sunlight and soil nutrients.

Alford *et al.* (2008) reported that growing crops in narrow rows reduces weed biomass and increases the interception of light which could lead to increase in yield.

Ramu and Reddy (2007) conducted the experiment at Tirupati and reported that grain yield of maize increased significantly with increase in plant population from 55555 plants ha^{-1} to 66666 plants ha^{-1} beyond which the increase in yield was not statistically significant.

Muniswamy *et al.* (2007) reported that plant height, leaf area and stem girth of maize increased linearly with the increase in spacing from 60 cm × 10 cm to 60 cm × 20 cm during kharif season at Bangalore.

Maddonni *et al*. (2006) reported that an increase in plant population from 3 plants m^{-2} to 9 plants m^{-2}, increased kernel number cob^{-1} and grain yield but reduced kernel weight on silty clay loam soils at Argentina.

Singh and Singh (2006) from their field study during rainy season observed significantly higher dry matter production $plant^{-1}$ with lower planting density of 66000 plants ha^{-1} (60 cm × 25 cm) as compared to that with higher densities of 83000 plants ha^{-1} (60 cm × 20 cm), 133333 plants ha^{-1} (50 cm × 15 cm) and 166666 plants ha^{-1} (50 cm × 12 cm) on clay loam soils of Udaipur (Rajasthan).

Sharratt and McWilliams (2005) from their two years of study at Morris found that corn row spacing did not influence grain yield in first year, but did affect yield in second year as corn grown in 38 cm rows produced 10 per cent more grain than corn grown in 76 cm rows. Harvest index was also not influenced significantly between narrow and conventional wider row spacings.

Alam *et al*. (2003) conducted an experiment during the period from April to July 2001 to find out effect of 3 levels of plant population (53000, 66000, 80000 plants ha^{-1}) and 4 levels of nitrogen fertilizer (100, 140, 180 and 220 kg ha^{-1}) in silty clay loam soil. The results showed that the yield and yield attributes characters varied significantly due to the variation in population densities and nitrogen rates. The lower plant population (53000 plants ha^{-1}) produced higher cobs $plant^{-1}$, cob length, grains cob^{-1} and 1000-grain weight, but the higher plant population (66000 and 80000 plants ha^{-1}) resulted significantly higher grain yield than lowest plant population.

Blumenthal *et al*. (2003) reported from their field study at Nebraska, reported that kernel yields were maximized by 202 kg N ha^{-1} with 27200 plants ha^{-1} and population increased above 27200 plants ha^{-1} resulted in inconsistent kernel yields. Planting of maize at 83333 plants ha^{-1} resulted in significantly higher yield attributes *viz.*, ear diameter, grain weight $plant^{-1}$, test weight and grains ear^{-1} than at 111111 plants ha^{-1} on clay loam soils of Akola.

Chowchong and Nagamprasitthi (2003) in Thailand used plant spacing of 25, 30 and 35 cm with one plant $hill^{-1}$, and 50 cm with 2 plants $hill^{-1}$, a row spacing of 75 cm and reported that 25 cm plant spacing recorded the highest yield of fresh ear with husk while low ear quality and lowest yield was obtained from 35 cm plant spacing with high ear quality.

Gozubenli *et al.* (2003) observed significant increase in grain yield when plant densities increased from 50,000 to 90,000 plants ha^{-1}. But further increase beyond 90,000 plants ha^{-1} decreased the grain yield.

Ameta and Dhakar (2000) from an experiment conducted on clay loam soils of Banswara (Rajasthan) revealed that with each successive increase in plant population from 65000 plants ha^{-1} to 95000 plants ha^{-1} there was significant increase in the grain yield of maize during winter season.

Bangarwa and Gaur (1998) also found that increasing of plant population from 37000 to 110000 plants ha^{-1} significantly increased the stover yield.

Tyagi *et al.* (1998) reported that cob length decreased (18.46 to 15.95 cm) significantly with increase in plant population from 53,333 to 88,888 plants ha^{-1}.

Singh *et al.* (1997) reported that dry matter production at 90 and 120 days after sowing (DAS) increased significantly with increase in population levels from 55556 plants ha^{-1} to 111111 plants ha^{-1} on silty loam soils of Faizabad (U.P.) during winter season.

Sachan and Gangawar (1996) from an experiment conducted during kharif at Kanpur observed that growth attributes of maize *viz.*,plant height, stem girth and number of functional leaves were significantly higher with wider row spacing (60 cm) than with narrow row spacing (45 cm).

2.2 Effect of leaf clipping

Bhandari *et al*. (2022) reported that detasseling + defoliation of three upper leaves and all leaves below the third leaf below the ear appeared to have lower grain yield. Hence, we can conclude that 50% detasseling is the best way to enhance the grain yield of the sweet corn.

Rankovic *et al.* (2021) conducted a study to observe direct and joint effects of three factors (genotypes, ecological environmental conditions and the applied crop density) on the level of defoliation intensity and yield. Three inbred lines (G) of maize (G_1–L217RfC, G_2–L335/99 and G_3–L76B004) were used in the study. The trials were performed in two years (Y) (Y_1 = 2016 and Y_2 = 2017) and in two locations (L) (L1 and L_2) under four ecological conditions of the year–location interaction (E_1–E_4) and in two densities (D_1 and D_2) (50,000 and 65,000 plants ha^{-1}). Prior to tasselling, the following five treatments of detasseling and defoliation (T) were applied: T_1—control, no leaf removal only detasseling, T_2–T_5—removal of tassels and top leaves (from one to four top leaves). The defoliation treatments had the most pronounced effect on the yield reduction in G_1 (T_1–Tn+1… T_5), $p < 0.05$.

Murindangabo *et al.* (2019) reported that removal of the lower leaves at the anthesis-silking stage can potentially increase the maize yield since it reduces the apical dominance, increases photo synthetically active radiation intercepted, reducing resources competition and water loss by transpiration.

Rokon *et al*. (2019) conducted a study in Crop Physiology and Ecology Research Field and Laboratory at Hajee Mohammad Danesh Science and Technology University, Bangladesh during the period of March to July-2013 to investigate the effect of leaf clipping and population density on fodder and grain yield in maize. Three population densities (D_1 = 75 cm × 25 cm, D_2 = 60 cm × 20 cm and D_3 = 50 cm × 20 cm) and three clipping treatments (C_1 = no clipping, C_2 = removal of all leaf blades below the lowermost cob and C_3 = removal of all leaf blades above the uppermost cob) at the silking stage were included as experimental treatments. The experiment was laid out in a two factors Randomized Complete Block Design (RCBD) with three replications. Results revealed that higher population density (D_3) with C_3 clipping treatment gave the highest plant height, whereas D_1 with non-clipping treatment gave the lowest. Highest total dry matter (TDM) was found in D_2 with C_1 and the lowest was found in D_1 with C_1 treatment. The highest yield (8.33 t ha^{-1}) and harvest index (35.5%) were obtained from C_1 treatment and the lowest yield (6.55 t ha^{-1}) and harvest index (33.5%) were obtained from C_3 treatment.

Shesh (2019) revealed that in maize significantly higher plant height (190.3 cm) was obtained from control (no de-topping) as compared to different stages of de-topping.

Vishnu (2019) revealed that no de-topping in maize recorded significantly highest grain yield (3923 kg ha^{-1}) over the other method of de-topping.

Amulya (2018) revealed that maize crop without de-topping recorded significantly higher dry matter (259 and 293 g $plant^{-1}$, respectively) at 90 DAS and at harvest which was statistically at par with de-topping at 20 days after silking with the removal of top two leaves (252 and 255 g $plant^{-1}$, respectively).

Jalilian and Delkhoshi (2014) revealed that without clipping of maize leaf recorded significantly higher cob length as compared to other treatments of leaf clipping.

Emam *et al*. (2013) revealed that significantly higher 1000-grain weight in control which was at par with defoliation of 50 per cent leaves at 30 days after silking.

Safari *et al*. (2013) reported that maize crop without defoliation recorded significantly highest dry matter accumulation (3450.40 g m^{-2}) as compared to other treatments of defoliation.

Heidari (2012) conducted a field experiment and a laboratory experiment in 2011 to determine the effect of intensity of defoliation on yield of maize (*Zea mays*). The field experiment included 7 defoliation intensities (0, 2, 4, 6, 8, 10 and whole leaves plant^{-1}) from top to bottom leaves. Results showed that defoliation had a significant effect on seed yield, rows number ear^{-1}, seed number on row, cob length, cob weight and harvest index (P<5%). Seed yield was reduced by increasing defoliation intensity. The results suggest that the two upper leaves should not be defoliated, because this treatment has a remarkable negative effect on the seed and biological yield.

Khaliliaqdam (2011) studied the effect of leaf defoliation on some agronomical traits of corn. Many factors were involved in estimating total loss of yield potential. These included effects from defoliation, stand loss and plant bruising and environmental condition during the remainder of growing season. Therefore, to evaluate the influence of leaf defoliation on agronomical trials of corn (*Zea mays* L.), a factorial experiment consisting of three growth stages of maize (vegetative, tasseling and flowering) and five levels of leaf defoliation (0, 25, 50, 75 and 100%) was conducted in 2011. Results revealed that plant height and ear height were significantly affected by leaf defoliation. Interaction of leaf defoliation and growth stages on seed depth, 1000-grain weight and grain yield was significant. Seed depth decreased significantly by increasing leaf defoliation only in flowering stage (-0.03 mm/1%D). Leaf defoliation diminished 1000-grain weight and grain yield in all growth stages. Overall, research demonstrated that flowering stage was more sensitive to leaf defoliation than tasseling and vegetative stage in corn.

Barimavandi *et al*. (2010) conducted a study to know the effect of different defoliation treatments on yield and yield components in maize (*Zea mays* L.) cultivar of S.C704. The experiment was followed completely randomized block design with 8 treatments in 4 replications. The treatments were: T_1 = control (without leaf removal), T_2 = removing of ear leaf, T_3 = defoliating leaves on top of the ear, T_4 = defoliating leaves under the ear, T_5 = defoliating just two leaves under ear, T_6 = defoliating two leaves on top of ear, T_7 = defoliation whole leaves (complete defoliation) and T_8 = defoliating just tassel leaf. Effects of these treatments were evaluated on the major traits of yield components.

Results showed that leaves defoliation had significantly effect on grain yield, rows number on cob, grains number on cob, grain dry weight and cob length. Leaf defoliation intensity and leaf position affected total dry matter. Complete defoliation reduced severely grains on cob. While defoliation on top of ear and underneath leaves of ear caused to reduce grains on row. The maximum leaf area index (LAI) belonged to control and the least amount was connected to T_4.

Alvanagh *et al*. (2009) reported that without leaf clipping in maize recorded significantly higher grain yield (7.6 t ha^{-1}) as compared to other treatments of leaf clipping.

Kokilavani *et al.* (2007) laid out field trial during summer season of the year 2007 in sandy clay loam soil to investigate the influence of morphological modification through terminal clipping (at 15, 25, 35, 45 DAS and no clipping) in selected varieties of sesame. The result of study indicated that maximum plant height was noticed in without clipping treatment as compared to other clipping treatments.

Chaudhary *et al*. (2005) reported that in maize no defoliation produced the maximum seed weight cob^{-1} and seed yield, while minimum seed weight cob^{-1} and seed yield were obtained in defoliation of all leaves below cob at two weeks after mid silking stage.

Imayavaramban *et al.* (2004) conducted an experiment during two consecutive summer season of the year 1998 and 1999 to study the effect of different levels of nitrogen, clipping and growth regulator on growth and yield of sesame. The results of the study revealed that clipping at 30 DAS recorded significantly the lowest plant height, while growth and yield attributes *viz.*, number of secondary branches $plant^{-1}$, capsules $plant^{-1}$, seeds $capsule^{-1}$, test weight and seed yield of sesame were observed the highest as compared to control.

Hassen (2003) reported that leaf defoliation at late whorl, tassel and milking stages significantly influenced the seed and stover yield of maize.

Zewdu (2003) studied the effect of defoliation and intercropping with forage legumes on maize yield and forage production. Leaf defoliation of maize at various growth stages significantly affected the yield of grain, stem, cob and defoliated leaf. Forage legumes could be established under maize without reducing the grain or stover yield. Leaf defoliation up to 50% did not affect the grain and stover yield components or the yield of under sown *Vicia villosa*.

Esechie and Al-Alawi (2002) found that in maize complete detasselling resulted in a 24 per cent increase in seed yield, whereas detasselling with restoration had no effect on seed yield. Similarly, removal of one leaf accompanied by detasselling with or without restoration had no effect on seed yield; however when two or three leaves were removed along with detasselling, seed yield was reduced by 18.2 and 24.2 per cent respectively.

El-Douby *et al*. (2001) reported that total defoliation or defoliation of the top most ear leaf in case of maize recorded highest percentage of barren, lodged and broken plants while, highest yield was recorded in no defoliation and defoliation of the bottom most ear leaf.

Tilahun (1993) found that there is direct relation between grain yield and the number of removed leaves in maize. The greatest yield diminishing is obtained under complete defoliation after anthesis stage.

Wilhelm *et al*. (1995) recorded linear decline in seed yield with number of leaves removed with tassel in maize (r^2= 0.97), the reduction in seed yield was attributed to the loss of photosynthetic capacity, the ability to intercept light and plant nitrogen because of the removal of the leaves from the plant at tasselling.

Kabiri (1996) found that removing of above leaves of ear could decrease the number of rows in cob and grain in row; since this type of defoliation causes to produce immature grains in the tip of ear.

CHAPTER III

MATERIALS AND METHODS

This part presents a concise depiction about the duration of the experimental period, site description, climatic state of the area, harvest or planting materials that are being utilized in the test, treatments, design, crop growing procedure, intercultural activities, data collection and statistical analyses.

3.1 Experimental period

The experiment was conducted during the period from October, 2021 to February, 2022 in Rabi season.

3.2 Site description

3.2.1 Geographical location

The experiment was directed at the Agronomy field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Agargaon, Dhaka, Bangladesh. The experimental site is topographically situated at 23°77′ N scope and 90°33′ E longitude at an elevation 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, it has been shown in the Map of AEZ of Bangladesh in Appendix-I (Banglapedia, 2014).

3.3 Climate and weather

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-II.

3.4 Soil

The soil of the experimental pots belongs to the general soil type, shallow red brown terrace soils under Tejgaon soil series. Soil pH ranges from 5.4–5.6. The land was above flood level and sufficient sunshine was available during the experimental period. The morphological, physical and chemical characteristics of the experimental soil have been presented in Appendix-III (Biswas *et al*., 2019).

3.5 Planting materials

In this research work, seeds of hybrid maize *viz*; BARI Hybrid Maize-7 was used as planting material. The seeds were obtained from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701

3.6 Treatment of the experiment

The experiment consists of two factors which are given below:

Factor A: Population density

P_1 = 60 cm × 15 cm (1,10,000 plants ha^{-1})
P_2 = 60 cm × 20 cm (83,000 plants ha^{-1})
P_3 = 60 cm × 25 cm (66,500 plants ha^{-1}) and
P_4 = 60 cm × 30 cm (55,500 plants ha^{-1})

Factor B: Leaf clipping

C_1 = Control (no clipping)
C_2 = Clipping of uppermost 2 leaves
C_3 = Clipping of uppermost 4 leaves and
C_4 = Clipping of uppermost 6 leaves

3.7 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 48 unit plots were made for the experiment with 12 treatments. The size of each unit plot was 4.25 m^2 (1.7 m × 2.5 m). Distance maintained between replication and plots were 0.5 m and 0.25 m, respectively. Layout of the experimental field was presented in Appendix-IV.

3.8 Detail of experimental preparation

3.8.1 Preparation of experimental land

The land was opened with the help of a tractor drawn disc harrow on (19 October 2021) 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 2021) according to experimental specification. Individual plots were cleaned and finally the plots were prepared.

3.8.2 Fertilizer application

Manures and fertilizers were used according the recommended dose of BARI Krishi Projukti Hatboi for hybrid maize fertilizer is as follows:

Fertilizers	Dose ha^{-1}
Cowdung	100 ton
Urea	400 kg
Triple super phosphate	200 kg
Gypsum	190 kg
Muriate of potash	200 kg
Zinc sulphate	10 kg
Boric acid	10 kg

(BARI Krishi Projukti Hatboi, 2019)

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 installments.

3.8.3 Seed sowing and maintaining spacing

The maize seeds were sown in lines according with par treatment requirement, allocating 2 seeds hole^{-1} under direct sowing in the well prepared plot on 20 October 2021.

3.9 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.

3.9.1 Gap filling and thinning

Gap filling was done at seventh day after sowing to maintain uniform plant population. Thinning was done two weeks after the sowing in order to maintain required plant density in each plot. By pulling out the excess seedlings in each spot, one seedling retained at each spot to maintain optimum plant population plot^{-1}.

3.9.2 Weed management

To check the weed growth, two inter cultivations were done during fourth and sixth week after sowing with the help of blade hoe and two hand weeding were carried out at 25 and 45 DAS.

3.9.3 Water management

Protective irrigation was provided to the crop depending upon the soil moisture content and prevailing weather conditions during the period of experiment. Five irrigations were given for the entire crop growth to avoid moisture stress.

3.9.4 Earthing up

Earthing up was done at 30 DAS along with second hand weeding and top dressed with urea and muriate of potash. It helped to give the better anchorage and favorable environment for root growth and development. It also helped to loosen the soil, to reduce the bulk density and to increase the water holding capacity of the soil**.**

3.9.5 Clipping

Leaf clipping was performed during the flowering stage at 75 DAS of maize in accordance with par treatment requirements. The leaves were clipped at the base.

3.10 Plant protection measure

Plant protection measures were adopted wherever found necessary during the crop growth period. Chlorpyrifos spray 2.5 ml lt^{-1} was sprayed once against the control of stem borer at 50 DAS.

3.11 Harvesting

The crop was harvested after attaining the physiological maturity at 110 days after sowing from all the plots. The cobs were picked up when ears were of full size, had tight husk and somewhat dried silks. At this stage, kernels were fully developed and exuded a milky liquid when punctured. The crop was harvested at milky stage by removing the cobs from the plot in the net plot area. The green fodder is obtained after harvest of the produce and the fresh cob yield, green fodder is worked out for t ha^{-1}. Harvesting was done on 20 February, 2022.

3.12 Data collection

Data on various parameters were collected from the sample plants. To avoid the border effect and achieve the highest level of accuracy, five plants were chosen at random from each plot to collect data. For this, the outside rows and the outer plants in the middle rows were avoided.

3.13 Collection of different data

Data were collected on the following parameters:

i. Plant height (cm)
ii. Total dry matter $plant^{-1}$ (g) at harvest
iii. Cob length (cm)
iv. Cob diameter (cm)
v. Number of rows cob^{-1}

vi. Number of grains cob^{-1}

vii. Grain weight $plant^{-1}$ (g)

viii. 100-grain weight (g)

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

x. Stover yield (t ha^{-1})

xi. Biological (t ha^{-1})

xii. Harvest index (%)

3.14 Procedure of recording data

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

i. Plant height (cm)

At harvest the height of five randomly selected plants from the inner rows per plot was measured from ground level to the tip of the plant portion and the mean value of plant height was recorded in cm.

ii. Total dry matter $plant^{-1}$ (g)

At harvest 5 plants from each plot were uprooted randomly. Then the plant was cut into pieces. Then the various pieces of the plant were put into a paper packet, in case of harvesting, cob was also put into a packet and placed in oven maintaining 70°C for 72 hours. Then the sample was transferred into desiccators and allowed to cool down at room temperature. Then the sample weight was taken and then the total dry matter of a plant for each plot was calculated. It was performed at harvest.

iii. Cob length (cm)

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

iv. Cob diameter (cm)

The cob diameter of five cobs from each plot was measured by using vernier calipers at harvesting stage and the means were worked out and expressed in centimeter.

v. Number of grain rows cob^{-1}

Five cobs from each plot were selected randomly and the number of grain rows cob^{-1} was counted. Then the average result was recorded.

vi. Number of grains cob^{-1}

The numbers of grains per cob was measured from the base to tip of the ear collected from five randomly selected cobs of each plot and finally average result was recorded.

vii. Grain weight plant^{-1}

Total grains from five plants were randomly selected from each plot and weighed in an electrical balance. In grams, the average grain weight was reported.

viii. 100-grain weight

A random sample of hundred grains was taken from total grain lots of each treatment, weighed and recorded as test weight in grams.

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

After removing the grain from the cob, grain yield was calculated. Grain yield was calculated from cleaned and well dried grains collected from 1 m^2 area of each plot and expressed as t ha^{-1}.

x. Stover yield (t ha^{-1})

After separation of grains from shell, all the parts excepts grains from harvested area was sun dried and the weight was recorded and then converted into t ha^{-1}.

xi. Biological yield (t ha^{-1})

Seed yield and stover yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Seed yield + Stover yield.

xii. Harvest Index (%)

Harvest Index indicates the ratio of economic yield (grain yield) to biological yield and it was calculated with the following formula:

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

3.15 Statistical data analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program Statistix 10 software .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

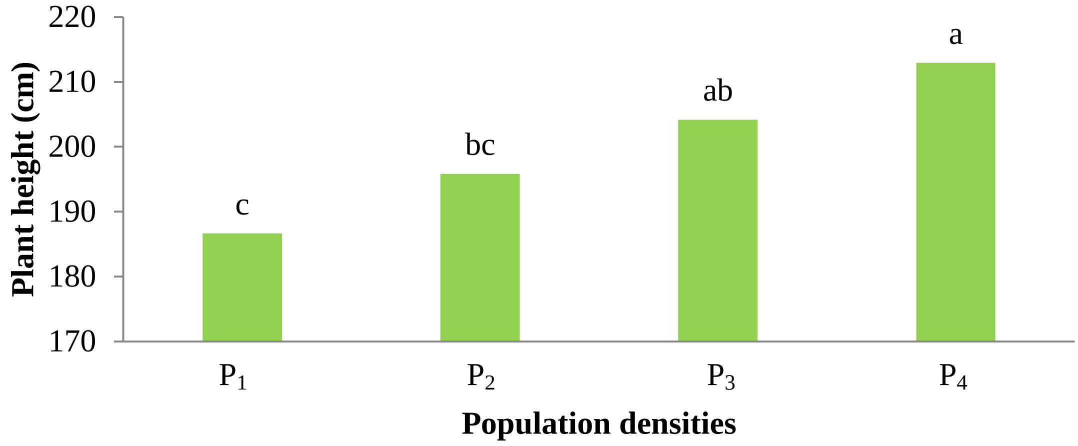
RESULTS AND DISCUSSION

This section contains a presentation and discussion of the study's findings on the effect of leaf clipping on productivity under different population densities of hybrid maize. The information was presented in various tables and figures. The findings had been discussed, and possible interpretations were provided under the headings listed below.

4.1 Plant height (cm)

Effect of population density

Plant height is an essential character of the vegetative stage of the crop plant and indirectly impacts on yield of crop plants. Different population densities significantly influenced on plant height of maize at different days after sowing (DAS). It was seen that height increased gradually with the age of the crop (Figure 1). Experimental result revealed that the highest plant height (212.94 cm at harvest) was observed in P_4 (55,500 plants ha^{-1}) treatment which was statistically similar with P_3 (204.19 cm) treatment. Whereas, the lowest plant height (186.64 cm at harvest) was observed in P_1 (1,10,000 plants ha^{-1}) treatment, which was statistically similar with P_2 (195.83 cm) treatment. Crowding of the plants and increased intra-specific competition for resources result from increased population density. This trend explains that as the number of plants in a given area increased, so did competition among plants for nutrients and sunlight, resulting in poor plant growth and development. The result was similar with the findings of Li *et al*. (2015) who reported that plant height decreases with increasing plant density.

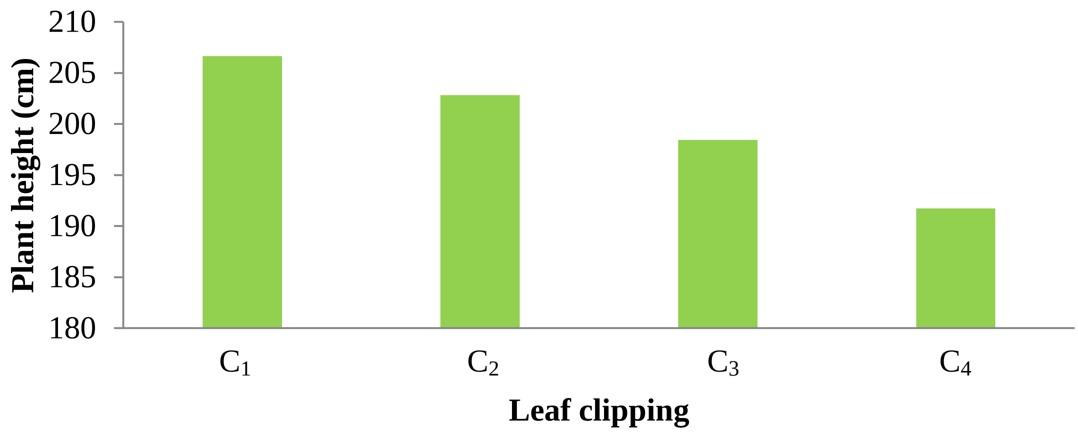


Here, P_1 = 60 cm × 15 cm (1,10,000 plants ha^{-1}), P_2 = 60 cm × 20 cm (83,000 plants ha^{-1}), P_3 = 60 cm × 25 cm (66,500 plants ha^{-1}), P_4 = 60 cm × 30 cm (55,500 plants ha^{-1}).

Figure 1. Effect of population density on plant height of maize at harvest

Effect of leaf clipping

Leaf clipping at reproductive stage had shown non-significant effect on plant height of maize (Figure 2). According to the experimental findings the highest plant height (206.64 cm at harvest) was observed in C_1 treatment while the lowest plant height (191.72 cm at harvest) of maize was observed in C_4 treatment.



Here, C_1 = Control (no clipping), C_2 = Clipping of uppermost 2 leaves, C_3 = Clipping of uppermost 4 leaves and C_4 = Clipping of uppermost 6 leaves.

Figure 2. Effect of leaf clipping on plant height of maize at harvest

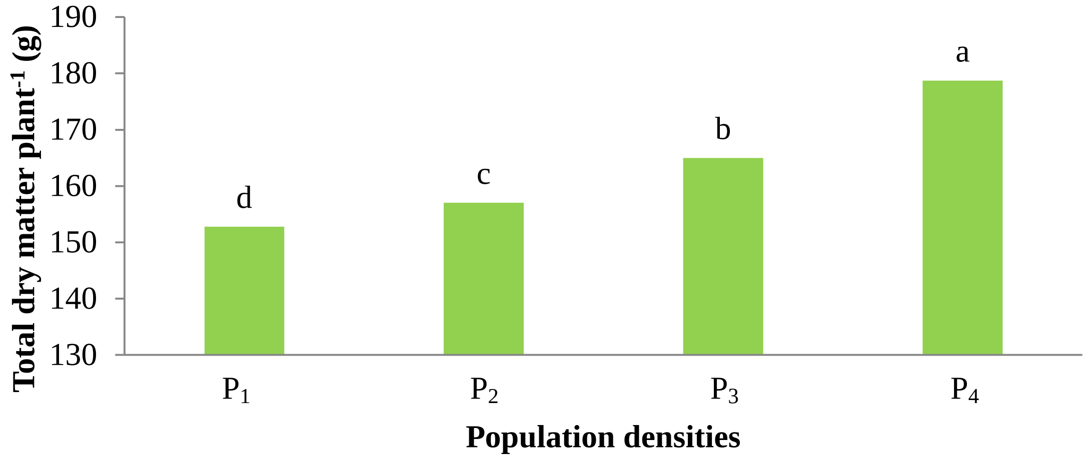
Combined effect of population density and leaf clipping

The combined effect of population density and leaf clipping caused significant variation in maize plant height at harvest (Table 1). Experimental result showed that, the highest plant height (223.11 cm) was observed in P_4C_1 combination treatment, which was statistically similar with all other combination treatments except P_1C_2, (190.44 cm) P_1C_3, (184.44 cm), P_1C_4 (176.78 cm) and P_2C_4 (186.11 cm) combination treatments, while the lowest plant height (176.78 cm) was observed in P_1C_4 combination treatment which was statistically similar with P_1C_2, (190.44 cm) P_1C_3, (184.44 cm) and P_2C_4 (186.11cm) combination treatments.

4.2 Total dry matter plant^{-1} (g)

Effect of population density

The result of the experiment showed that different plant population density had shown significant effect on the total dry matter plant^{-1}of maize at harvest respectively (Figure 3). According to the experimental result, the highest total dry matter plant^{-1} (178.72 g) was observed in P_4 treatment while the lowest total dry matter plant^{-1} (152.76 g) was observed in P_1 treatment. Dry matter plant^{-1} decreased with increase in population density. Greater reduction in dry matter plant^{-1} was observed with increase in population density from 55500 to 110000 plants ha^{-1}. This clearly indicated that increased dry matter plant^{-1} at low population density may be due to less inter plant competition for space, light, nutrients and moisture resulting in better utilization of available resources. Each individual plant may be able to obtain adequate supply of plant nutrients from relatively large volume of soil. Yan *et al*. (2017) reported that a high plant density of 9.0 plants m^{-2} decreased the N accumulation, leaf N concentration and net photosynthesis, which reduced the dry matter production, resulting in a low yield and nutrient use efficiency.

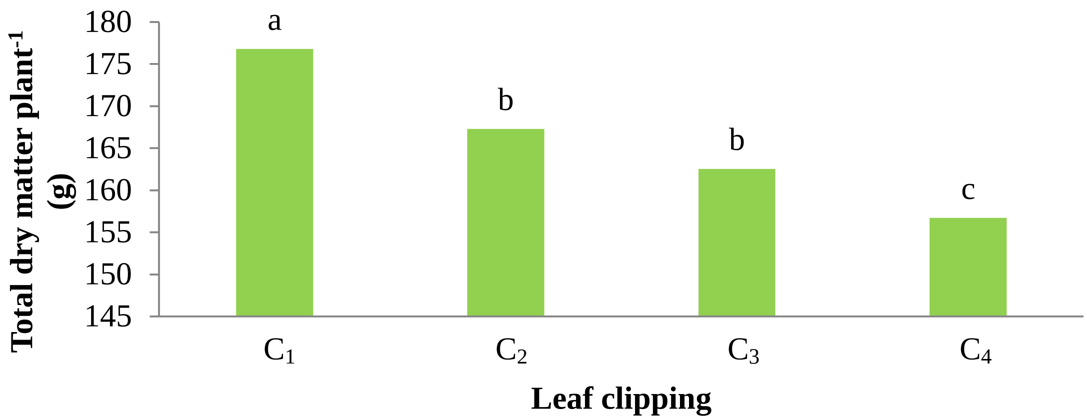


Here, P_1 = 60 cm × 15 cm (1,10,000 plants ha^{-1}), P_2 = 60 cm × 20 cm (83,000 plants ha^{-1}), P_3 = 60 cm × 25 cm (66,500 plants ha^{-1}), P_4 = 60 cm × 30 cm (55,500 plants ha^{-1}).

Figure 3. Effect of population density on total dry matter plant^{-1} of maize at harvest

Effect of leaf clipping

Leaf clipping during the reproductive stage had a significant effect on the total dry matter plant^{-1} of maize at harvest (Figure 4). Experimental result showed that the highest total dry matter plant^{-1} (176.81 g) was observed in C_1 treatment while the lowest total dry matter plant^{-1} (156.71 g) was observed in C_4 treatment. Various leaf clipping reduced the number of leaves, which ultimately impacted on leaf area, because leaf area is related to the number of leaves, and reducing it reduces photosynthesis activities of the plant, which has an impact on maize growth, development, and grain yield. The result was similar with the findings of Safari *et al*. (2013) who reported that maize crop without defoliation recorded significantly highest dry matter accumulation (3450.40 g m^{-2}) as compared to other treatments of defoliation.



Here, C_1 = Control (no clipping), C_2 = Clipping of uppermost 2 leaves, C_3 = Clipping of uppermost 4 leaves and C_4 = Clipping of uppermost 6 leaves.

Figure 4. Effect of leaf clipping on total dry matter plant^{-1} of maize at harvest

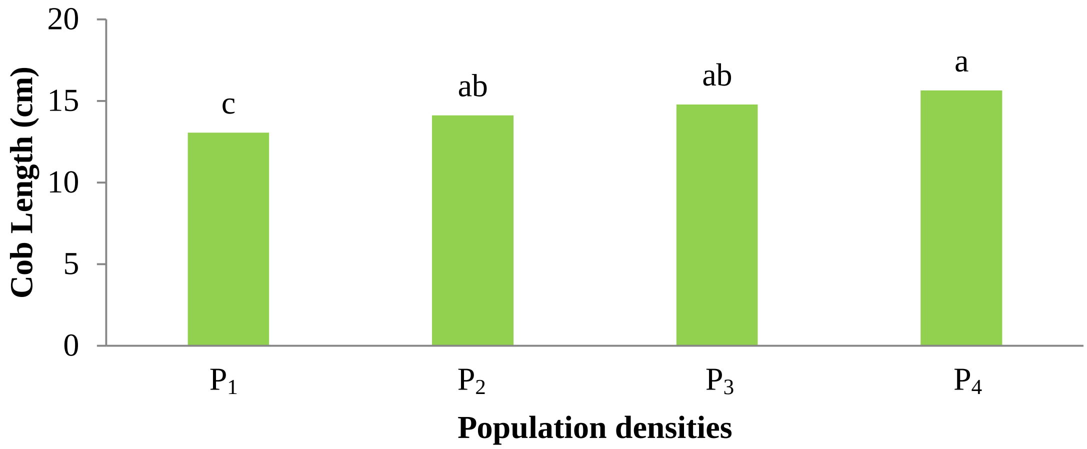
Combined effect of population density and leaf clipping

The combined effect of population density and leaf clipping caused significant variation in total dry matter plant^{-1} of maize at harvest (Table 1). Experimental result showed that, the highest total dry matter plant^{-1} of maize (186.93 g) was observed in P_4C_1 combination treatment, which was statistically similar with P_4C_2 (179.48 g) and P_3C_1 (181.18 g) combination treatments, while the lowest total dry matter plant^{-1} of maize (144.43 g) was observed in P_1C_4 combination treatment which was statistically similar with P_1C_3 (147.29 g) combination treatments.

4.3 Cob length (cm)

Effect of population density

The cob length of maize was significantly influenced by different population density (Figure 5). Experimental result revealed that the highest cob length of maize (15.64 cm) was found in P_4 treatment which was statistically similar with P_3 (14.78 cm) and P_2 (14.12 cm) treatment, whereas the lowest cob length of maize (13.06 cm) was found in P_1 treatment. With increasing plant density, the length of the cob was reduced because the space required by the plant was reduced and the plant absorbed fewer nutrients and at the same time transferred fewer nutrients to the cobs, which led to the production of smaller cobs. Mashiqa *et al.* (2011) found that the cob length and diameter of maize were more in lower plant densities.

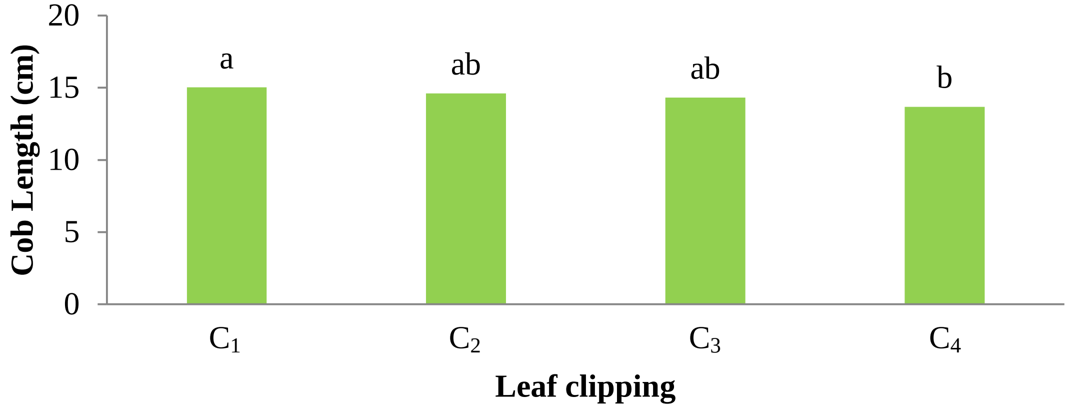


Here, P_1 = 60 cm × 15 cm (1,10,000 plants ha^{-1}), P_2 = 60 cm × 20 cm (83,000 plants ha^{-1}), P_3 = 60 cm × 25 cm (66,500 plants ha^{-1}), P_4 = 60 cm × 30 cm (55,500 plants ha^{-1}).

Figure 5. Effect of population density on cob length of maize

Effect of leaf clipping

Different leaf clipping practices had shown significant effect on cob length of maize at harvest (Figure 6). Experimental result showed that the highest cob length of maize (15.02 cm) was found in C_1 treatment which was statistically similar with C_2 (14.60 cm) and C_3 (14.31 cm) treatment, whereas the lowest cob length of maize (13.68 cm) was found in C_4 treatment. The uppermost leaf is the primary source of photosynthetic energy during reproduction and grain filling, is one of the most important parameters for cob development. Therefore clipping of these leaves has an impact on phenology, morphology, dry mass production, and partitioning of plant products. In maize crops, the leaf is the primary source of assimilate supply for developing vegetative organs, as well as cob production and grain yield. Depending on the magnitude of leaf clipping, leaf removal may influence yield and yield contributing characters via photosynthetic production and distribution into plant parts. Jalilian and Delkhoshi (2014) revealed that without clipping of maize leaf recorded significantly higher cob length as compared to other treatments of leaf clipping.



Here, C_1 = Control (no clipping), C_2 = Clipping of uppermost 2 leaves, C_3 = Clipping of uppermost 4 leaves and C_4 = Clipping of uppermost 6 leaves.

Figure 6. Effect of leaf clipping on cob length of maize

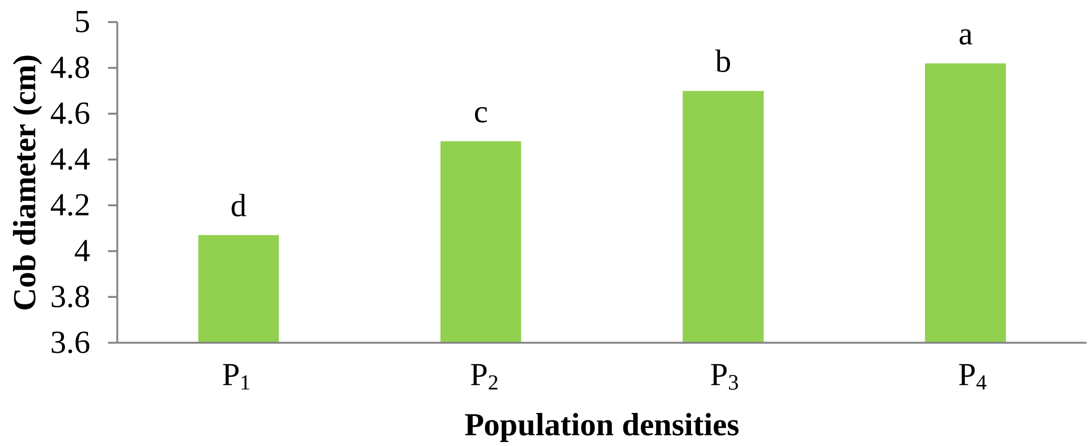
Combined effect of population density and leaf clipping

At harvest, the cob length of maize significantly varied due to the combined effect of population density and leaf clipping. Experimental result showed that, the highest cob length of maize (16.27 g) was observed in P_4C_1 combination treatment, which was statistically similar with P_4C_2 (16.11 cm), P_4C_3 (15.25 cm), P_4C_4 (14.93 cm), P_3C_1 (15.11 cm), P_3C_2 (14.82 cm), P_3C_3 (14.68 cm), P_3C_4 (14.53 cm), and P_2C_1 (14.62 cm) combination treatments, while the lowest cob length of maize (11.93 cm) was observed in P_1C_4 combination treatment which was statistically similar with P_1C_2 (13.17 cm), P_1C_3 (13.07 cm) and P_2C_4 (13.32 cm) combination treatments (Table 1).

4.4 Cob diameter (cm)

Effect of population density

Different population densities had shown significant impact on maize cob diameter (Figure 7). The results of the experiment showed that the P_4 treatment had the highest maize cob diameter (4.82 cm), while the P_1 treatment had the smallest maize cob diameter (4.07 cm).

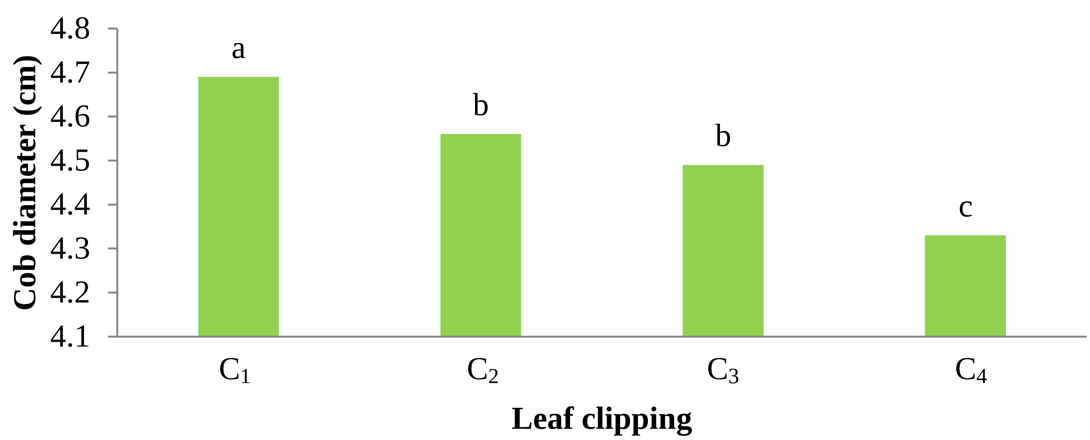


Here, P_1 = 60 cm × 15 cm (1,10,000 plants ha^{-1}), P_2 = 60 cm × 20 cm (83,000 plants ha^{-1}), P_3 = 60 cm × 25 cm (66,500 plants ha^{-1}), P_4 = 60 cm × 30 cm (55,500 plants ha^{-1}).

Figure 7. Effect of population density on cob diameter of maize

Effect of leaf clipping

The diameter of the maize cob at harvest was significantly impacted by various leaf clipping techniques (Figure 8). The results of the experiment indicated that the C_1 treatment had the highest diameter of cob (4.69 cm), while the C_4 treatment had had the lowest maize cob diameter (4.33 cm).



Here, C_1 = Control (no clipping), C_2 = Clipping of uppermost 2 leaves, C_3 = Clipping of uppermost 4 leaves and C_4 = Clipping of uppermost 6 leaves.

Figure 8. Effect of leaf clipping on cob diameter of maize

Combined effect of population density and leaf clipping

Due to the combined effect of population density and leaf clipping, the diameter of maize cobs significantly varied at harvest (Table 1). The results of the experiment revealed that the P_4C_1 combination treatment had the highest cob diameter of maize (5.03 cm), which was statistically comparable to P_4C_2 (15.25 cm) combination treatments. While the P_1C_4 combination treatment showed the lowest cob diameter of maize (3.80 cm).

Table 1. Combined effect of population density and leaf clipping on plant height, dry matter weight plant^{-1}, cob length and cob diameter of maize at harvest

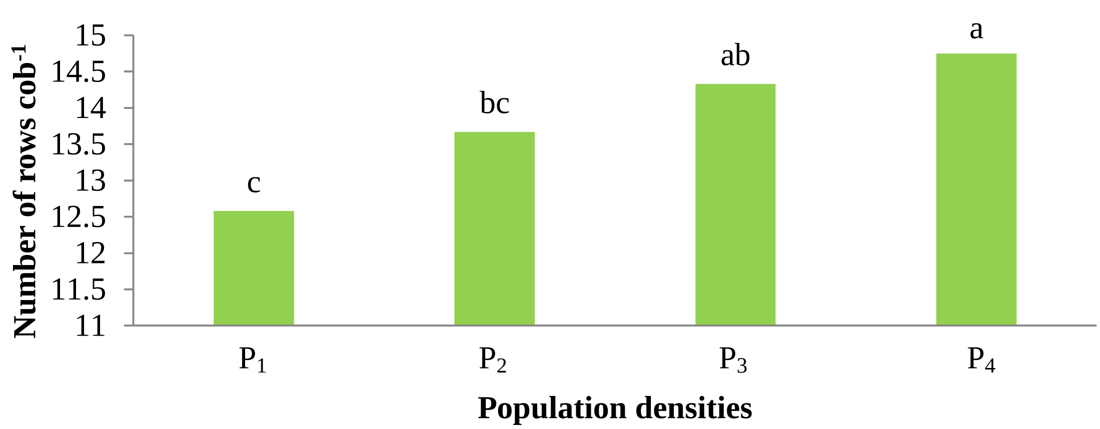
Treatment combinations	Plant height (cm)	Total dry matter plant^{-1} (g)	Cob length (cm)	Cob diameter (cm)
P_1C_1	194.89 a-d	164.56 c-e	14.07 c-f	4.26 g
P_1C_2	190.44 b-d	154.77 e-g	13.17 e-g	4.14 gh
P_1C_3	184.44 cd	147.29 gh	13.07 fg	4.06 h
P_1C_4	176.78 d	144.43 h	11.93 g	3.80 i
P_2C_1	201.56 a-d	174.57 b	14.62 a-f	4.62 de
P_2C_2	198.67 a-d	163.02 c-e	14.31 b-f	4.52 e
P_2C_3	197.00 a-d	159.65 d-f	14.24 c-f	4.48 ef
P_2C_4	186.11 cd	150.62 f-h	13.32 d-g	4.29 fg
P_3C_1	207.00 a-d	181.18 ab	15.11 a-d	4.82 bc
P_3C_2	206.00 a-d	171.89 bc	14.82 a-f	4.75 bcd
P_3C_3	203.00 a-d	167.12 cd	14.68 a-f	4.63 cde
P_3C_4	200.78 a-d	159.44 d-f	14.53 a-f	4.58 de
P_4C_1	223.11 a	186.93 a	16.27 a	5.03 a
P_4C_2	216.11 ab	179.48 ab	16.11 ab	4.85 ab
P_4C_3	209.33 a-c	176.10 b	15.25 a-c	4.76 b-d
P_4C_4	203.22 a-d	172.36 bc	14.93 a-e	4.63 c-e
$LSD_{(0.05)}$	32.40	9.86	1.84	0.19

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, P_1 = 60 cm × 15 cm (1,10,000 plants ha^{-1}), P_2 = 60 cm × 20 cm (83,000 plants ha^{-1}), P_3 = 60 cm × 25 cm (66,500 plants ha^{-1}), P_4 = 60 cm × 30 cm (55,500 plants ha^{-1}), C_1 = Control (no clipping), C_2 = Clipping of uppermost 2 leaves, C_3 = Clipping of uppermost 4 leaves and C_4 = Clipping of uppermost 6 leaves.

4.5 Number of rows cob^{-1}

Effect of population density

The number of rows cob^{-1} was significantly affected by various population densities (Figure 9). The results of the experiment showed that the P_4 treatment had the highest number of rows cob^{-1} of maize (4.82 cm) which was statistically similar with P_3 (14.33) treatment. While the P_1 treatment had the lowest number of rows cob^{-1} of maize (12.58) which was statistically similar with P_2 (13.67) treatment. An increase in population densities from 55,500 to 1,10,000 plants ha^{-1} resulted in reduction in yield attributes of individual plant such as number of rows cob^{-1}. Reduction in yield attributes at high plant density evidently shows that increasing the population level per unit area would sharply affect the ancillary characters of yield. Better growth of individual plant in low-density populations and resultant utilization of accumulated photosynthates influenced the growth and development of yield attributes. Gurmu and Eshetu Yadete (2020) reported that increasing plant density intensifies competition between adjacent plants and leads to shorter cob production in the plant, thus reducing the length of each row of cob seeds and consequently the number of seeds row^{-1} of cobs.

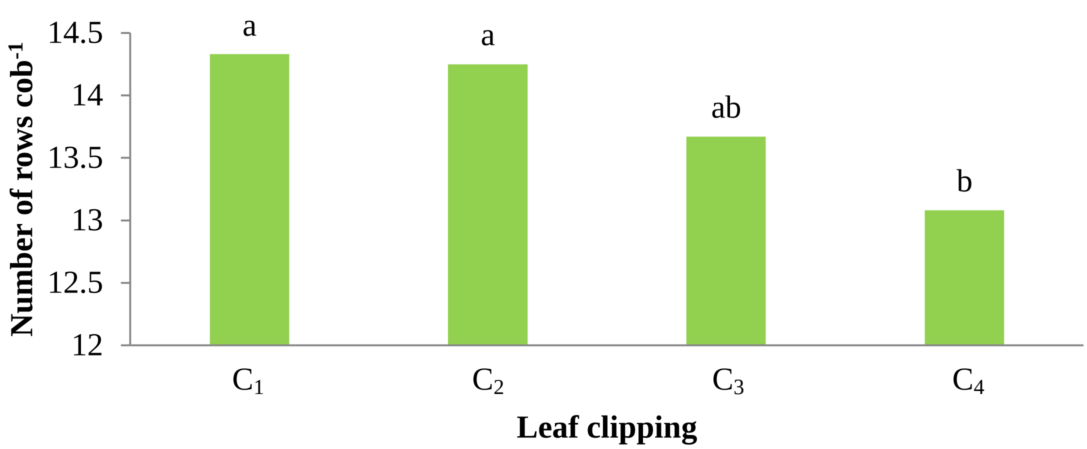


Here, P_1 = 60 cm × 15 cm (1,10,000 plants ha^{-1}), P_2 = 60 cm × 20 cm (83,000 plants ha^{-1}), P_3 = 60 cm × 25 cm (66,500 plants ha^{-1}), P_4 = 60 cm × 30 cm (55,500 plants ha^{-1}).

Figure 9. Effect of population density on number of rows cob^{-1} of maize

Effect of leaf clipping

Leaf clipping at reproductive stage of maize significantly influenced number of rows cob^{-1} (Figure 10). According to the experimental findings the highest number of rows cob^{-1} of maize (14.33 cm) was observed in C_1 treatment which was statistically similar with C_2 (14.25) and C_3 (13.67) treatment. While the C_4 treatment had the lowest number of rows cob^{-1} of maize (13.08).The reduction in yield attributes at higher clipping could be attributed to the removal of maximum leaves above the cob during the early reproductive phase of the maize crop. Bhandari *et al*. (2022) reported that detasseling + defoliation of three upper leaves and all leaves below the third leaf below the ear appeared to have lower yield contributing characters.



Here, C_1 = Control (no clipping), C_2 = Clipping of uppermost 2 leaves, C_3 = Clipping of uppermost 4 leaves and C_4 = Clipping of uppermost 6 leaves.

Figure 10. Effect of leaf clipping on number of rows cob^{-1} of maize

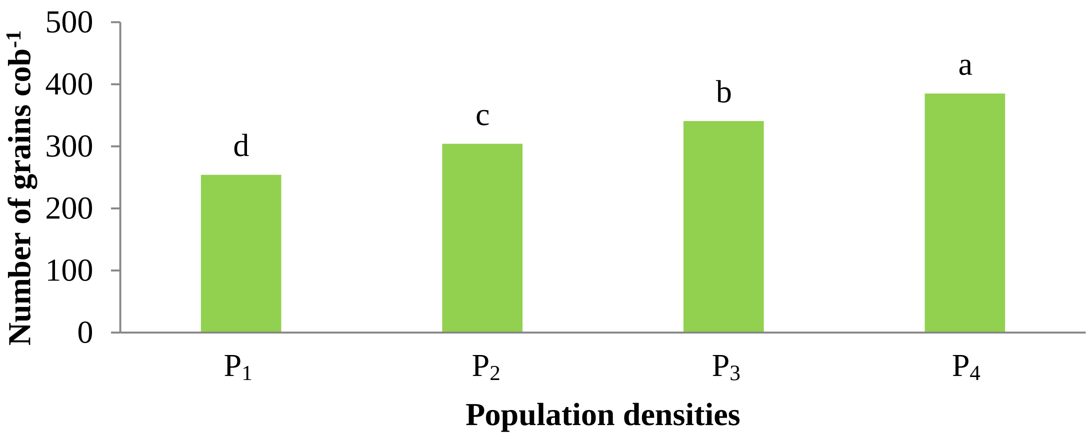
Combined effect of population density and leaf clipping

The number of rows cob^{-1} of maize significantly varied at harvest as a result of the combined impact of population density and leaf clipping (Table 2). According to the experimental findings, the P_4C_1 combination treatment had the highest number of rows cob^{-1} of maize (15.00), which was statistically similar with all other treatments excepts P_1C_4 (11.33) and P_1C_3 (11.67) combination treatments. While the P_1C_4 combination treatment showed the lowest number of rows cob^{-1} of maize (11.33) which was statistically similar with P_1C_3 (11.67) combination treatments.

4.6 Number of grains cob^{-1}

Effect of population density

Different population densities had shown significant impact on the number of grains cob^{-1} (Figure 11). The experimental findings revealed that the P_4 treatment had the highest number of grains cob^{-1} of maize (385.04). While the P_1 treatment had the lowest number of grains cob^{-1} of maize (254.12). Kareem *et al*. (2017) found that, the number of kernels ear^{-1} was significantly decreased due to increasing plant density.

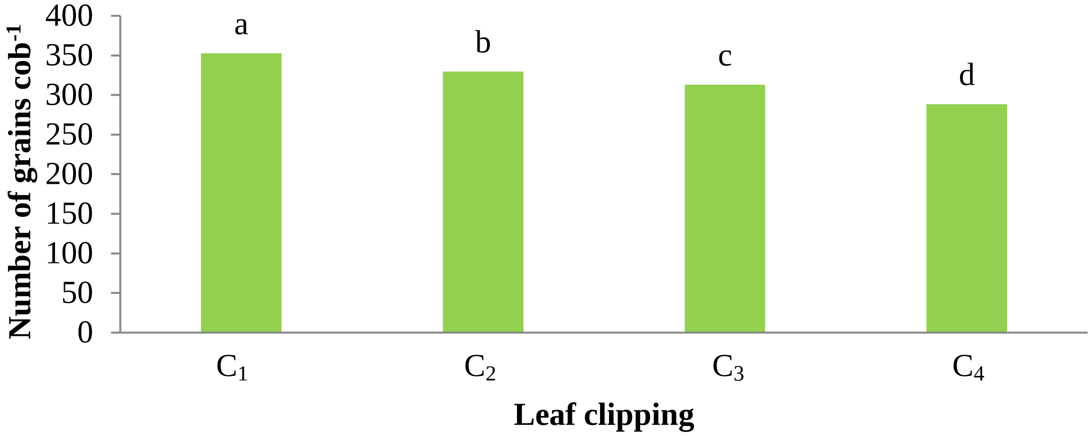


Here, P_1 = 60 cm × 15 cm (1,10,000 plants ha^{-1}), P_2 = 60 cm × 20 cm (83,000 plants ha^{-1}), P_3 = 60 cm × 25 cm (66,500 plants ha^{-1}), P_4 = 60 cm × 30 cm (55,500 plants ha^{-1}).

Figure 11. Effect of population density on number of grains cob^{-1}of maize

Effect of leaf clipping

The number of grains cob^{-1} in maize at the reproductive stage was significantly influenced by leaf clipping (Figure 12). According to the experimental results, the C_1 treatment had the highest number of grains cob^{-1} of maize (352.65). While the C_4 treatment, on the other hand, had the lowest number of grains cob^{-1} of maize (288.51). Different leaf cutting practices reduced the number of leaves, which ultimately had an impact on leaf area and leaf area index. Leaf area index is correlated with the number of leaves, and a decrease in either one has an adverse effect on the plant's capacity for photosynthesis, which in turn has an adverse effect on growth, development, and grain yield in maize. The result was similar with the findings of Barimavandi *et al*. (2010) who reported that leaf defoliation on top of ear and underneath leaves of ear caused to reduce grains on cob.



Here, C_1 = Control (no clipping), C_2 = Clipping of uppermost 2 leaves, C_3 = Clipping of uppermost 4 leaves and C_4 = Clipping of uppermost 6 leaves.

Figure 12. Effect of leaf clipping on number of grains cob^{-1} of maize

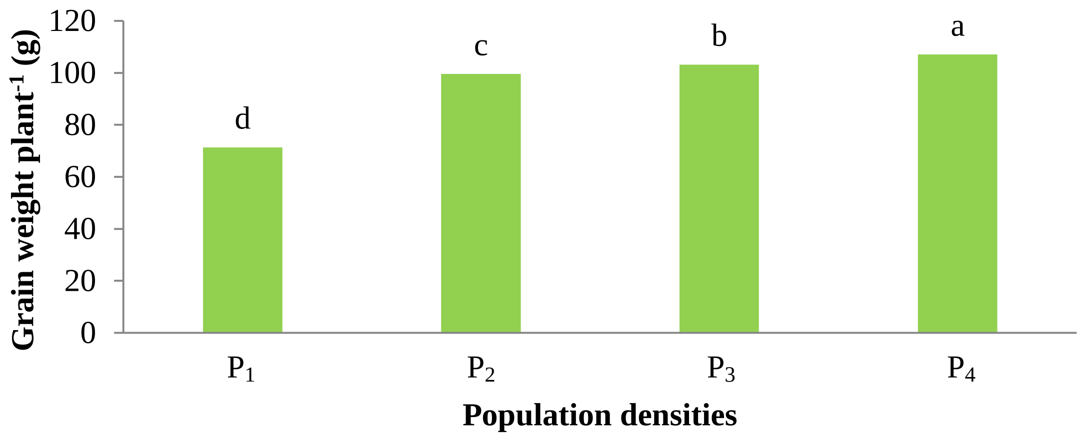
Combined effect of population density and leaf clipping

The combined effects of population density and leaf clipping caused a significant variation in the number of grains cob^{-1} of maize at harvest. According to the experimental findings, the P_4C_1 combination treatment had the highest number of grains cob^{-1} of maize (420.66) which was statistically similar with P_4C_2 (400.70) combination treatment. While the P_1C_4 combination treatment showed the lowest number of grains cob^{-1} of maize (223.09) which was statistically similar with P_1C_3 (246.89) combination treatments (Table 2).

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

Effect of population density

The grain weight plant^{-1} of maize had been significantly impacted by various population densities (Figure 13). According to the experimental findings the highest grain weight plant^{-1} of maize (107.07 g) was observed in P_4 treatment, while the lowest grain weight plant^{-1} of maize (71.34 g) was observed in P_1 treatment. The increase in grain weight in P_4 treatment might be due to availability of more resources to plants on account of low population density. When the number of individuals per area is increased beyond the optimum plant density, there is a series of consequences that are detrimental to ear ontogeny that result in barrenness and lower grain weight plant^{-1} of maize. Zamir *et al.* (2011) reported that the lower grain weight in higher plant population density was occurred probably due to less availability of photosynthates for grain development on account of high inter-plant competition which resulted in low rate of photosynthesis and high rate of respiration as a result of enhanced mutual shading.

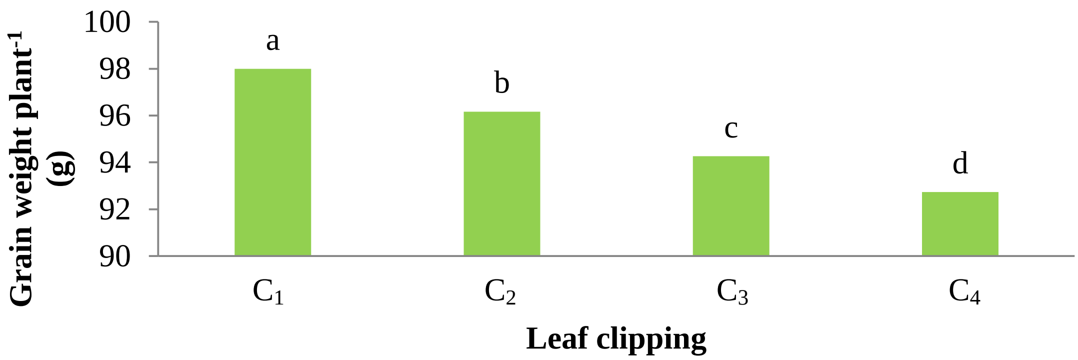


Here, P_1 = 60 cm × 15 cm (1,10,000 plants ha^{-1}), P_2 = 60 cm × 20 cm (83,000 plants ha^{-1}), P_3 = 60 cm × 25 cm (66,500 plants ha^{-1}), P_4 = 60 cm × 30 cm (55,500 plants ha^{-1}).

Figure 13. Effect of population density on grain weight plant^{-1} of maize

Effect of leaf clipping

The grain weight plant^{-1} of maize at harvesting was significantly influenced by leaf clipping (Figure 14). According to the experimental results, the C_1 treatment had the highest grain weight plant^{-1} of maize (98.00 g). While the C_4 treatment, on the other hand, had the lowest grain weight plant^{-1} of maize (92.73 g). Bhandari *et al*. (2022) also found similar result in maize which supports the present findings.



Here, C_1 = Control (no clipping), C_2 = Clipping of uppermost 2 leaves, C_3 = Clipping of uppermost 4 leaves and C_4 = Clipping of uppermost 6 leaves.

Figure 14. Effect of leaf clipping on grain weight plant^{-1} of maize

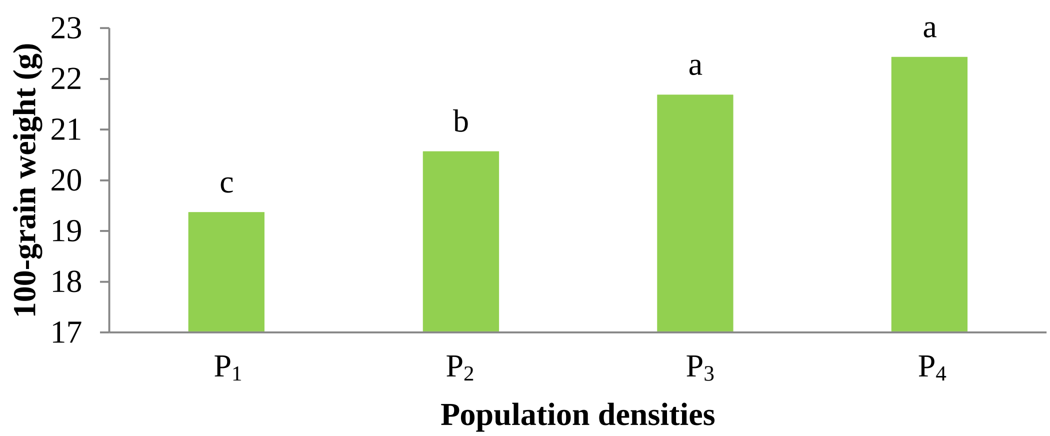
Combined effect of population density and leaf clipping

The grain weight plant^{-1} of maize at harvest significantly varied due to the combined effects of population density and leaf clipping (Table 2). The experimental results show that the P_4C_1 combination treatment had the highest grain weight plant^{-1} of maize (109.19 g) which was statistically similar with P_4C_2 (107.74 g) combination treatment, while the P_1C_4 combination treatment showed the lowest grain weight plant^{-1} of maize (69.04 g) which was statistically similar with P_1C_3 (70.67 g) combination treatments.

4.8 100-grain weight (g)

Effect of population density

The effect of different population densities on 100-grain weight of maize was found to be significant (Figure 15). Experimental results show that the highest 100-grain weight of maize (22.45 g) was observed in P_4 treatment which was statistically similar with P_3 (21.71 g) treatment. While the lowest 100-grain weight of maize (19.39 g) was observed in P_1 treatment. The individual plant growth in higher population was retarded much due to increase in mutual shading and greater interplant competition. The internal competition within the individual plant between vegetative and reproductive parts becomes most severe as competition between plants increases with higher population densities. As plant density increased, changes may occur in the allocation of assimilates to different plant parts as a result of which a greater proportion of plants may become barren and also there may be a critical period for light in relation to grain formation at higher population levels result in lowest 100 grain weight of maize. Qian *et al.* (2016) showed that with each increase of 10,000 plants ha^{-1}, the weight of 1000 corn grains decreases by 6 to 9 grams.

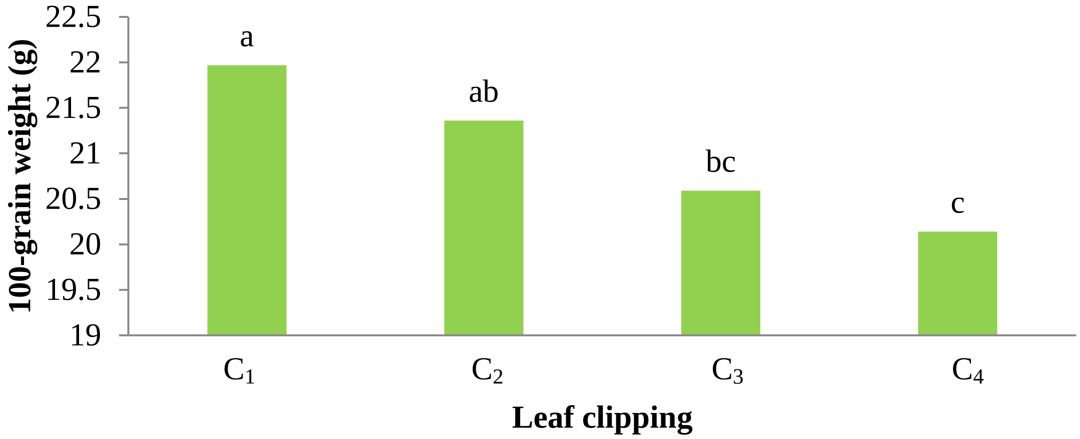


Here, P_1 = 60 cm × 15 cm (1,10,000 plants ha^{-1}), P_2 = 60 cm × 20 cm (83,000 plants ha^{-1}), P_3 = 60 cm × 25 cm (66,500 plants ha^{-1}), P_4 = 60 cm × 30 cm (55,500 plants ha^{-1}).

Figure 15. Effect of population density on 100-grain weight of maize

Effect of leaf clipping

The 100-grain weight of maize at harvesting was significantly influenced by leaf clipping (Figure 16). According to the experimental results, the C_1 treatment had the highest 100-grain weight of maize (21.97 g) which was statistically similar with C_2 (21.36 g) treatment. While the C_4 treatment, on the other hand, the lowest 100-grain weight of maize (20.14 g) which was statistically similar with C_3 (20.59 g) treatment. The result was quite similar with the findings of Emam *et al*. (2013) who revealed that significantly higher 1000-grain weight of maize was observed in control treatment or no defoliation treatment which was at par with defoliation of 50 per cent leaves at 30 days after silking.



Here, C_1 = Control (no clipping), C_2 = Clipping of uppermost 2 leaves, C_3 = Clipping of uppermost 4 leaves and C_4 = Clipping of uppermost 6 leaves.

Figure 16. Effect of leaf clipping on 100-grain weight of maize

Combined effect of population density and leaf clipping

Due to the combined effects of population density and leaf clipping, the 100-grain weight of maize at harvest significantly varied (Table 2). The experimental results show that the P_4C_1 combination treatment had the highest 100-grain weight of maize (23.42g) which was statistically similar with P_4C_2 (22.65 g), P_4C_3 (21.90 g), P_4C_4 (21.82 g), P_3C_1 (22.41 g), P_3C_2 (21.88 g) and P_3C_2 (21.63 g) combination treatment, while the P_1C_4 combination treatment showed the lowest 100-grain weight of maize (18.33 g) which was statistically similar with P_1C_3 (18.55 g) and P_1C_2 (19.79 g) combination treatment.

Table 2. Combined effect of population density and leaf clipping on number of rows cob^{-1}, number of grains cob^{-1}, grain weight plant^{-1} and 100-grain weight of maize

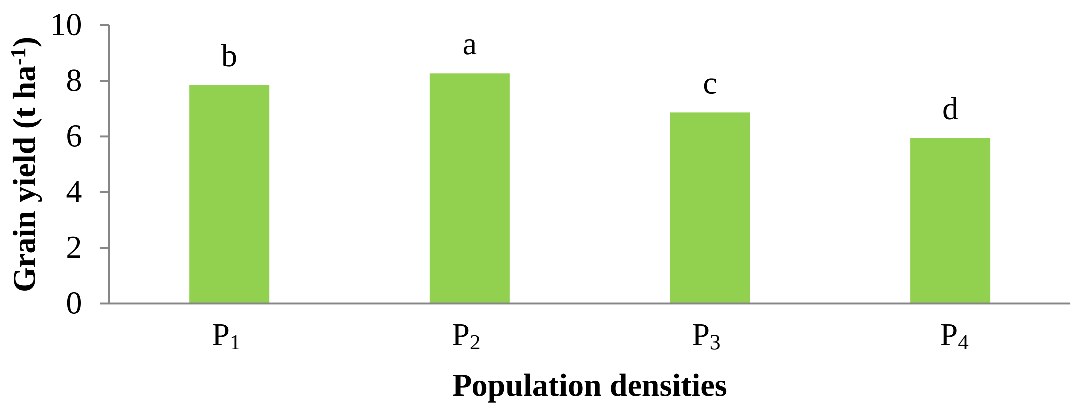
Treatment combinations	No. of rows cob^{-1}	No. of grains cob^{-1}	Grain weight plant^{-1} (g)	100-grain weight (g)
P_1C_1	13.67 ab	290.52 f	73.44 i	20.56 c-f
P_1C_2	13.67 ab	254.98 g	72.20 ij	19.79 e-h
P_1C_3	11.67 c	246.89 gh	70.67 jk	18.55 gh
P_1C_4	11.33 c	223.09 h	69.04 k	18.33 h
P_2C_1	14.00 ab	313.65 ef	102.74 de	21.48 b-e
P_2C_2	14.00 ab	308.96 ef	100.20 fg	21.10 b-f
P_2C_3	14.00 ab	303.40 f	98.25 gh	20.28 d-g
P_2C_4	12.67 bc	290.38 f	97.06 h	19.50 f-h
P_3C_1	14.67 ab	385.76 b	106.61 bc	22.41 a-c
P_3C_2	14.33 ab	354.04 cd	104.56 cd	21.88 a-d
P_3C_3	14.33 ab	317.68 ef	101.79 ef	21.63 a-e
P_3C_4	14.00 ab	305.25 f	99.80 fg	20.91 b-f
P_4C_1	15.00 a	420.66 a	109.19 a	23.42 a
P_4C_2	15.00 a	400.70 ab	107.74 ab	22.65 ab
P_4C_3	14.67 ab	383.46 bc	106.34 bc	21.90 a-d
P_4C_4	14.33 ab	335.33 de	105.03 cd	21.82 a-d
$LSD_{(0.05)}$	2.01	29.60	2.51	1.86

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, P_1 = 60 cm × 15 cm (1,10,000 plants ha^{-1}), P_2 = 60 cm × 20 cm (83,000 plants ha^{-1}), P_3 = 60 cm × 25 cm (66,500 plants ha^{-1}), P_4 = 60 cm × 30 cm (55,500 plants ha^{-1}), C_1 = Control (no clipping), C_2 = Clipping of uppermost 2 leaves, C_3 = Clipping of uppermost 4 leaves and C_4 = Clipping of uppermost 6 leaves.

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

Effect of population density

Different population densities had shown significant variation in respect of grain yield of maize (Figure 17). According to the experimental findings the highest grain yield of maize (8.27 t ha^{-1}) was observed in P_2 treatment while the lowest grain yield of maize (5.94 t ha^{-1}) was observed in P_4 treatment. The possible reason for the lowest grain yield at widest spacing might be due to the presence of less number of plants per unit area. The result was similar with the findings of Abuzar *et al.* (2011) who showed that the plant population of 40000 ha^{-1} produced maximum number of grains per row and grains per ear. However, 60000 plants ha^{-1} produced the maximum number of ears per plant, number of grain rows per ear, biomass yield and grain yield.

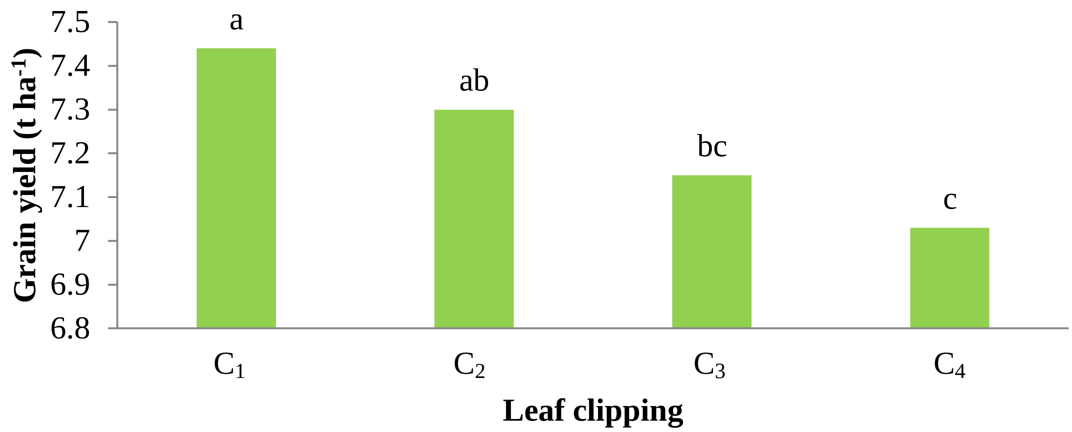


Here, P_1 = 60 cm × 15 cm (1,10,000 plants ha^{-1}), P_2 = 60 cm × 20 cm (83,000 plants ha^{-1}), P_3 = 60 cm × 25 cm (66,500 plants ha^{-1}), P_4 = 60 cm × 30 cm (55,500 plants ha^{-1}).

Figure 17. Effect of population density on grain yield of maize

Effect of leaf clipping

Leaf clipping had a significant effect on maize grain yield at harvest. According to the experimental results, the C_1 treatment had the highest maize grain yield (7.44 t ha^{-1}), which was statistically similar to the C_2 treatment (7.30 t ha^{-1}). While the C_4 treatment, on the other hand, had the lowest maize grain yield (7.03 t ha^{-1}), which was statistically similar to the C_3 (7.15 t ha^{-1}) treatment (Figure 18). The result was similar with the findings of Chaudhary *et al*. (2005) who reported that in maize no defoliation produced the maximum seed weight per cob and seed yield while, minimum seed weight per cob and seed yield were obtained in defoliation of all leaves below cob at two weeks after mid silking stage. El-Douby *et al*. (2001) reported that total defoliation or defoliation of the top most ear leaf in case of maize recorded highest percentage of barren, lodged and broken plants while, highest yield was recorded in no defoliation and defoliation of the bottom most ear leaf.



Here, C_1 = Control (no clipping), C_2 = Clipping of uppermost 2 leaves, C_3 = Clipping of uppermost 4 leaves and C_4 = Clipping of uppermost 6 leaves.

Figure 18. Effect of leaf clipping on grain yield of maize

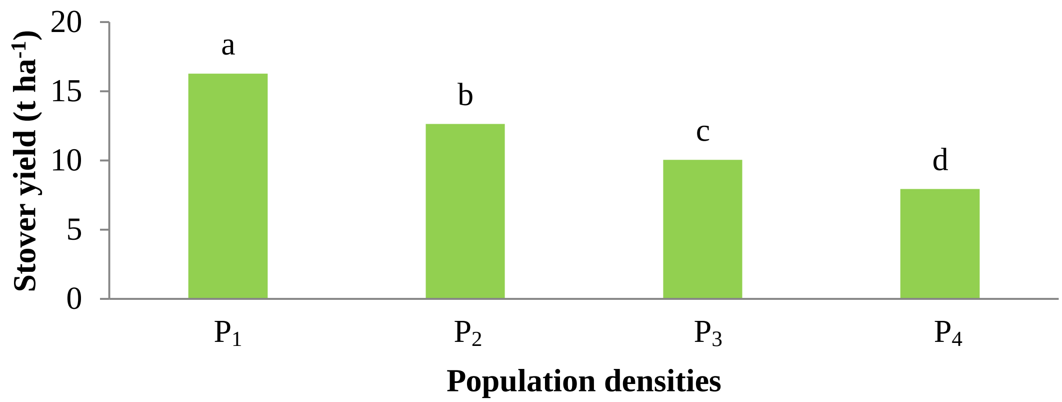
Combined effect of population density and leaf clipping

The grain yield of maize at harvest varied significantly due to the combined effects of population density and leaf clipping (Table 3). The P_2C_1 combination treatment had the highest grain yield of maize (8.53 t ha^{-1}), which was statistically similar with P_2C_2 (8.32 t ha^{-1}) combination treatments and was significantly differed from all other treatments. While the P_4C_4 combination treatment had the lowest grain yield of maize (5.83 t ha^{-1}), it was statistically comparable to the P_4C_3 (5.90 t ha^{-1}), P_4C_2 (5.98 t ha^{-1}) and P_4C_1 (6.06 t ha^{-1}) combination treatment.

4.10 Stover yield (t ha^{-1})

Effect of population density

Different population densities varied significantly in terms of maize stover yield (Figure 19). The results of the experiment showed that the P_1 treatment produced the highest stover yield of maize (16.28 t ha^{-1}), whereas the P_4 treatment produced the lowest stover yield of maize (7.93 t ha^{-1}). Worku and Derebe (2020) reported that stover and grain yields were significantly increased with increasing plant density, as plant density is influenced by spacing, wide spacing cause low plant density and narrow spacing cause high plant density which ultimately impact on stover and grain yield of the crop.

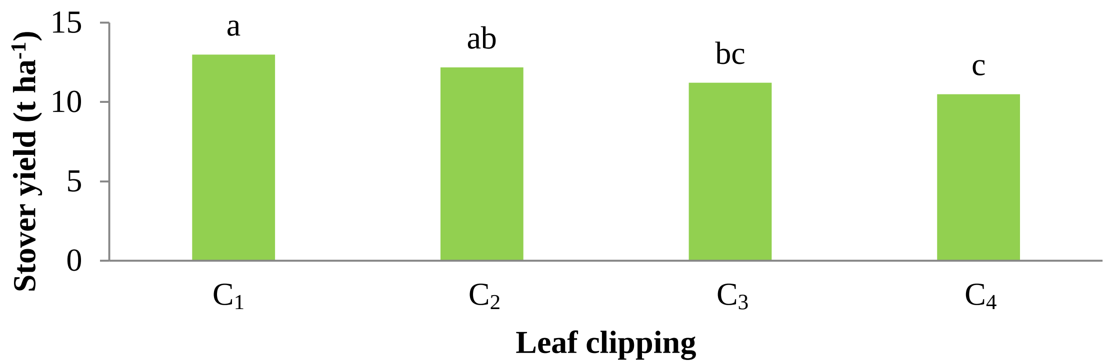


Here, P_1 = 60 cm × 15 cm (1,10,000 plants ha^{-1}), P_2 = 60 cm × 20 cm (83,000 plants ha^{-1}), P_3 = 60 cm × 25 cm (66,500 plants ha^{-1}), P_4 = 60 cm × 30 cm (55,500 plants ha^{-1}).

Figure 19. Effect of population density on stover yield of maize

Effect of leaf clipping

At harvest, leaf clipping had shown significant effect on the stover yield of maize (Figure 20). The experimental results showed that the C_1 treatment had the highest maize stover yield of maize (12.99 t ha^{-1}), which was statistically similar to the C_2 treatment (12.18 t ha^{-1}). The lowest maize stover yield was recorded by the C_4 treatment (10.50 t ha^{-1}), which was statistically similar to the C_3 (11.21 t ha^{-1}) treatment. The result was similar with the findings of Hassen (2003) who reported that leaf defoliation at late whorl, tassel and milking stages significantly influenced the seed and stover yield of maize.



Here, C_1 = Control (no clipping), C_2 = Clipping of uppermost 2 leaves, C_3 = Clipping of uppermost 4 leaves and C_4 = Clipping of uppermost 6 leaves.

Figure 20. Effect of leaf clipping on stover yield of maize

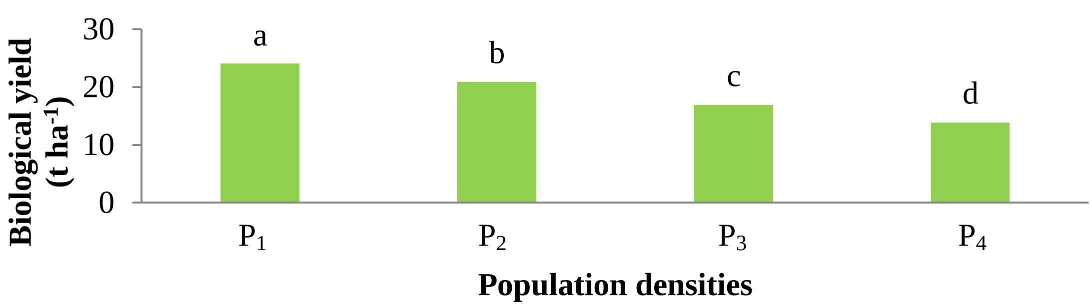
Combined effect of population density and leaf clipping

The combined effects of population density and leaf clipping resulted in significant variations in the stover yield of maize at harvest (Table 3). The P_1C_1 combination treatment had the highest stover yield of maize (18.32 t ha^{-1}), which was statistically similar with P_1C_2 (16.84 t ha^{-1}) combination treatments and was significantly differed from all other treatments. While the P_4C_4 combination treatment had the lowest stover yield of maize (7.13 t ha^{-1}), it was statistically comparable to the P_4C_3 (7.59 t ha^{-1}), P_4C_2 (8.08 t ha^{-1}) and P_4C_1 (8.93 t ha^{-1}) combination treatment.

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

Effect of population density

The biological yield of maize varied significantly across different population densities (Figure 21). The results of the experiment showed that the P_1 treatment produced the highest biological yield of maize (24.12 t ha^{-1}), whereas the P_4 treatment produced the lowest biological yield of maize (13.88 t ha^{-1}). The possible reason for the lowest biological yield at widest spacing might be due to the presence of less number of plants per unit area. The result was similar with the findings of Abuzar *et al.* (2011) who showed that the plant population of 40000 ha^{-1} produced maximum number of grains per row and grains per ear. However, 60000 plants ha^{-1} produced the maximum number of ears per plant, number of grain rows per ear, biological yield and grain yield.

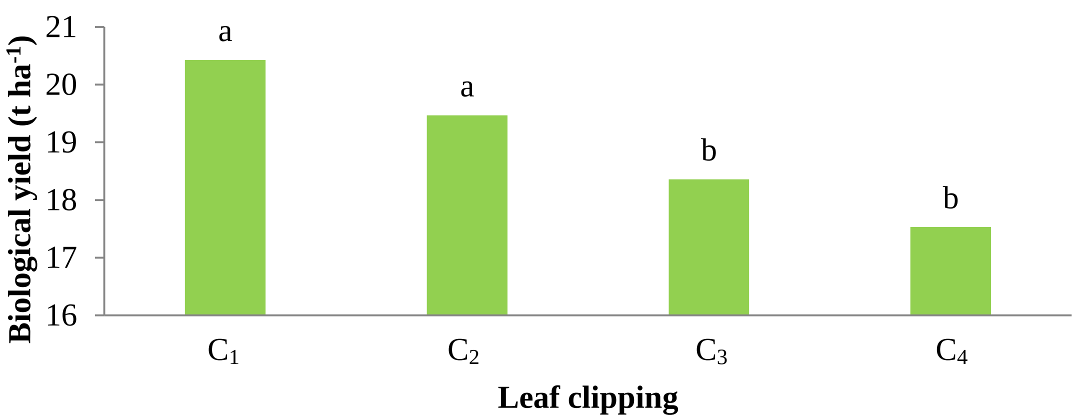


Here, P_1 = 60 cm × 15 cm (1,10,000 plants ha^{-1}), P_2 = 60 cm × 20 cm (83,000 plants ha^{-1}), P_3 = 60 cm × 25 cm (66,500 plants ha^{-1}), P_4 = 60 cm × 30 cm (55,500 plants ha^{-1}).

Figure 21. Effect of population density on biological yield of maize

Effect of leaf clipping

Leaf clipping had a significant impact on the biological yield of maize at harvest. The experimental results showed that the C_1 treatment had the highest maize biological yield of maize (20.43 t ha^{-1}), which was statistically similar to the C_2 treatment (19.47 t ha^{-1}). The lowest maize biological yield was recorded by the C_4 treatment (17.53 t ha^{-1}), which was statistically similar to the C_3 (18.36 t ha^{-1}) treatment (Figure 22). Excessive leaf removal decreased the production of dry matter, which ultimately decreased yield. As biological yield is made up of the combined yields of grains and stover, excessive leaf removal affects growth, which affects the characters that contribute to yield, reducing both yield and growth. Similar result also observed by Heidari (2012) who reported that the upper leaves of maize should not be defoliated, because this treatment has a remarkable negative effect on the seed and biological yield.



Here, C_1 = Control (no clipping), C_2 = Clipping of uppermost 2 leaves, C_3 = Clipping of uppermost 4 leaves and C_4 = Clipping of uppermost 6 leaves.

Figure 22. Effect of leaf clipping on biological yield of maize

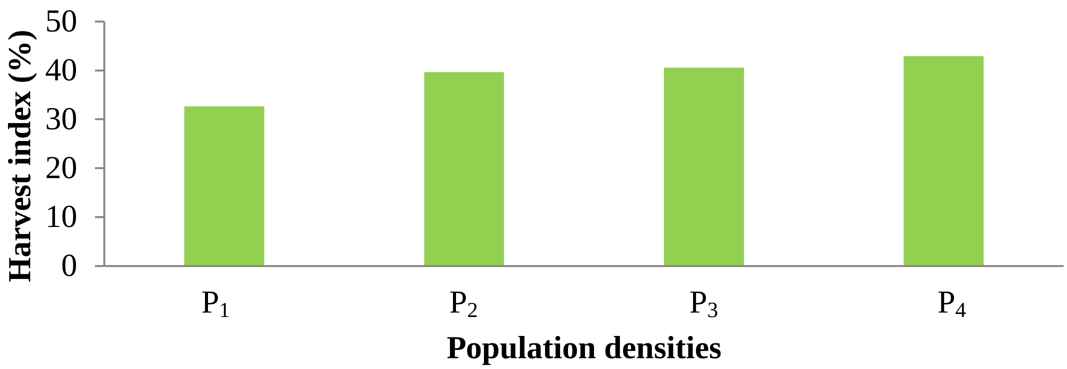
Combined effect of population density and leaf clipping

The biological yield of maize at harvest showed significant variations as a result of the combined effects of population density and leaf clipping (Table 3). The P_1C_1 combination treatment had the highest biological yield of maize (26.40 t ha^{-1}), which was statistically similar with P_1C_2 (24.78 t ha^{-1}) combination treatments and was significantly differed from all other treatments. While the P_4C_4 combination treatment had the lowest biological yield of maize (12.96 t ha^{-1}), it was statistically comparable to the P_4C_3 (13.49 t ha^{-1}), P_4C_2 (14.06 t ha^{-1}) and P_4C_1 (14.99 t ha^{-1}) combination treatment.

4.12 Harvest index (%)

Effect of population density

Various population densities had shown non-significant effect on maize harvest index (Figure 23). The results of the experiment showed that the P_4 treatment recorded the highest harvest index of maize (42.92 %), whereas the P_1 treatment produced the lowest highest harvest of maize (32.62 %).

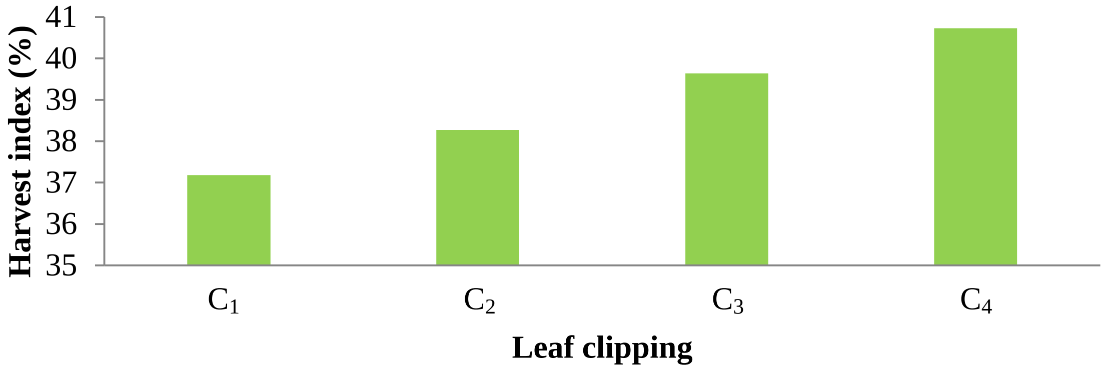


Here, P_1 = 60 cm × 15 cm (1,10,000 plants ha^{-1}), P_2 = 60 cm × 20 cm (83,000 plants ha^{-1}), P_3 = 60 cm × 25 cm (66,500 plants ha^{-1}), P_4 = 60 cm × 30 cm (55,500 plants ha^{-1}).

Figure 23. Effect of population density on biological yield of maize

Effect of leaf clipping

At harvest, leaf clipping had shown non-significant effect on the harvest index of maize (Figure 24). The experimental results revealed that the C_4 treatment had the highest harvest index of maize (40.73%). The C_1 treatment, on the other hand had the lowest harvest index of maize (37.18%).



Here, C_1 = Control (no clipping), C_2 = Clipping of uppermost 2 leaves, C_3 = Clipping of uppermost 4 leaves and C_4 = Clipping of uppermost 6 leaves.

Figure 24. Effect of leaf clipping on biological yield of maize

Combined effect of population density and leaf clipping

The harvest index of maize at harvest showed non-significant variations as a result of the combined effects of population density and leaf clipping (Table 3). The P_4C_4 combination treatment had the highest harvest index of maize (44.98%), while the P_1C_1 combination treatment had the lowest harvest index of maize (30.60%).

Table 3. Combined effect of population density and leaf clipping on grain yield, stover, biological yield and harvest index of maize

Treatment combinations	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
P_1C_1	8.08 b-d	18.32 a	26.40 a	30.60
P_1C_2	7.94 c-e	16.84 ab	24.78 ab	32.03
P_1C_3	7.77 de	15.66 bc	23.43 bc	33.16
P_1C_4	7.59 e	14.28 cd	21.87 c-e	34.71
P_2C_1	8.53 a	14.04 cd	22.57 b-d	37.79
P_2C_2	8.32 ab	13.57 de	21.89 c-e	38.02
P_2C_3	8.15 bc	11.76 ef	19.91 d-f	40.93
P_2C_4	8.06 b-d	11.14 fg	19.20 e-g	41.98
P_3C_1	7.09 f	10.68 f-h	17.77 f-h	39.89
P_3C_2	6.95 fg	10.21 f-h	17.16 f-h	40.51
P_3C_3	6.77 fg	9.84 f-i	16.61 g-i	40.75
P_3C_4	6.64 g	9.45 g-j	16.09 h-j	41.26
P_4C_1	6.06 h	8.93 h-k	14.99 h-k	40.44
P_4C_2	5.98 h	8.08 i-k	14.06 i-k	42.52
P_4C_3	5.90 h	7.59 jk	13.49 jk	43.74
P_4C_4	5.83 h	7.13 k	12.96 k	44.98
$LSD_{(0.05)}$	0.36	1.96	2.81	6.50

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, P_1 = 60 cm × 15 cm (1,10,000 plants ha^{-1}), P_2 = 60 cm × 20 cm (83,000 plants ha^{-1}), P_3 = 60 cm × 25 cm (66,500 plants ha^{-1}), P_4 = 60 cm × 30 cm (55,500 plants ha^{-1}), C_1 = Control (no clipping), C_2 = Clipping of uppermost 2 leaves, C_3 = Clipping of uppermost 4 leaves and C_4 = Clipping of uppermost 6 leaves.

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from October, 2021 to February, 2022 in Rabi season, to study the effect of leaf clipping on productivity under different population densities of hybrid maize. The experiment consisted of two factors, and followed Randomized Complete Block Design (RCBD) with three replications. Factor A: Population density (4 levels) *viz:* P_1 = 60 cm × 15 cm (1,10,000 plants ha^{-1}), P_2 = 60 cm × 20 cm (83,000 plants ha^{-1}), P_3 = 60 cm × 25 cm (66,500 plants ha^{-1}), P_4 = 60 cm × 30 cm (55,500 plants ha^{-1}) and Factor B: Leaf clipping (4 levels) *viz:* C_1 = Control (no clipping), C_2 = Clipping of uppermost 2 leaves, C_3 = Clipping of uppermost 4 leaves, C_4 = Clipping of uppermost 6 leaves. For the purpose of evaluating the experimental outcomes, data on various parameters were evaluated. The analysis of various parameter data revealed significant differences in maize growth and yield, as a result of population density and leaf clipping and their combination treatment.

In case of different population densities of maize the highest plant height (212.94 cm at harvest), total dry matter $plant^{-1}$ (178.72 g), cob length (15.64 cm), cob diameter (4.82 cm), number of rows cob^{-1} (4.82 cm), number of grains cob^{-1} (385.04), grain weight $plant^{-1}$ (107.07 g), 100-grain weight (22.45 g) and harvest index (42.92 %) were observed in P_4 (55,500 plants ha^{-1}) treatment. However, the highest grain yield (8.27 t ha^{-1}) was observed in P_2 (83,000 plants ha^{-1}) treatment. The highest stover yield of maize (16.28 t ha^{-1}) and biological yield (24.12 t ha^{-1}) were observed in P_1 (1,10,000 plants ha^{-1}) treatment. Whereas, the lowest plant height (186.64 cm at harvest, respectively), total dry matter $plant^{-1}$ (152.76 g), cob length (13.06 cm), cob diameter (4.07 cm), number of rows cob^{-1} (12.58), number of grains cob^{-1} (254.12), grain weight $plant^{-1}$ (71.34 g), 100-grain weight (19.39 g) and highest harvest index (32.62%) were observed in P_1 (1,10,000 plants ha^{-1}) treatment. The lowest grain yield of maize (5.94 t ha^{-1}), stover yield (7.93 t ha^{-1}) and biological yield (13.88 t ha^{-1}) were observed in P_4 treatment.

Growth and yield of maize was significantly influenced due to the effect of leaf clipping at reproductive stage on maize. Experimental result revealed that the highest plant height (206.64 cm at harvest), total dry matter plant^{-1} (176.81 g), cob length (15.02 cm), cob diameter (4.69 cm), number of rows cob^{-1} (14.33 cm), number of grains cob^{-1} (352.65), grain weight plant^{-1} (98.00 g), 100-grain weight (21.97 g), grain yield (7.44 t ha^{-1}), stover yield (12.99 t ha^{-1}), biological yield (20.43 t ha^{-1}) and harvest index (40.73%) were observed in C_1 treatment, while the lowest plant height (191.72 cm at harvest), total dry matter plant^{-1} (156.71 g), cob length (13.68 cm), cob diameter (4.33 cm), number of rows cob^{-1} (13.08), number of grains cob^{-1} (288.51), grain weight plant^{-1} (92.73 g), 100-grain weight (20.14 g), grain yield (7.03 t ha^{-1}), stover yield (10.50 t ha^{-1}), biological yield (17.53 t ha^{-1}) and harvest index (37.18%) were observed in C_4 treatment.

In case of combination, P_4C_1 combination treatment gave the highest plant height (223.11 cm), total dry matter plant^{-1} (186.93 g), total dry matter plant^{-1} (144.43 g), cob length (16.27 g), cob diameter (5.03 cm), number of rows cob^{-1} (15.00), number of grains cob^{-1} (420.66), grain weight plant^{-1} (109.19 g) and 100-grain weight of maize (23.42g). The P_2C_1 combination treatment gave the highest grain yield of maize (8.53 t ha^{-1}) compared to other treatment combinations. The P_1C_1 combination treatment had the highest stover (18.32 t ha^{-1}) and biological (26.40 t ha^{-1}) yield of maize. While the lowest plant height (176.78 cm), total dry matter plant^{-1} (144.43 g), cob length (11.93 cm), cob diameter (3.80 cm), number of rows cob^{-1} (11.33), number of grains cob^{-1} (223.09), grain weight plant^{-1} (69.04 g), 100-grain weight (18.33 g) were was observed in P_1C_4 combination treatment. The P_4C_4 combination treatment gave the lowest grain yield (5.83 t ha^{-1}), stover yield (7.13 t ha^{-1}) and biological yield (12.96 t ha^{-1}) of maize.

Conclusion

Based on the above findings, experimental results revealed that different population densities and leaf clipping on maize at reproductive stage significantly influenced the growth and yield of maize. However, considering above all facts, it may be concluded that Population density at the rate of 83,000 plants ha^{-1} (P_2) without leaf clipping treatment (C_1) and their combination (P_2C_1) seems promising for increasing growth and yield of maize than compared to other combination treatment. Therefore, it was suggested that planting 83,000 plants ha^{-1} along with no leaf clipping (P_2C_1) combination treatment would help to influenced plant growth and increase its ability to enhanced better yield production of maize.

Recommendations

Considering the results of the experiment, further studies in the following areas are suggested:

- ✓ Other population densities of maize and different agronomic management practices may be taken for further experiments to get more accurate result.
- ✓ 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.

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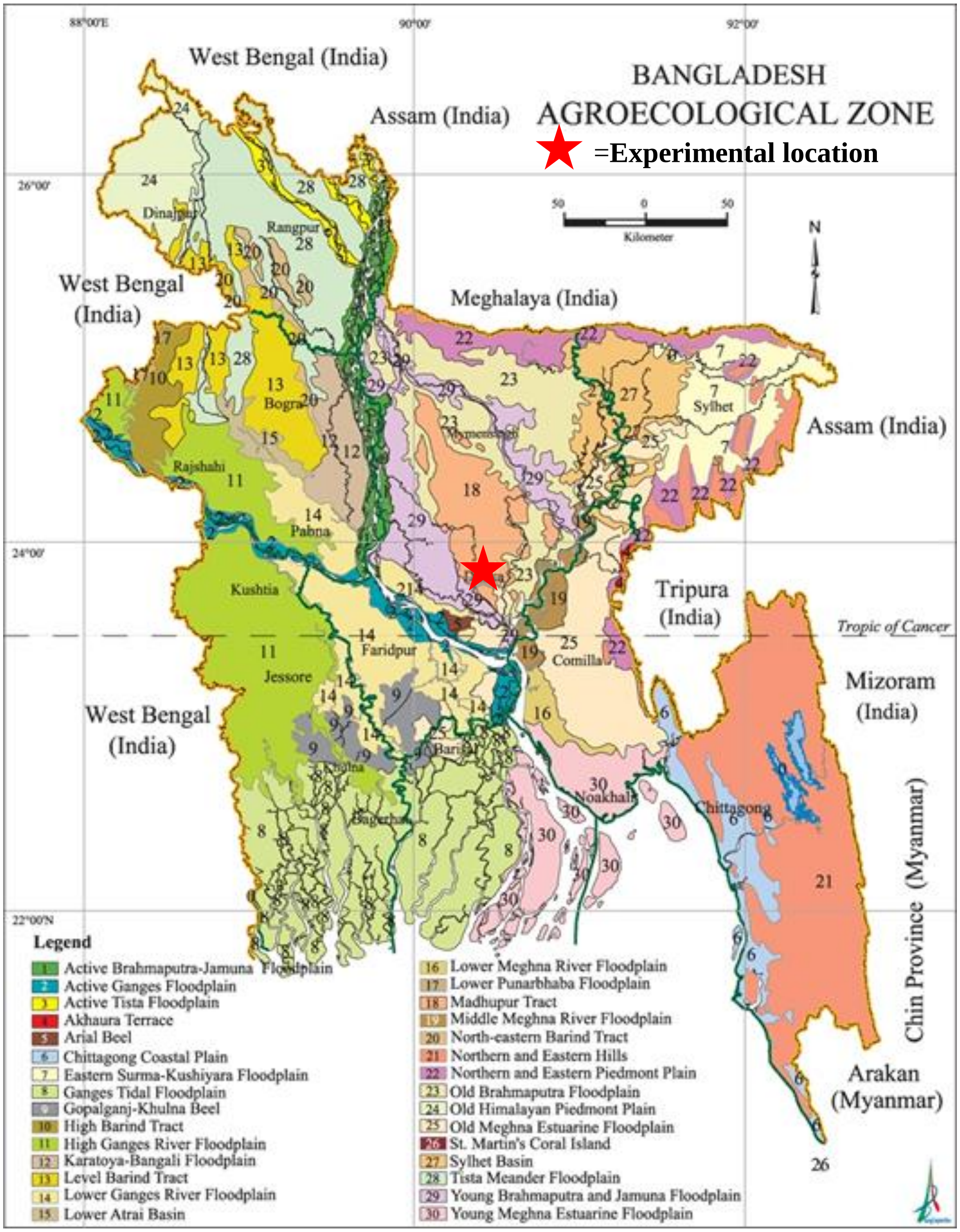
APPENDICES

Appendix-I. Map showing the experimental location under study



Appendix-II. Monthly meteorological information during the period from October, 2021 to February, 2022.

Year	Month	Air temperature (°C)		Relative humidity (%)	Average rainfall (mm)
		Maximum	Minimum		
2021	October	31.2	23.9	76	52 mm
	November	29.6	19.8	53	00 mm
	December	28.8	19.1	47	00 mm
2022	January	25.5	13.1	41	00 mm
	February	25.9	14	34	7.7 m

Source: Meteorological Centre, Agargaon, Dhaka (Climate Division)

Appendix-III. Soil characteristics of the experimental field

A. Morphological features of the experimental field

Morphological features	Characteristics
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Location	Sher-e-Bangla Agricultural University
	Agronomy Research Field, Dhaka
Soil series	Tejgaon
Topography	Fairly leveled

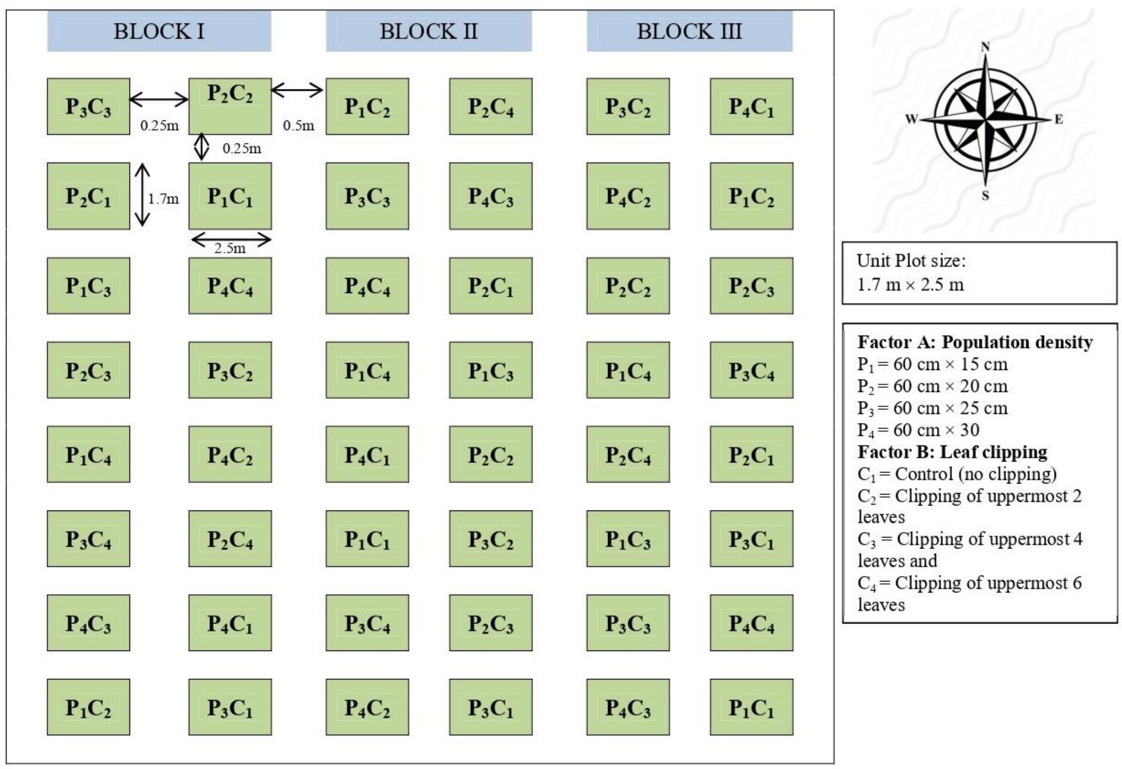
B. The initial physical and chemical characteristics of soil of the experimental site (0-15 cm depth)

Physical characteristics	
Constituents	**Percent**
Clay	29
Sand	26
Silt	45
Textural class	Silty clay

Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

Appendix-IV: Layout of the experimental field



Appendix-V. Analysis of variance of the data on plant height, total dry matter plant^{-1}, cob length and cob diameter of maize at harvest.

Source	DF	Plant height	Total dry matter plant^{-1}	Cob length	Cob diameter
Replication (R)	2	167.53	0.22	0.68	0.02
Density (D)	3	1523.98*	235.82*	14.25*	1.31*
Clipping (C)	3	491.40^{NS}	138.66*	3.82*	.27*
D×C	9	25.01*	1.80*	0.30*	0.01*
Error	30	376.57	5.59	1.22	.01

*: Significant at 0.05 level of probability
^{NS}: Non-significant

Appendix-VI. Analysis of variance of the data on number of rows cob^{-1}, number of grains cob^{-1}, grains weight plant^{-1} and 100 grain weight of maize

Source	DF	No. of rows cob^{-1}	No. of grains cob^{-1}	Grain weight plant^{-1} (g)	100-grain weight (g)
Replication (R)	2	1.65	223.73	17.12	4.00
Density (D)	3	10.72*	36987.50*	3173.33*	22.56*
Clipping (C)	3	4.06*	8777.04*	62.76*	7.90*
D×C	9	0.85*	611.78*	1.08*	0.21*
Error	30	1.45	315.01	7.61	1.25

*: Significant at 0.05 level of probability
^{NS}: Non-significant

Appendix-VII. Analysis of variance of the data on grain yield, stover, biological yield and harvest index of maize

Source	DF	Grain yield	Stover yield	Biological yield	Harvest index
Replication (R)	2	0.12	0.80	1.40	5.07
Density (D)	3	12.97*	20.71*	6.67*	175.29^{NS}
Clipping (C)	3	0.38*	273.04*	337.08*	678.68^{NS}
D×C	9	0.01*	2.87*	1.16*	20.15^{NS}
Error	30	0.21	1.37	2.83	7.92

*: Significant at 0.05 level of probability
^{NS}: Non-significant

PLATES

Plate 1. Seedling of maize

Plate 2. Data collection

Plate 3. Data collection

Plate 4. Clipping of maize leaves (clipping upper 6 leaves)