OPTIMIZING PLANTING GEOMETRY FERTILIZER AND IRRIGATION FOR WHITE MAIZE IN DIFFERENT AGROCLIMATIC REGIONS OF BANGLADESH

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CERTIFICATE

This is to certify that the thesis entitled '**OPTIMIZING PLANTING GEOMETRY FERTILIZER AND IRRIGATION FOR WHITE MAIZE IN DIFFERENT AGROCLIMATIC REGIONS OF BANGLADESH**' submitted to the faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY IN AGRONOMY**, embodies the result of a piece of bona fide research work carried out by **MD. MAHIRUL ISLAM BISWAS**, Registration No.15-06898 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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DEDICATED TO MY BELOVED
PARENTS
AND
FAMILY MEMBERS

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OPTIMIZING PLANTING GEOMETRY FERTILIZER AND IRRIGATION FOR WHITE MAIZE IN DIFFERENT AGROCLIMATIC REGIONS OF BANGLADESH

ABSTRACT

Ten field trials were conducted at three different locations, Sher-e-Bangla Agricultural University (SAU) of Dhaka, Dhamrai Upazilla, Dhaka and Rangpur Sadar Upazilla, Rangpur to evaluate the performance of seven white maize hybrids (PSC-121, KS-510, Changnuo-1, Q-Xiangnuo-1, Changnuo-6, Yangnuo-7 and Yangnuo-30) under different planting geometries using row to row and plant to plant distance (row to row 50 -70 cm and plant to plant 20-25 cm) for three consecutive rabi seasons of 2015-16 through 2017-18 in Bangladesh. In experiment 1 at SAU, the Changnuo-6 out yielded other varieties when sown at 60cm x 25 cm spacing (8.77 t ha^{-1}). In second, third and fourth experiment at SAU, Dhamrai and Rangpur in rabi 2015-16 PSC-121 gave significantly the highest seed yield in all the locations (7.37 - 9.63 t ha^{-1}) when planted at 50cm x 25cm spacing. Fifth, sixth and seventh experiments were set at SAU, Dhamrai and Rangpur during the rabi season of 2016-17 using PSC-121 where 50cm x 20cm, 50cm x 25cm and 60cm x 20 cm giving significantly higher yields (9.99-13.87 t ha^{-1}). Eighth experiment was set at SAU in the rabi season of 2016-17 to evaluate four varieties under four different irrigation regimes (25+75, 25+50+75, 25+50+75+100 DAS and 'when required') where PSC-121 showed higher seed yields both with four or 'when required' irrigation treatments (10.50 - 11.20 t ha^{-1}). Ninth experiment was set also at SAU in the same rabi season of 2016-17 to evaluate different varieties under four different fertilizer levels (Recommended, half of the recommended, 25% more than recommended and 25% less than the recommended) where variety PSC-121, Yangnuo-30 and Changnuo-1 gave significantly higher seed yields (13.96-14.84 t ha^{-1}) with the applied fertilizer dose of 25% more than recommended. Tenth experiment was set also at SAU in third year rabi season of 2017-18 to evaluate four planting geometries using the variety PSC-121 under two different fertilizer levels (Recommended and 25% more than recommended) where the spacing 50cm x 20cm, 50cm x 25cm and 60cm x 20cm gave significantly higher seed yields (10.93 -11.08 t ha^{-1}) with the applied fertilizer dose of 25% more than recommended. It was observed that the grain yield followed the number of grains per ear, 100 grain weight and population density. So, it may be concluded that at all the locations the variety PSC-121 can be grown at 60cm x 20cm planting geometry using the fertilizer dose 25% more than the recommended and four irrigations at 25 DAS+50 DAS +75 DAS+100 DAS. However, to validate the findings, the study may be repeated in all the agro-climatic zones of Bangladesh.

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LIST OF ABBREVIATIONS

ABBREVIATIONS	FULL WORD
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
Appl.	Applied.
Biol.	Biology
Ecol.	Ecology
Environ.	Environmental
AEZ	Agro Ecological Zone
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agriculture Research Institute
RCBD	Randomized Complete Block Design
cm	Cen-timeter
Nat.	Natural
Physiol.	Physiologcal
Res.	Research
m^{-2}	Meter squre
%	Percent
@	At the rate
^{0}C	Degree Centigrade
Sci	Science
Soc.	Society
N	Nitrogen
Exptl.	Experimental
CV	Coefficient of Variance
cv.	Cultivar
DAS	Days after sowing
d.f	Degrees of freedom
TDM	Total dry matter
et al.	And Others, et alii
etc.	etce

ABBREVIATIONS	FULL WORD
OM	Organic matter
FAO	Food and Agriculture Organization
g	gram
HI	Harvest Index
i.e.	That is
kg	Kilogram
Kg ha^{-1}	Kilogram per hectare
LSD	Least Significance Difference
m	Meter
MOP	Muriate of Potash
TSP	Triple Super Phosphate
R	Regression
r	Correlation coefficient
SRDI	Soil Resource and Development Institute
t ha^{-1}	Ton per hectare
Viz.	Namely
mg	miligram

CHAPTER I

INTRODUCTION

Maize (*Zea mays* L.) has become the third most important cereal crop in the world because of its high adaptability and productivity (Mosisa *et al.,* 2002). Globally maize is grown under diverse climatic conditions but yields best under moderate temperatures with sufficient water (Aldrich *et al.*, 1978). Maize has a higher carbohydrate production potential per unit land than other cereals and was the first major cereal to undergo rapid and widespread technological transformation in its cultivation (Palwal, 2000). In developed countries, maize is grown mainly for animal feed and as raw materials for industrial products, such as starch, glucose, and dextrose and bio fuel. Its grain contains 72% starch, 10% protein, and 4% fat, supplying an energy density of 365 Kcal/100g (Nuss and Tanumihardjo, 2010). Therefore, maize occupies an important position next to rice and wheat in Bangladesh. At present its area under cultivation accounts near about 963000 acres (BBS, 2017) with a projected production of 3.023 million metric tons a year almost the sole of which is used as livestock or poultry feed (BBS, 2017).

Bangladesh produces food grains of nearly 38.33 million tons annually from rice and wheat which is enough for its 160 millions of people (BBS, 2015). However, due to the increased population of Bangladesh it is speculated that the current yield productivity of rice and wheat once upon a time may not be able to cope with the increased food demand leaving an uncertainty in sustaining food security. Being C_3 in genetic nature these two crops have lower yield productivity compared to maize which is a C_4 crop having two to three fold more compared to rice and wheat.

With the growing population and rising income, demand of food is on the increase in one hand, and shrinking of agricultural land due to urbanization, industrialization and infrastructure development on the other hand. Therefore, growing food keeping pace with the demand faces unprecedented challenges (Dass *et al*., 2012) while raising the yield and production of rice remains questionable (Chen *et al*., 2014). It is against this backdrop, introduction of white maize in Bangladesh as human food can be a viable alternative for sustaining food security given the productivity of maize much higher than rice and wheat (Ray *et al*., 2013).

A very small fraction of the grown maize grains in Bangladesh is used for human consumption. Although concentrated in the North Bangladesh, maize is also grown in other regions. In the hilly areas of Chittagong (Chittagong hill tracts, CHT), the ethnic communities have been growing local races of maize for centuries to consume themselves. But in the other regions farmers produce the crop as a cash crop to feed cattle and poultry. The varieties grown excepting CHT's ones are mostly hybrids with the average yield of 6.95 t ha^{-1} (BBS, 2015).

Maize was planted in single row and twin (double) rows. Results showed that greater yields were observed in irrigated corn planted at higher populations. Increasing the planting population of a corn product with strong roots and stalks can provide greater yield potential than the same corn product planted at a lower population. Corn planted in twin rows yielded more than corn planted in single rows. An optimum planting population between 36,000 and 49,000 seeds/ acre (Monsanto, 2009; Monsanto, 2012).

Finding the optimum distance between neighboring rows and plants at any particular plant density has several advantages and is another attempt to further increase biological productivity. Firstly, it reduces competition among plants within rows for light, water and nutrients due to a more equidistant plant arrangement (Olson & Sander, 1988; Porter *et al.*, 1997). The more favorable planting pattern provided by closer rows enhances maize growth rate early in the season (Bullock *et al.*, 1988), leading to a better interception of sunlight, a higher radiation use efficiency and a greater grain yield (Westgate *et al.*, 1997). Secondly, the maximization of light interception derived from early canopy closure also reduces light transmittance through the canopy (McLachlan *et al.*, 1993). The smaller amount of sun light striking the ground reduces the potential for weed interference, especially for shade intolerant species (Gunsolus,1990; Teasdale, 1995; Johnson *et al.*, 1998).

Grain yield per unit land area is the product of grain yield per plant and number of plants per unit land area. At low densities, grain yield is limited by the inadequate number of plants whereas at higher densities, yield declines mostly because of an increase in the number of aborted kernels and/or barren plants (Swank *et al.*, 1982). Optimum plant density should be maintained to exploit natural resources, such as nutrients, sunlight and soil water fully to ensure satisfactory yields. Many studies were conducted with the aim of determining the optimum plant density for maize. There is no single recommendation for all conditions, because the optimum plant density varies depending on environmental factors such as soil fertility, water supply, crop management and genotype (ARC-GCI, 1999, Gonzalo *et al.*, 2006). Hence, cultural practices such as row spacing and plant density, collectively known as spatial variation could influence water use efficiency. For each production system, there is a plant density that optimizes the use of available resources, allowing the expression of maximum attainable grain yield in that environment. Generally, irrigation farmers use a 0.915 m row spacing with plant densities that varies from 75, 000 to 95, 000 plant per hectare. Therefore, row spacing and plant density guidelines to maximize attainable potential yield of an ultra-fast maize hybrid have to be developed for specific conditions.

Although maize was introduced in Bangladesh during seventies of the last centuries, its expansion was limited up to a certain time and there after its acreage increased due to the expansion of livestock and poultry industries. The varieties either imported or developed by the inland research organizations are yellow which are mostly used worldwide as fodder. Since its inception the maize in Bangladesh is seldom used as human food. Although the white maize is used mostly as human food worldwide, it is completely a new crop to Bangladeshi people and so it was needed to be introduced among the consumers as the human food. Under the entrepreneurship of a project, a number of exotic white maize varieties were imported from abroad to evaluate their adaptability and identifying some of the major agronomic technologies.

This study includes mostly to find out the proper planting configuration for the production of white maize in Bangladesh. As the planting configuration interacts with nutrient and water supply (FAO, 2015) this aspect is also needed to evaluate. Cox (1997); Widdicombe and Thelen (2002); Stranger and Lauer (2006) indicated that there is a need to regularly monitor the response of maize grain yield to plant density for new hybrids to maintain accurate recommendations for growth.

Objectives of this research work:

1. To find out the most suitable variety of white maize in Bangladesh.
2. To find out the optimum planting geometry for white maize varieties under Bangladesh conditions.
3. To determine the frequency of the irrigation for the production of white maize varieties in Bangladesh.
4. To assess optimum fertilizer dose for the production of white maize varieties in Bangladesh.

CHAPTER II

REVIEW OF LITERATURES

2.1. Introduction

Maize is a member of the Poaceae family, a tall grass with a large stalk, long arching leaves with evenly ruffled edges. Its origin is from the American continent where it was cultivated by various Indian tribes and attained a high level of development centuries ago. Soon after the discovery of America the maize plant was rapidly distributed to other parts of the globe (Saunders, 1930).

2.2. Planting geometry impact on growth attributes

Plant growth has been defined differently by different authors. Hunt (1990) stated that growth definitions range from unequivocal statements about change in specified dimensions to the abstract state of affairs in which the verb 'to grow' means nothing more than to live or even to exist.

Fussel *et al.* (1980) and Wareing and Phillips (1981) defined growth as it is also as a process of cell division and elongation. Boyer (1985) defined plant growth as an irreversible increase in size of organs, due to predominately increase in cellular water content accompanied by the simultaneous extension and synthesis of the cell wall and accumulation of the solutes.

Chiariello *et al.* (1989) described growth as the capacity to change in size, mass, form, and/or number which is an essential feature of life referring the term 'growth' to anant heighty or all of these types of change.

Plant growth and growth components may show different levels of responses depending on varying growth attributes. Ballaré *et al.* (1990), Maddonni *et al.* (2001) and Chelle (2005) stayed that whole plant canopy level might vary with relative positions of different organs. It is now an established facts that among other major factors population density affects plant growth greatly.

Tetio and Gardner (1988); Edmeades and Lafitte (1993); Subedi *et al.* (2006) observed that the effects of high plant density on corn morphological development have been studied extensively at the canopy level.

Tetio-Khago and Gardner (1988b); Sarquis *et al*. (1998) observed that the effect of plant density on maize growth results from the onset of inter and intra plant competition during the growing period. Interplant competition commonly occurs earlier at higher densities whereas intra plant competition is more intense at low densities. They found that plant density strongly affects the rate and duration of crop growth and ultimately the fate of multiple ears.

Sangakkara *et al*. (2004) found that plant populations affect most growth parameters of maize even under optimal growth conditions and therefore it is considered a major factor determining the degree of competition between plants.

Researchers also came to an opinion that light interception by a certain crop is mainly dependent on the canopy volume of the field. In a study it was unveiled that a 30% reduction in light interception by the canopy during the crop cycle was sufficient to completely suppress the development of a second ear in maize. Apparently the reduction of light interception limits source capacity, which in turn could retard second-ear growth severely.

According to Willey and Heath (1970) the effects of plant density normally refer to plant number per unit area, but spatial arrangement of plants should be considered regarding per unit area occupied by a single plant.

Plant spacing is an important factor which plays a significant role on growth, development and yield of maize. Optimum plant population provides scope to the plants for efficient utilization of solar radiation and nutrients. Sunlight can penetrate more easily and can reach the soil surface which may cause excessive evaporation of soil moisture. Closer spacing hampers intercultural operations and as such more competition arises among the plant for nutrients, air and light. As results, plant becomes shorter, weaker, thinner and consequently reduces yield of maize. FAO (2012) proposed that adjustment of proper plant spacing in the maize field is important to ensure maximum utilization of solar energy by the crop and reduce evaporation of soil moisture. Plant growth is generally measured by assessing plant height, number of leaves plant^{-1}, leaf area per plant^{-1}, leaf area index, stem diameter, total dry matter, crop growth ratio (CGR), relative growth ratio (RGR), net assimilation rate (NAR) light interception etc. Effect of plant spacing on various growth attributes are discussed below.

2.2.1. Plant height

Gynes-Hegyi *et al*. (2002) revealed that maize plant height is a genetic trait in maize and determined by the number and length of internodes. Plant height may vary from 0.3 to 7 m depending on the maize cultivar and environmental growing conditions.

Koester *et al*. (1993) noticed that usually early maturing cultivars are shorter and late maturing ones taller. In the tropics where the growing season may be as long as 11 months, certain late maturing maize cultivars can grow to a height of 7 m.

Yakozawa & Hara (1995) indicated that the final height of maize plants is strongly influenced by environmental conditions during stem elongation. Temperature and photoperiod may influence stalk height by affecting the number of internodes. However, other factors include water, nutrition, temperature, pest, diseases, light quality and quantity (Baggett & Kean, 1989). Moisture stress might simply affect the length of internodes by inhibiting the elongation of developing cells.

Yakozawa and Hara (1995) also indicated that the final height of maize plants is strongly influenced by environmental conditions during stem elongation. Previous research results involving different plant densities revealed that maize plants grew taller as mutual shading increased with a considerable cultivar variation in this characteristic.

Sher *et al.* (2017) reported that plant population recognized as an important factor determining the degree of competition between plants. The development of earlier hybrids, with shorter plant height, lower leaf number, upright leaves, smaller tassels and more synchronized floral development improved maize ability to withstand high plant densities without presenting a higher percentage of barren plants.

According to Zuber *et al.* (1957); El-Lakany and Russel (1971) the morphology of plant height is very important factor which is affected by plant density. Plant height is not correlated with root lodging but it is was significantly correlated with grain yield.

A study was carried out by Enujeke (2013a) in Teaching and Research Farm of Delta State University, Asaba Campus from March, 2008 to June, 2010 to evaluate the effects of variety and spacing on growth characters of hybrid maize. Three hybrid maize varieties were evaluated under three different plant spacing for such growth characters as plant height, number of leaves, leaf area and stem diameter. Result revealed that the highest plant height 176.7 cm was recorded from plants sown on 75 cm x 15 cm and the lowest one 152.7 cm was recorded from plants sown on 75 cm x 35 cm spacing.

Jula *et al*. (2013) conducted a field experiment during the cropping seasons of 2009 and 2010 in Samaru, Zaria, Nigeria to evaluate the effects of various intra-row spaces on the growth and yield of maize intercropped into ginger. The experiment consisted of six treatments laid out in a Randomized Complete Block Design and replicated three times. The results showed that, plant heights in intercropped spacing 75× 75 cm were taller (158.8 cm) ($P<0.05$) than the sole maize plants treatment (89.27 cm).

Shafi *et al.* (2012) conducted an experiment to investigate the effect of planting density on plant growth and yield of maize varieties at Agricultural Research Farms Khyber Pukhtunkhwa Agricultural University Peshawar, Pakistan. The experiment consist of four maize varieties viz., Azam, Pahari, Jalal-2003 and Sarhad white as main plot factor and three plant densities of 45000, 55000 and 65000 plants ha^{-1} as sub plot factor. Result showed that the maximum plant height was recorded from the treatment of 65000 plants ha^{-1}. Minimum plant height was attained by 45000 plants ha^{-1}.

Abuzar *et al*. (2011) conducted a field experiment to determine the effect of plant population densities on maize was conducted at the Agricultural Research Institute, Dera Ismail Khan, in mid July 2009. The effect of six plant population densities i.e. T_1 (40000 plants $ha^{–1}$), T_2 (60000 plant $ha^{–1}$), T_3 (80000 plants $ha^{–1}$), T_4 (100000 plants $ha^{–1}$), T_5 (120,000 plants $ha^{–1}$) and T_6 (140,000 plants $ha^{–1}$) was investigated using maize variety Azam. Result showed that the tallest plants (197.2cm) were recorded in T_4 (100000 plants ha^{-1}), which were, however, statistically at par (193.0cm) with T_3 (80000 plants ha^{-1}). Short statured plants (150.8cm) were recorded in T6 (140,000 plants ha^{-1}) due to crowding effect of the plant and higher intra-specific competition for resources.

Studies were conducted by Asafu-Agyei (1990) in four locations in Ghana in 1986 to determine the effect of seven planting densities: 10, 20, 30, 40, 50, 60 and 70 x 10^3 $plants^{-1}$ ha on grain yield of three maize varieties differing in maturity: early, medium and full season. He found that, the highest plant height (200 cm) was recorded from 40 $\times 10^3$ plants ha^{-1} and the lowest one (180 cm) from 10 $\times 10^3$ plants ha^{-1}.

2.2.2. Phenology

Plant density impacts on synchrony of flowering where high plant densities may reduce the supply of nitrogen (Lemcoff & Loomis, 1994), photosynthates (Jacobs &

Pearson, 1991) and water (Westgate, 1994) to the growing ear. Restrictions in carbon or nitrogen metabolism in dense stands may delay specific developmental events and reduce both spikelet number and silk extrusion, contributing to a decrease in the number of spikelets that can be fertilized through coincidence of pollen shed with silking of individual spiklets (Jacobs & Pearson, 1991). Thus, barrenness and the production of nubbin ears, associated with increasing plant density, have been linked with delayed silk or growth of ear premordia. Stevens *et al.*, 1986).

Edmeades and Daynard (1979) reported that a plant density of 200 000 plants ha^{-1} shortened the period of initiation of spikelet primordial, thereby reducing the number of spikelet premordia per row. Plant density (Buren et al., 1974), water stress (Herrero & Johnson, 1981; Hall *et al*., 1982) and nitrogen supply (Anderson *et al*., 1984) generally influence the synchrony of flowering and hence grain yield. This indicates that plant density has both a direct and indirect effect on synchronization of flowering.

2.2.3. Leaf number

A study was carried out by Enujeke (2013a) in Teaching and Research Farm of Delta State University, Asaba Campus from March, 2008 to June, 2010 to evaluate the effects of variety and spacing on growth characters of hybrid maize. Result revealed that plants sown on 75 cm x 15 cm gave the highest number of leaves plant^{-1} (13.8) whereas plants sown on 75 cm x 35 gave the lowest number of leaves plant^{-1} (12.2).

A field experiment was carried out by Jula *et al*. (2013) during the cropping seasons of 2009 and 2010 in Samaru, Zaria, Nigeria to evaluate the effects of various intra-row spaces on the growth and yield of maize intercropped into ginger. The results showed that, the highest number of leaves plant^{-1} (12.33) was recorded from maize intercrop planted at 75 × 75cm and the lowest number of leaves plant^{-1} (8.00) was reported for sole maize crop treatment at 75 × 25 cm spacing.

2.2.4. Stem diameter

A study was carried out by Enujeke (2013a) in Teaching and Research Farm of Delta State University, Asaba Campus from March, 2008 to June, 2010 to evaluate the effects of variety and spacing on growth characters of hybrid maize. Result showed that plants sown on 75 cm x 35 cm gave the maximum stem diameter (99.4 mm) where as plants sown on 75 cm x 15 gave the minimum stem diameter (76.6 mm).

Rajcan and Swanton (2001) found that plants that grow within a dense canopy or at a high plant density receive a different quality of light, enriched with far red (FR) and impoverished in red (R) radiation. High ratios of FR/R triggers a number of morphological alterations in plant architecture, stimulating stem elongation, favouring apical dominance and decrease in stem diameter.

Argenta *et al*. (2001) found that stalk lodging represents one of the most serious constraints to the utilization of high plant densities in maize cultivation. Thus, during breeding many high yielding maize hybrids are often rejected during development because of stalk lodging. Field crop growth was characterized by a system of growth analysis based mostly on dry matter accumulation rates. In crowded maize plants stems having smaller diameter and shanks due to mutual shading are easily lodged posing the make maize stalks more susceptible to breakage before kernels reach physiological maturity. The population density may act differently on plant base on the growth phases.

According to Fournier and Andrieu (2000) the kinetics of stem/plant elongation in crop growth was found to be composed of four phases. Elongation rate rises exponentially during phase I, then increase sharply during phase II (a relative short period), followed by a major period of constant growth rate (phase III) before it enters the last period of decline (phase IV). Moreover, during phase I, elongation appears to be integrated at the level of the whole apical cone. From phase II onwards elongation becomes determined at the level of phytomer. Such elongation of stem is profoundly be affected by plant’s stand and population density.

Ritchie and Alagarswamy (2003) reported that barrenness occurred more frequently when plant densities exceed 10 plants/m2. Similarly, plants become taller and weaker at higher densities which lead to higher lodging. Gardner *et al.* (1985) also reported the increased lodging with increasing plant density.

2.5.5. Leaf area and leaf area index

Gardner *et al*. (1985) stated that crop growth can also be expressed on the basis of leaf area, because leaf surfaces intercept sunlight and absorb CO_2, releasing water during photosynthesis.

Hunter (1980) reported that the grain yield of maize can be increased by increasing the leaf area per plant. He concluded that a large leaf area per plant produced more assimilate in the plant, resulting in increased yield.

Watson (1997) defined leaf area index of a crop as the one-sided area of green leaf tissue per plant unit area of land occupied by that crop. That is the area of leaf per area of land. Leaf area and its distribution over land area is one of the major factors that determine light interception, which affects photosynthesis, transpiration and dry matter accumulation. Leaf area index can be estimated and used in crop growth models to compute photosynthesis, assimilate partitioning, gas exchange and energy exchange (Fortin *et al.*, 1994). The coverage of ground surface by the foliage is measured by leaf area index (LAI).

Jula *et al*. (2013) conducted a field experiment during the cropping seasons of 2009 and 2010 in Samaru, Zaria, Nigeria to evaluate the effects of various intra-row spaces on the growth and yield of maize intercropped into ginger. The results showed that, maximum leaf area plant^{-1} (559.24 cm^2) was recorded from intercropped spacing 75 X 75 cm where as the minimum leaf area plant^{-1} (221.90 cm^2) was reported for sole maize crop treatment at 75 × 25 cm spacing.

Stewart and Dwyer (1999) stated that leaf area index is a key plant growth parameter frequently measured and estimated from leaf shape characteristics.

According to Modarres *et al*., (1998) the efficient interception of radiant energy incident to the crop surface needs appropriate leaf area, uniformly distributed to provide complete ground cover which can be achieved by manipulating stand density and distribution over land surface.

Andrade *et al*. (2002) found that the capacity of the crop to intercept photosynthetically active radiation and synthesis of carbohydrates for growth is a nonlinear function of LAI. .

A study was carried out by Enujeke (2013a) in Teaching and Research Farm of Delta State University, Asaba Campus from March, 2008 to June, 2010 to evaluate the effects of variety and spacing on growth characters of hybrid maize. Result showed that plants sown on 75 cm x 35 cm gave the maximum leaf area (713.7 cm^2) where as plants sown on 75 cm x 15 gave the minimum leaf area (587.3 cm^2).

Pearce *et al.* (1965) stated that canopy light interception and photosynthesis are closely related to LAI up to the critical LAI, which is required to intercept 95% incident irradiance.

Bos and Vos (2000); Song *et al.*, (2016) observed the effect of plant density on leaf area expansion through two parts i.e., lamina length and lamina width, the first being consistently decreased in both lower and upper phytomers whereas the second being increased in lower phytomers and decreased in upper phytomers.

Yu *et al.*, (1998); Maddonni *et al.*, (2001): Li and Li (2004) found that maize growth and yield can also be related to increased plant density effect on plant morphology and physiology. Improved morphology was the key for promoting light use efficiency per plant.

Walker (1988) stated that growth and more specifically crop growth can generally be measured by biomass accumulation and an increase of LAI at the vegetative phase of maize.

Edmeades *et al*. (1997) showed that assimilates moved preferentially from a leaf to its nearest sink. This implies that leaves above and immediately below the primary ear supply the majority of assimilates for grain filling while assimilates from the lower leaves are probably translocated into the root system and lower stem.

Monteith (1981) found that during the vegetative growth phase, leaf area determines the total amount of light interception. Thus, the amount of CO_2 fixed is proportional to leaf area available. It is reported that only 50% of incident solar radiation can be used as photosynthetically active radiation. The remaining energy is worthless with respect to photosynthesis and increases leaf temperature if absorbed.

Grant and Hesketh (1992); Murphy *et al.*, (1996) stated that in a crop canopy, factors such as plant shape, plant populations, and row width affected leaf distributions, PAR interception and yield. Leaf area, leaf sheath and internode mass decreased with higher planting density, with greater decrease was at higher nodes.

Hay and Walker (1989); Cox (1996); Maddonni and Otegui (2004) found that at higher plant densities, leaf area per plant is decreased in later phases of growth, 40% increased in LAI at high plant density from mid-vegetative to early grain fill even though per plant biomass decreased 40 to 60% at high plant density.

Tetio-Kagho and Gardner (1988b) and Cox (1996) stated that grain yield in maize is also interrelated to LAI and hence canopy structure with respect to light interception. Basically to achieve optimum LAI, it requires an appropriate arrangement of row spacing by plant density combination for a particular genotype.

Tetio and Gardner (1987); Hashemi-Dezfouli and Herbert (1992); Stewart *et al.* (2003) found that increasing planting density accelerated leaf senescence increased the shading of leaves and reduced the net assimilation of individual plants.

Abuzar *et al.* (2011) conducted a field experiment to determine the effect of plant population densities on maize was conducted at the Agricultural Research Institute, Dera Ismail Khan, in mid July 2009. The effect of six plant population densities i.e. T_1 (40000 plants ha^{-1}), T_2 (60000 plant ha^{-1}), T_3 (80000 plants ha^{-1}), T_4 (100000 plants ha^{-1}), T_5 (120,000 plants ha^{-1}) and T_6 (140,000 plants ha^{-1}) was investigated using maize variety Azam. They reported that the treatments having plant population of 120,000 and 140,000 plants ha^{-1} produced higher LAI of 2.77 and 2.52, respectively. The lowest LAI was obtained with population of 40000 plants ha^{-1}.

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

Studies were carried out by Asafu-Agyei (1990) in four locations in Ghana in 1986 to determine the effect of seven planting densities: 10, 20, 30, 40, 50, 60 and 70 x 10^3 plants^{-1} ha on grain yield of three maize varieties differing in maturity: early, medium and full season. Result revealed that, the maximum leaf area index (LAI)(3.00) was recorded from 60 $\times 10^3$ plants ha $^{-1}$ and the minimum LAI (0.80) from 10 $\times 10^3$ plants ha $^{-1}$.

2.2.6. Crop growth

Brown (1984) observed a meaningful analysis of crop growth is preferably based on a land area rather than an individual plant basis. Therefore, the most commonly used growth analysis is crop growth rate (g m^{-2} day^{-1}) defined as the dry matter accumulation rate per unit of land per unit time.

Jeffery *et al*. (2005) stated that the reason for this is that CGR is directly related to the amount of radiation intercepted by the crop.

Dehdashti and Riahinia (2008) revealed that increasing plant density above an optimum may decrease CGR due to low dry matter accumulation on a per plant basis.

Tajul *et al.* (2013) also revealed that plant growth, light interception (LI), yield attributes, and grain yield varied significantly due to the variations in population density and N-rates. Crop growth rate (CGR) was the highest with the population of 80,000 ha^{-1} receiving 220 $kgNha^{-1}$, while relative growth rate (RGR) showed an opposite trend of CGR. Light absorption was maximum when most of densely populated plant received the highest amount of N (220 kg N ha^{-1}).

Bavec and Bavec (2002) stated that plant density was recognized as a major factor determining the degree of competition between plants. In order to obtain a maximum crop growth rate (CGR), plant density in a cropping system needs to be adjusted in a manner that optimizes LAI for maximum solar radiation interception.

According to Hashemi-Dezfouli and Herbert (1992) increasing plant density results in a reduction of CGR due to mutual shading of leaves.

Williams *et al*. (1968) found that light interception and CGR increased linearly as LAI increased up to 3, but CGR increased asymptotically as LAI was increased further to a maximum at 99% light interception. Plant density resulting in interplant competition affects both vegetative and reproductive growth. They also observed that the effect of canopy architecture on vertical distribution of light within the maize canopy was a major determinant of photosynthetic efficiency and growth.

Watson (1958) and Shuting *et al*. (1993) found that the photosynthetic capacity of crops is a function of leaf area index (LAI) and the photosynthetic efficiency can be described by the net assimilation rate (NAR = rate of increase of dry matter per unit of leaf area per unit time). The dry matter accumulation rate per unit of leaf area per unit of time is termed net assimilation rate (NAR) and is a measure of the photosynthetic efficiency of leaves per unit leaf area.

Dwyer *et al.* (1991) reported that an increase of plant density from 20000 to 130 000 plants ha-1 caused a NAR reduction from 0.85 to 0.11 g m-2 of CO_2. Increasing plant density results in a reduction of net assimilation rate.

2.2.7. Dry matter accumulation

Donald (1963), Williams *et al*. (1968); Daughty *et al.* (1983) stated that dry matter accumulation of crop plants is directly related to the utilization of solar radiation, which is influenced by canopy structure.

Duncan (1958) and Gardner *et al*. (1985) observed that maize reproductive responses to plant density have generally shown that individual plant dry matter decreases with increasing plant density, whereas dry matter per unit area increases with the increase in population density.

Baenziger and Glover (1980) indicated that ear and kernel dry weight increased but total dry matter per unit land area decreased by reducing plant density. This reduction of total dry matter per unit land area was associated with the reduction of number of ears per plant as the plant density increased.

Jula *et al*. (2013) conducted a field experiment during the cropping seasons of 2009 and 2010 in Samaru, Zaria, Nigeria to evaluate the effects of various intra-row spaces on the growth and yield of maize intercropped into ginger. The results showed that the dry matter accumulation was highest (29.17 g plant^{-1}) for maize intercrop planted at 75 × 25cm, which was significantly better than all other treatments with the least dry matter accumulation (10 g plant^{-1}) obtained in the sole maize crop treatment at 75 × 25 cm spacing.

Gardner *et al*. (1985) concluded that plant growth and development are combinations of a host of complex processes of growth and differentiation that lead to the accumulation of dry matter.

Bewley and Black (1985) stated that the dry matter accumulation of maize kernels begins shortly after fertilization and progresses in a sigmoid pattern in which three phases can be distinguished.

2.3. Planting geometry impact on yield components and yield

Plant density is defined as the number of plants per unit area of ground. Plant density has a marked impact on crop yield and is regarded as an agricultural “input” in much the same way as fertilizer. An integral aspect of plant density is spatial arrangement, that is, the pattern of distribution of plants covering the ground area. Plant density has remarkable effects on grain yield and yield contributing parameter.

2.3.1. Yield components

2.3.1.1. Ear length and diameter

Plant density has a profound impact on ear length and ear diameter. Increased plant density, especially above a critical optimum on a particular environment reduces ear length and diameter, and ultimately the grain yield (EL-Lakany & Russel, 1971; Begna, 1996; Kgasago, 2006).

Ross and Hallauer (2002) suggested that ear length and diameter are basic components affecting kernel yield. Waezi *et al.* (1998) revealed that ear length and diameter are some of the dominant traits of grain yield of maize.

EL-Lakany and Russel (1971), Begna, (1996) and Kgasago (2006) reported that plant density has a profound impact on ear length and ear diameter. Increased plant density, especially above a critical optimum on a particular environment reduces ear length and diameter, and ultimately the grain yield.

2.3.1.2. Number of grains per row and cob

Grain number per row and cob are yield components that have a profound impact on maize grain yield. In general, kernel number accounts for most of the differences in grain yield.

Tetio-kagho and Gardner (1988a) and Andrade *et al*. (1993) reported that the kernel number per row and ear declined sharply with increasing plant density. The decline of both yield components with increasing plant density was likely to be due to a decrease in photosynthetic rate per plant (Edmeades and Daynard, 1979) and hence plant growth rate.

Echarte *et al*. (2000) reported grain yield response to plant density to be positively and strongly related to number of kernels per ear and negatively and weakly related to weight per kernel. For instance, an increase in plant density from 50 000 to 145 000 plants ha-1 increased kernel number per ear by 38 to 56%.

The highest reduction in kernel number per ear occurred in plants shaded during the lag phase of grain filling (Andrade *et al*., 1993).

Sangoi *et al*. (2002) indicated that the number of potential grain sites per ear measured when silking commenced and before pollination showed a decline from 550 to 474 grains per ear at a high plant density. This was ascribed to poor pollination for ears delayed in silking and abortion for some fertile grains thereafter (Hashemi-Dzefouli & Herbert, 1992).

Tokatlidis & Koutroubas (2004) also reported that under high plant densities the reduced assimilate supply caused an abortion of kernels, especially at the tip.

Edmeades and Daynard (1979) reported that a plant density of 200000 plants ha^{-1} shortened the period of initiation of spikelet primordial, thereby reducing the number of spikelet premordia per row.

A study was carried out by Enujeke (2013b) in the Teaching and Research Farm of Delta State University, Asaba Campus (Nigeria) from March to December in 2008 and replicated between March and December, 2009, to evaluate the effects of variety and spacing on yield indices of Open-pollinated maize.. Four open-pollinated varieties (Suwan -1- SR, ACR97, BR9922-DMRSF$_2$ and AMATZBRC$_2$WB) were evaluated under three different plant spacing (75 cm x 15 cm, 75 cm x 25 cm and 75 cm x 35 cm) for such yield indices as number of cobs/plant, cob length, grain weight and number of grains/cob of maize. The results obtained indicated that plants sown on 75 cm x 35 cm had the highest number of grains cob^{-1} (432.0) in 2008 and (440.5) in 2009, while plants sown at 75 cm x 15 cm had the lowest number of grains cob^{-1} (363.0) in 2008 and (369.0) in 2009.

Sangoi *et al.* (2002) indicated that the number of potential grain sites per ear measured when silking commenced and before pollination Sarquis *et al.* (1998) found that at high plant densities, the equilibrium between two ears seem to be affected by a stronger competition between the ears as evidenced by a more severe decrease in grain mass with increasing time between the two pollinations, regardless of which ear was pollinated first.

Otegui (1995) mentioned that maize grain yield is mainly determined by kernel size and number per unit land area.

Salvador and Pearce (1995) found that at high plant densities, yield may be restricted by limitations in the capacity for endosperm growth either by number, size or activity of endosperm cells. There is a possibility of interaction between kernel position and number in terms of competition for substrates required for growth, which is accentuated at high plant densities.

Cheng *et al*. (1983) and Stevens *et al.* (1986) found in maize that kernel number is a function of the rate and duration of differentiation of spikelet cessation prior to the initiation of the silk, fertilization which requires synchronization of flowering of tassel and ears, and kernel abortion after fertilization. Examination of spikelet production has been largely qualitative.

Sher *et al.* (2017) revealed that the use of higher plant populations enabled corn to intercept virtually all the available solar radiation earlier in the season, transforming this energy into storage carbohydrates and other foods in more grains per area.

Tokatlidis and Koutroubas (2004) also reported that under high plant densities the reduced assimilate supply caused an abortion of kernels, especially at the tip under the condition of insufficient solar radiation interception. Tollenaar and Aquilera (1992) reported that lower barrenness in modern maize hybrids compared with older hybrids at higher plant densities was associated with higher plant growth rate from one week pre-silking to three weeks pre-silking.

Sangoi (1996) found that plant density beyond an optimum limits the conversion of light energy to grain and initiates the development of barren plants. The mechanism of ear development needs clear understanding of its differentiation to silking. This enables to describe plant density impacts on the number of female inflorescence produced per plant and the number of viable differentiated spikelets.

Jacobs and Pearson (1991) opined that barrenness is the physiological alteration that can be associated with high plant density which delays ear differentiation and growth of ear primordia.

2.3.1.3. Number of grain rows per cob

Abuzar *et al.* (2011) conducted a field experiment to determine the effect of plant population densities on maize was conducted at the Agricultural Research Institute, Dera Ismail Khan, in mid July 2009. The effect of six plant population densities i.e. T_1 (40000 plants ha^{-1}), T_2 (60000 plant ha^{-1}), T_3 (80000 plants ha^{-1}), T_4 (100000 plants ha^{-1}), T_5 (120,000 plants ha^{-1}) and T_6 (140,000 plants ha^{-1}) was investigated using maize variety Azam. They reported that the treatments having population of 60000 and 80000 plants ha^{-1} produced the highest number of rows per cob of 15.44 each.

Hashemi *et al*. (2005) reported a linear decline in number of kernel rows/ear with increasing plant density. The high barrenness (%) at high densities was due to the absence of the usual sink for the assimilate supply and limiting optimum conversion of light energy to grain in maize grown at high plant densities which inhibited the plants to produce viable ears.

2.3.1.4. Grain weight

Plant density has a prominent influence on grain weight. The differences in kernel weight at variable plant densities may result from differences in the initial size of the spikelets and in the growth rate during the exponential and linear phases of grain accumulation.

Lemcoff & Loomis (1986) observed that the initial grain weight after pollination was a key factor in the early growth of the kernel. Thus, at a high plant density, the kernels was smaller, which could inturn be due to a delay in development (later initiation of spikelets) and a smaller initial size of the spikelets primordia. The final kernel weight correlates strongly with number of cells and starch granules formed, particularly in the endosperm tissue, representing about 80% of the mass of mature maize grains.

Westgate *et al*. (2004) stated that the second phase of seed growth is known as the effective grain filling period and involves active biomass accumulation, which is generally more important than the lag phase in actual size determination.

Westgate (2000) also found that during this phase, kernel water content reaches its maximum and begins to decline, closely coordinated with dry matter deposition. In the third phase, kernels achieve their maximum dry weight (commonly referred to as physiological maturity) and enter a quiescent state.

Andrade *et al*. (1993) found that the highest reduction in kernel number per ear occurred in plants shaded during the lag phase of grain filling due to the reduction in interception of photosynthetically active radiation in that phase.

Buren *et al*. (1974) also reported that grain yield of many hybrids cultivated at high plant densities are considerably reduced as a result of barrenness. Therefore, factors influencing barrenness have to be determined and understood to carryout possible selection of genotypes that are tolerant to high plant densities.

Buren *et al*. (1974) and Anderson *et al.* (1984) observed that prolific maize lines that produced multiple ears at low plant densities, maintained a higher kernel number than did single-eared lines when grown at high plant densities. This was due to better synchronization between pollen shed of the tassel and silk extrusion of the ears. Cob growth also accelerates during this period with the onset of grain filling. Approximately 10 to 15 days after silking, depending on the maize cultivar, leaf and stalk growth is terminated and sugars produced by photosynthesis in the leaves move into the grain where they are converted into starches, protein and oils. Grain development is rapid during the next 30 to 35 days. Kernel number per row and ear are yield components that have a profound impact on maize grain yield. In general, kernel number accounts for most of the differences in grain yield. Plant density has a prominent influence on kernel weight. The differences in kernel weight at variable plant densities may result from differences in the initial size of the spikelets and in the growth rate during the exponential and linear phases of grain accumulation.

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

2.2.1.5. Grain yield

Forbes and Watson (1992) defined grain yield as the economic parts of the crop harvested per unit area of land.

Tollenaar and Lee (2002) reported that maize has a limited ability to take advantage of increased resources under suboptimal plant densities, indicating that future yield improvement will likely be related to greater stress tolerance, allowing for higher plant densities.

Van Averbeke and Marais (1992) stated that factor affecting barrenness leading to a greater proportion of barren plants is excessive population pressure. This could ultimately reduce grain yield. Scarsbrook and Doss (1973) reported that stover yields of hybrid maize usually increased with each increment of plant population up to 80,000 plants/ha.

Buren *et al*. (1974) and Anderson *et al.* (1984) observed that prolific maize lines that produced multiple ears at low plant densities, maintained a higher kernel number than did single-eared lines when grown at high plant densities. This was due to better synchronization between pollen shed of the tassel and silk extrusion of the ears. Cob growth also accelerates during this period with the onset of grain filling. Approximately 10 to 15 days after silking, depending on the maize cultivar, leaf and stalk growth is terminated and sugars produced by photosynthesis in the leaves move into the grain where they are converted into starches, protein and oils. Grain development is rapid during the next 30 to 35 days. Kernel number per row and ear are yield components that have a profound impact on maize grain yield

Carcova and Otegui (2001) and Maddonni and Otegui (2004) established that maize has a distinctive response to plant density beyond a certain threshold. This response to plant density derives from the combined effects of (i) a decrease in photosynthetic rate per plant and plant growth rate and (ii) a hierarchical pattern in reproductive development in which tassel growth dominates ear growth.

According to Willey (1982) as plant density increases, the yield per plant increases up to a threshold after which it decreases due to increasing competition for growth resources. On an area basis, however, the increased plant number gives greater utilization of resources and total biological yield increases in the form of a diminishing response curve that levels off when plant density is sufficient for maximum resource utilization. With further increases in plant density, the total biological yield of maize per unit area generally remains reasonably constant.

Kmen *et al*. (2001) stated that maize grain yield is a product of the yield components that include the number of plants per land area, number of ears per plant, seeds per ear and 1000-grain weight.

Shapiro and Wortmann (2006) mentioned that plant population is another factor which affects the plant yield. Yield was increased by 4% with increasing plant density.

Ritchie and Alegarswamy (2003) reported that a high maize yield (kg ha^{-1}) at high plant densities ranging from 70 000 to 100 000 plants ha^{-1}, but barrenness was initiated more frequently at plant densities above 100 000 plants ha^{-1}. Increased plant density does not only affect barrenness positively, but also plant growth rate.

According to Vega *et al.* (2001) maize grain yield is more affected by variations in plant density than other members of the grass family due to its low tillering capacity.

Stone *et al.* (2000) observed that there was no significant effect of row spacing on any component of yield or quality for crops grown at 'normal' plant populations (90,000 plants/ha). Consequently, the results from this limited set of experiments suggest that, at the current 'standard' population, there is no benefit from narrow (25 or 50 cm rows) compared with standard (75 cm) row spacing.

Paszkiewicz (1998) mentioned that the majority of research on crop row spacing was done from the early 1980’s and focused on reducing row spacing to less than 0.76 m. Investigation in many areas of the northern United States indicated yield increases up to 9.9% by growing maize in rows narrower than 0.76 m. Increasing in the population density significantly increased seed yield (by an average 7% for every additional 10,000 plants/ha) up to a plateau that usually occurred at *ca* 1,20,000 plants/ha.

Eszter Murányi (2015) showed that optimal plant densities of the hybrids were different in the two studied crop years: in 2013, regarding the treatments set with the row distance of 45 cm, increasing plant densities resulted in higher yields, while in 2014, the yield showed decreasing tendency parallel to the increasing plant densities, that is confirmed by the fact that plant densities of 50000 and 65000 plants ha^{-1} proved to be more favourable.

In another study Echarte *et al*. (2000) reported grain yield response to plant density to be positively and strongly related to number of kernels per ear and negatively and weakly related to weight per kernel. For instance, an increase in plant density from 50000 to 145000 plants ha^{-1} increased kernel number per ear by 38 to 56%. Regarding the treatments with a row distance of 76 cm, hybrids obtained their yield maximums by 80 327 plants ha^{-1} in 2013, while in the vegetation of 2014, by higher plant density (85 845 plants ha^{-1}).

Fancelli and Dourado (2000) also found a strong relationship between maize grain yield and plant density. They highlighted that for each production system there is a plant density that optimizes the use of available resources, thereby allowing the expression of maximum attainable grain yield in that environment.
Abdul *et al*. (2007) reported that higher plant population produce 25% more grain yield and 38% more biomass as compared with low plant population and early sown crop produce 19% more grain yield and 11% more biomass than late planted crop.

Ying *et al.* (2000); Duvick (2005) conducted several experiments on modern maize genotypes and observed greater tolerance to insect feeding, pathogen infection, drought, low soil fertility, saturated and/or cool soils, above and below average seasonal temperatures, low night temperatures during the grain filling period; and inter and intra-species competition (maize-maize and maize-weed, respectively), solar radiation, water and soil nutrients.

Tollenaar *et al.* (1997) revealed that maize grain yield declines when plant density is increased beyond the optimum plant density primarily because of a decline in the harvest index and increased stem lodging. Such cases represent intense interplant competition for incident photosynthetic photon flux density, soil nutrients and soil water. When maize is planted in narrower rows at the same plant density, the plants are more uniformly distributed over the soil surface. This makes the crop more effective in intercepting solar radiation and shading weeds. The canopy will usually close sooner and result in lower soil temperatures, thus reducing evaporation from the soil surface.

Ullah *et al.* (2016) conducted a study at Sher-e-Bangla Agricultural University farm to evaluate the performance of seedling transplantation of four white maize hybrids (Changnuo-1, Q-Xiannuo-1, Changnuo-6 and Yangnuo-7) under two planting geometries (D1 =Row to row spacing 75 cm and plant to plant spacing within each row 25 and D2 = Row to row spacing 60 cm and plant to plant spacing within each row 25). D1 had 55 whereas D2 had 66.666 thousands plants per hectare. Results showed that varieties differed significantly in days to maturity showing the earliest (108 days) with the Yangnuo-7. Other varieties matured in between 135-137 days. Number of grains cob-1 was the highest with Changnuo-6 (419) whereas, the least with Yangnuo-7 (276). Yangnuo-7 had the lowest 100-seed weight (24.33 g, other varieties showed 31.83-34.67 g). Significantly the highest seed yield per hectare was observed with Changnuo-6 (8.198 tons) followed by Changnuo-1 (7.457 tons) and Q-Xinagnuo-1 (6.718 tons). Yangnuo-7 showed the lowest seed yield (4.393 tons) than others. Planting configuration D_2 had significantly greater yield (7.551 t/ha) than that of D2 (5.832 t ha^{-1}). The greater seed yield of D2 was attributed to the significantly higher grain number per cob of D_2 (369.78) than D1 (337.29). Interaction effect of the variety with the planting configuration showed that the varieties Changnuo-6 and Changnuo-1 when transplanted at higher population densities (D2) showed identical seed yields (9.253 and 7.938 t/ha, respectively), but were significantly higher than others. Seedling leaf area had positive effects on grain number cob-1 and seed yield ha^{-1}.

Akbar *el al.* (2016) reported that generally grain yield increased with increasing planting density. Planting in twin-rows giving 80,000 plants per ha produced 17.7% higher yield compared with planting in single rows 60 cm apart giving 66,667 plants per ha. Planting in twin-rows produced significantly higher yield compared with single rows.

Hammer *et al.* (2009) stated that to maximize crop yield, it is essential to optimize the stand uniformity by minimizing the plant to plant variation. Modern maize hybrids released for production have had increasing tolerance to the stress associated with high plant densities as compared with older hybrids.

Ramulu *et al.* (2006) stated that due to closer spacing grain yield gradually decreased and under closer planting spacing, the rate of yield reduction occurred in response to decreasing solar radiation, nutrient, moisture and air.

Liu *et al*. (2004) reported that maize yield differs significantly under varying plant density levels due to difference in genetic potential having differential plant structure.

Mock and Pearce (1975) proposed a maize ideotype that would maximally utilize an optimum production environment. Plant density above a critical density has a negative effect on grain yield per plant. .This yield reduction per plant is ascribed to the effects of interplant competition for light, water, nutrients and other potentially yield limiting environmental factors. Crop management for this environment includes high plant densities and narrow row spacing for maize ideotypes characterized by stiff, vertically oriented leaves above the ear, maximum photosynthesis efficiency, and efficient conversion of photosynthate to grain.

According to Tollenaar and Lee (2002) and Tokatlidis and Koutroubas, (2004) the tolerance of modern maize hybrids to intense competition for available resources at high plant densities has improved much more than other environmental stress tolerance over the past 40 to 50 years.

Tollenaar (1989) and Tokatlidis and Koutroubas (2004) reported that principally this progress has been driven by maize breeders selecting for grain yield and/or beneficial morpho-physiological traits in environments commonly encountered in commercial maize production. Thus, to optimize grain production and maximize grain yield potential in today’s production systems, modern hybrids must be grown at higher plant densities than their predecessors.

According to Derieum (1987); Tollenaar, (1989) and Dwyer and Tollenaar (1989) leaf photosynthesis of early maturing maize cultivars is less sensitive to stress. These hybrids also require higher plant densities to maximize grain yield due to their compact plant architecture.

Teasdale (1995); Begna *et al.* (2001); Stewart (2001); Tharp and Kellers (2001) revealed that in addition to improving crop yield, reduced row spacing can also provide the crop with a competitive advantage over weeds. Several studies have shown that narrow rows are more efficient at intercepting (0 to 11%) light than wide rows.

Cardwell (1982); Neilsen (1988) and Widdicombe and Thelen (2002) indicated that reduction of row spacing from 1.07 to 0.90 m in maize was estimated to result in an overall mean yield increase of 175 kg ha-1. Maize yield may be further increased by reducing row spacing from 0.90 to 0.76 and even to 0.38 m.

Olson and Sander (1988); Porter *et al*. (1997); Westgate *et al*. (1997); Lee (2006) stated that a considerable amount of research showed increased crop yield when row spacing is reduced.

Jolliffe *et al.* (1985) revealed that plant density affects crop yields indirectly through an increased level of competition. Individual plant interference with the equal sharing of growth resources increases almost linearly with an increase of plant density. Most investigations assessed yield-density responses on the basis of observations made at the final harvest, but further insight into the origins of yield-density responses should be gained by following the development of those responses as a plant grows.

Duncan (1984) reported that the yield of a single maize plant is affected by the proximity to adjacent plants. Buren *et al*. (1974), Herrero and Johnson (1981), Hall *et al*. (1982) and Anderson *et al*. (1984) observed that plant density, water stress and nitrogen supply generally influence the synchrony of flowering and hence grain yield. This indicates that plant density has both a direct and indirect effect on synchronization of flowering.

De Wit (1967) as cited by Bos *et al.* (2000) showed that crop canopies convert only 5% of incident solar radiation into chemical energy during the crop growing season. So, increasing plant density is one management tool for increasing the capture of solar radiation within the canopy. Maize grain yield rises with planting density to some maximum value and then declines. The rate that produces maximum yield varies with varieties, environment, fertility and planting pattern. For a given hybrid, the yield of maize generally increases as plant density rises until one or more factors such as water supply, available plant nutrients and other growth influencing factors become limiting.

Kiniry and Knievel (1995) indicated that in the absence of nutrient deficiencies, temperature extremes or water stress, solar radiation intercepted by plants is the major limitation to growth, development and yield.

Caliskan *et al.* (2007) indicated that plant density is an important agronomic factor that manipulates micro environment of the field and affects growth, development and yield formation of crops. Within certain limits, increase of plant population density decrease the growth and yield per plant but the reverse occurs yield per unit area.

Stewart *et al.* (2003) Li and Wang (2010) stated that maize growth and yield influenced canopy morphology, light interception and ultimately yield. Gardner *et al.* (1985); Tetio-Khago and Gardner (1988b); Sarquis *et al*. (1998) observed that high plant density results in a reduction of light interception per plant due to mutual shading that affects source capacity to supply a second ear with sufficient photoassimilates. Hence, apical ear yield seem to be sink limited,while source capacity seem to limit growth of the second ear.

Shafi *et al.* (2012) conducted an experiment to investigate the effect of planting density on plant growth and yield of maize varieties at Agricultural Research Farms Khyber Pukhtunkhwa Agricultural University Peshawar, Pakistan. The experiment consist of four maize varieties viz., Azam, Pahari, Jalal-2003 and Sarhad white as main plot factor and three plant densities of 45000, 55000 and 65000 plants ha^{-1} as sub plot factor. They reported that, plant population of 65000 plants ha^{-1} had significantly gave highest yield and the lowest yield was recorded from plant population 55000 plants ha^{-1}.

Abuzar *et al.* (2011) conducted a field experiment to determine the effect of plant population densities on maize was conducted at the Agricultural Research Institute, Dera Ismail Khan, in mid July 2009. The effect of six plant population densities i.e. T_1 (40000 plants ha$^{–1}$), T_2 (60000 plant ha$^{–1}$), T_3 (80000 plants ha$^{–1}$), T_4 (100000 plants ha$^{–1}$), T_5 (120,000 plants ha$^{–1}$) and T_6 (140,000 plants ha$^{–1}$) was investigated using maize variety Azam. Result revealed that the maximum grain yield (2604 kg ha^{-1}) was recorded in T_2 (60000 plants ha^{-1}) followed by T_3 (80000 plants ha^{-1}) which produced grain yield of 2346 kg ha^{-1}. The minimum grain yield of 746.3 kg ha^{-1} was recorded in T_6 having population of 140,000 plants ha^{-1}.

Muhammad *et al*. (2006) indicated that there was maximum grain yield 6.6 t ha^{-1} of maize against the minimum 3.28 t ha^{-1} at narrow spacing, although narrow plant spacing (10-15 cm) caused substantial reduction in yield components such as grain cob^{-1} and 1000 kernel weight compared to the wide plant spacing, accordingly they recommend 60 cm by 10 or 15 cm plant spacing for maximum yield.

Studies were conducted by Asafu-Agyei (1990) in four locations in Ghana in 1986 to determine the effect of seven planting densities: 10, 20, 30, 40, 50, 60 and 70 x 10^3 plants^{-1} ha on grain yield of three maize varieties differing in maturity: early, medium and full season. Result revealed that, the highest grain yield (5.8 t ha^{-1}) was recorded from 50 $\times 10^3$ plants ha $^{-1}$ and the lowest grain yield (2.10 t ha^{-1}) from 10 $\times 10^3$ plants ha $^{-1}$.

Tollenaar *et al*. (1997) also reported that maize grain yield declines when plant density is increased beyond an optimum, primarily because of the decline in harvest index (HI) and increased stem lodging. Such cases represent intense interplant competition for incident photosynthetic flux density, soil nutrients and water. Under higher plant densities, the rate of yield reduction was in response to decreasing light, moisture, nutrient and other environmental resources available to each plant.

Cardwell (1982); Duvick, (2005); Lee and Tollenaar (2007) observed that yield increases in maize have become largely attributed to genetic gains made by breeders (50-70%) and superior agronomic management practices (30-50%).
Norwood (2001) stated that selection of appropriate cultivars, planting dates, fertilization and plant densities are cultural practices that have been shown to affect maize yield potential and stability. Sarquis *et al.* (1998) also stated that the total yield per plant would be maximized when both ears were pollinated at the same time.

2.2.1.6. Stover yield

Edmeades and Daynard (1979), Maddonni and Otegui (2004) and Ciampitti and Vyn (2010) mentioned that the decrease in per plant biomass is due to the reduction in photosynthetic rate per plant which may increase plant barrenness as plant population increased.

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

Abuzar *et al.* (2011) conducted a field experiment to determine the effect of plant population densities on maize was conducted at the Agricultural Research Institute, Dera Ismail Khan, in mid July 2009. The effect of six plant population densities i.e. T_1 (40000 plants ha^{-1}), T_2 (60000 plant ha^{-1}), T_3 (80000 plants ha^{-1}), T_4 (100000 plants ha^{-1}), T_5 (120,000 plants ha^{-1}) and T_6 (140,000 plants ha^{-1}) was investigated using maize variety Azam. Result revealed that treatments having population of 60000 and 80000 plants ha^{-1} produced the maximum biomass yield of 16890 kg ha^{-1} each, while the lowest biomass yield (13330 kg ha^{-1}) was recorded with population of 140,000 plants ha^{-1}.

Gardner (1988) found that kernel yield per unit area increased to a maximum yield of 1080 g m^{-2} at the density of about 10 plants m^{-2}, whereas total dry matter yield asymptotically increased up to 12.5 plants m^{-2}.The positive relationship between grown yield and plant density was due to the high number of ears harvested and high number of plants per unit area. The increase of stover yield with the increase of plant densities may be due to increasing numbers of plants and dry matter yield.

2.2.1.7. Harvest index

In an experiment conducted by Howell *et al*. (1996) an average harvest index value of 0.52 was reported for all seasons, hybrids and fields in the experiment.

Howell (1990) found that the ratio of economic yield to above-ground dry matter yield is termed the harvest index and is a useful index in characterizing the physiological efficiency and ability of a crop for converting total dry matter into economic yield. Harvest index is a widely cited index and provides information on the relation of economic and biological yields.

Rhoads and Bennett (1990 reported that harvest indices of traditional maize varieties ranged from 0.32 to 0.48.

Kanemasu (1983) found that the harvest index gives no information on specific yield components, for example, head number and kernels per head. Most of the yield increases in high yielding varieties is accredited to the increase in harvest index.

Kanemasu (1983) concluded that harvest indices obtained in one environment had no predictable relationship to grain yields in a different environment.

Tollenaar *et al*. (1997) revealed that harvest index is highly positively correlated with grain yield and decreases with increasing plant density above a certain optimum due to consequent increase in plant barrenness and lodging. This illustrates that the harvest index values are intimately correlated with grain yield and vary with environment.

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

2.4. Fertilizer impact on growth, phenology, yield components and yield

Gungula *et al*. (2007) reported that there will be more synchrony in flowering with higher nitrogen, thus reducing the rate of barrenness during grain filling period. The higher degree of barrenness under lower nitrogen application might be attributed to poor development of sinks and reduced translocation of photo synthates. Under nitrogen stress environments there may be asynchronous flowering, abortion of seed, and ultimately the reduction in the number of seeds.

A field experiment was conducted by Mechi (2015) to asses the response of maize hybrid variety “BH-661” to nitrogen (N) fertilizer and inter row spacing in the main cropping season of 2014 at Nejo. The experiment was arranged in a factorial combination of four levels of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and four inter row spacing (55, 65, 75 and 85cm) in randomized complete block design (RCBD) with three replications. Result revealed that, the highest harvest index (53.16%) was recorded from inter row spacing 85 cm and the lowest harvest index (42.91%) was given by inter row spacing 55 cm.

Field experiments were conducted by Ma *et al*. (2002) to evaluate maize response to row spacing and N fertility over a 4-yr period (1997–2000). A randomized complete block design, arranged in a split plot was used with four replications each year with modifications of treatments over years. Row spacing of 0.51 m, 0.76 m and 0.76 m paired row alone or in combination with hybrid were tested in the subplot whereas combination of fertilizer N by population density (1997 and 1998) or N alone was assigned to the main plot. In 1997 and 1998, combinations of N by density consisted of 0, 60, 120, 180 and 240 kg N ha^{-1} at 89 000 plants ha^{-1}, and 60 and 180 kg N ha^{-1} at 69 000 plants ha^{-1} using a single hybrid, Pioneer 3893. In 1999 and 2000, N fertility levels of 0, 80 and 180 kg N ha^{-1} were the main plots and six combinations of hybrids (Pioneer 3893 and Pioneer 38P06 Bt) by row spacing were grown in the subplots at 69 000 plants ha^{-1}.They found that, harvest index was significantly higher under the 0.51 m spacing than the other spacing treatments.

Imran *et al.* (2015) also reported that plant population of 95000 plants ha^{-1} took more number of days to tasseling (70), silking (75) and maturity (107). Taller plants (197 cm) were measured for plant population of 95000 plants ha^{-1}. Maximum number of leaves $plant^{-1}$ (10.45) was recorded for plant population of 80000 plants ha^{-1}. Higher leaf area $plant^{-1}$ (2585 cm^2) and leaf area index (2.59) were recorded for 65000 plants ha^{-1} which was statistically at par with 80000 plants ha^{-1}. Higher ear length (17.71 cm), ear weight (145 g), grains ear^{-1} (515) and thousand grain weight (252 g) were recorded from 65000 plants ha^{-1} which was similar to 80000 plants ha^{-1}. Plant population of 95000 plants ha^{-1} produced maximum biological yield (7276 kg ha^{-1}) while plant population of 80000 plants ha^{-1} produced maximum grain yield (2551 kg ha^{-1}) and harvest index (35.95%). It is concluded from the study that application of 150 kg N ha^{-1} produced maximum grain yield and plant population of 80000 plants ha^{-1} produced higher grain yield.

Bender *et al*. (2013) demonstrated that a modern hybrid maize with moderate yield potential takes up 287 kg N, 50 kg P, 167 kg K, 26 kg S, 8 kg Zn and 1.3 kg B per ha.

Tajul *et al.* (2013) also revealed that plant growth, light interception (LI), yield attributes, and grain yield varied significantly due to the variations in population density and N-rates. Crop growth rate (CGR) was the highest with the population of 80,000 ha^{-1} receiving 220 $kgNha^{-1}$, while relative growth rate (RGR) showed an opposite trend of CGR. Light absorption was maximum when most of densely populated plant received the highest amount of N (220 $kgNha^{-1}$). Plant height was the maximum at the lowest plant density with the highest amount of N. Plants that received 180 kg N ha^{-1} with 80,000 plants ha^{-1} had larger foliage and higher amount of grains cob^{-1} that contributed to the maximum yield (5.03 t ha^{-1}) and the maximum harvest index (HI) compared to the plants in other treatments.

Liu *et al*. (2011) stated that application of fertilizer is one of the major agronomic practices regulating potential yield in maize, since sufficient and timely nutrient supply affects both grain number and mean grain weight through adjusting grain formation, filling rate and duration.

Khan *et al.* (2011) showed that all the N levels, maize varieties and their interactions showed significant effects on plant growth and crop yield. The maximum plant height, number of grain rows/cob, cob diameter, number of grains/cob, 1000-grain weight, harvest index, biological yield and grain yield were produced by the application of 300 kg N ha^{-1} Ayeni and Adetunji (2010) stated that Nitrogen fertilization increase corn yield when N supply by soil is low.

Shakarami and Rafiee (2009); Pandey *et al.* (2002) showed that the higher degree of infertility under lower (50 kg N ha-1) application might be attributed to poor development of sinks and reduced translocation of photosynthates. Under nitrogen stress conditions there may be big chance to asynchronous flowering and seed infertility, thus reduction in the number of seeds cob^{-1}.

Field trials were conducted by Sharifai *et al*. (2012) during the rainy seasons of 2006, 2007 and 2008 at the Institute for Agricultural Research (I.A.R.) Farm, Samaru to determine the performance of extra early maize (Zea mays L.) as affected by intra-row spacing, nitrogen and poultry manure rates. The treatments consisted of factorial combinations of three intra-row spacing (20, 25 and 30 cm), three rates of nitrogen (40, 80 and 120 kg ha^{-1}) and four rates of poultry manure (0, 2, 4 and 6 t ha^{-1}). The results showed that the highest number of rows cob^{-1} (14.14) was recorder for intra-row spacing 30 cm where as the lowest number of rows cob^{-1} (13.39) was found for intra-row spacing 20 cm.

Ullah *et al.* (2007) also reported the increased grain and stover yield with increasing nitrogen levels.

Shrestha (2007) reported increased physiological maturity and SFD with increasing levels of nitrogen in open pollinated varieties of maize. Delayed maturity at higher nitrogen was because the plant was staying green. Higher nitrogenous fertilizer delays the senescence of leaves and increased succulence of plants.

Gungula *et al*., (2007) reported that there will be more synchrony in flowering with higher nitrogen, thus reducing the rate of barrenness during grain filling period.

According to Fageria and Baligar (2005); Subedi and Ma (2005) nitrogen (N) is the major macro nutrient determining the crop size and yield formation. Sahar *et al.* (2005) stated that grain and stalk yield were significantly influenced by the increased rate of nitrogen thus increased the harvest index.

Akbar *et al.* (2002); Gokmen *et al*. (2001); Niazuddin *et al*. (2002) also observed the same results of the present study that increased in TGW has been increased with the nitrogen levels. Niazuddin *et al*. (2002); Dawadi and Sah, (2012) found that increased in thousand grain weight has been linked with increase in nitrogen levels.

Ogola *et al.* (2002) reported that Nitrogen fertilization plays significant role in improving soil fertility and increasing crop productivity. Nitrogen fertilization results in increased grain yield (43-68%) and biomass (25-42%) in maize Singh *et al.* (2000) indicated that grain and stover yield increased with the increase in nitrogen level from 0-200 kg/ha.

Singh *et al.*(2000) also observed that application of 200 kg N ha^{-1} increased grain yield of maize. However, a substantial percentage of applied N is also lost due to volatilization, leaching, and denitrification. Therefore, N should be applied in such a way that would maximize its utilization for grain production. Maize producers require more information on how N-fertilization and plant density practices affect dry-matter yield and quality.

Thakur *et al.* (1997); Diallo *et al.* (1996); Adhikari *et al.* (2004) stated that Higher N applications increase the cell division, cell elongation, nucleus formation as well as green foliage. It also encourages the shoot growth. Therefore, higher doses of nitrogen increased the chlorophyll content which increased the rate of photosynthesis and extension of stem resulting increased plant height

Sanjeev and Bangarwa (1997) observed that Nitrogen fertilizer is universally accepted as a key component to high yield and optimum economic return as it plays very important part in crop productivity and its deficiency is one of the major yield limiting factors for cereal production.

Sanjeev and Bangarwa (1997) also reported that High density is undesirable because it encourages inter plants competition for resources. N has been found to be the most important nutrient for maize production.

Obi and Ebo (1995) found that chemical fertilizer application could not be avoided completely since they are the potential sources of high amount of nutrients in easily available forms and maize is more responsive to it.

Khan *et al.* (1994); Alvi (1994) observed that an increase in yield of maize with increasing rate of nitrogen has been reported by many researchers primarily due to its favorable effect on yield components of maize.

Natr (1992) reported that biomass production of a crop largely depends on the function of leaf area development and consequential photosynthetic activity. Balanced and optimum use of nitrogen plays a pivotal role in increasing the yield of maize. Nitrogen increases biomass production of a crop which largely depends on the function of leaf area development and consequential photosynthetic activity.

Khot and Umrani (1992) observed that photosynthetic rate can substantially be increased with N-fertilization. Application of N-fertilizer has also been reported to have significant effect on grain yield and quality of maize. Prasad and Singh (1990) also observed a decrease in ASI with increasing levels of N application.

Adhikari *et al*. (2004) reported that the highest grain yield of 9,352 kg ha^{-1} was produced when the crop was fertilized with 120 kg N ha^{-1} on the crop planted under the plant pop Nitrogen lation of 53,333 plants ha^{-1} and they noted the lowest yield (6,657 kg ha^{-1}) with the crop supplied with 60 kg ha^{-1} under plant population of 44,444 plants ha^{-1}.

Marschner (1986); Schrader (1984) stated that among the essential nutrients for plant growth, N plays a dominant role in plant growth as it is required for chlorophyll production, as a constituent of enzymes, proteins, nucleic acids and cell walls. N is also constituent of low molecular weight plant compounds including nucleotides, amides and amines. Consequently, sufficient N is a prerequisite for achieving good crop yields.

Hardas and Karagianne-Hrestou (1985) reported that 180 kgN ha^{-1} was optimum for maize. Rai (1961) reported that application of nitrogen as well as increase in its rate induced earliness of tasseling and silking stages. The shorter ASI with higher nitrogen was because of inducing early and rapid growth. They also mentioned that optimum population nitrogen (N) levels should be maintained to exploit maximum natural resources, such as nutrients, sunlight, and soil moisture, to ensure satisfactory growth and yield. Increased in 1000-grain weight has been reported with increase in nitrogen levels (Akbar *et al.,* 2002; Gokmen *et al*., 2001; Niazuddin *et al.,* 2002).

2.5. Irrigation impact on growth, phenology, yield components and yield

Irrigation is an important determinant of crop growth and yield because it is associated with many factors of the plant environment, which influence growth and development. Water use efficiency (WUE) of maize is a function of multiple factors that include physiological characteristics, genotype, and soil characteristics such as soil water holding capacity, meteorological conditions and agronomic practices. Thus, to improve water use efficiency of maize, integrated measures should be taken to optimize cultivar selection and agronomic practices to be adopted.

Sani *et al.* (2008) observed that plants irrigated with the full consumptive use (CU) regime also had significantly taller plants than plants irrigated with the half CU irrigation regime. At flowering, plants irrigated with the full CU regime were significantly than the other treatments. At cob filling, the trend is maintained with plants irrigated with full CU regime having significantly taller plants than plants irrigated with three-forth and half CU regimes respectively. They also observed that the amount of water applied to crops at different growth stages must be such as to meet their consumptive use requirements. So that the water use and water use efficiency were highest with application of full consumptive use requirement at each stage of growth.

Sani *et al.* (2008) revealed that water use and water use efficiency were highest with application of full consumptive use requirement at each stage of growth. The highest plant population density used water more efficiently (25% less than other populations). Therefore, the water use efficiency of maize was changed through the manipulation of plant population density.

Sani *et al.* (2008) concluded that for this particular condition, application of full water requirement of plants is not economical. It is advisable to irrigate with 75% water requirement. This gives similar yield while saving a lot on water and labour.

However, the 66,000 plants per hectare treatment should be used as it translates to higher yield and more protection for the soil.

Ullah *et al* (2013) reported that the response of three hybrid maize (Zea mays L.) varieties on five irrigation levels was evaluated in an experiment at Bangladesh Agricultural University, Mymensingh. The experiment included two factors – irrigation and maize variety. The Irrigation treatments/levels were Io (no irrigation), I_1 (irrigation at IW (irrigation water need)/CPE (cumulative pan evaporation) = 0.4), I_2 (IW/CPE = 0.6), I3 (IW/CPE = 0.8) and I_4 (IW/CPE = 1.0). The maize varieties were V_1 (BARI Hybrid Maize 5, BHM-5), V_2 (BARI Hybrid Maize 7, BHM-7) and V_3 (Pacific 984 Treatment I4 produced the highest (9.30 t ha^{-1}) and Io produced the lowest (7.62 t ha^{-1}) grain yield. V3 (Pacific 984) produced the highest (8.60 t ha^{-1}) and V2 (BHM-7) produced the lowest (7.31 t ha^{-1}) grain yield. The grain yield, however, did not vary significantly (p = 0.05) due to the effects of irrigations and varieties. The treatment combination I_4V_3 produced the highest (9.31 t ha^{-1}) and IoV_2 produced the lowest (6.34 t ha^{-1}) grain yield.

Morrison *et al*. (2008) stated that globally and locally, irrigated agriculture is vital in ensuring food security to meet the food requirement for a rapidly growing population.

According to Hassan and Manaf (2006) water use encompasses the amount of water evaporated from soil surface and transpired from plants while runoff and drainage are often negligible per land area, but not in irrigated agriculture.

According to Saif *et al.* (2003) availability of adequate amount of moisture at crucial stage of plant growth not only optimizes the metabolic process in the plant cell but also increases the effectiveness of the mineral nutrients apply to the crop.

Balasubramaniaya and Palaniappan, (2001) indicated that sustainable and efficient use of water is of paramount importance for successful crop production. Plant growth and development can be affected by water deficits at any time during the crop life cycle, but the extent and nature of damage, the capacity for recovery and the impact on yield depends on the developmental stage at which a crop encounters stress.

Hatfield (2001) stated that development of agronomic systems that are based on efficiency, rather than production will increase the sustainability of production systems.

Khan *et al.* (2001) concluded that a higher water use efficiency of a certain hybrid, therefore, provides a potential explanation for its better yield performance compared with other hybrids.

Argenta *et al*. (2001) stated that strategizing plant arrangement through manipulation and modification of row spacing is one of the crop management practices that enable plants to intercept sufficient photosynthetically active radiation that may lead to efficient water utilization.

Wallace (2000) mentioned that the main benefit will before varying densities sustained in most areas of the world and especially those in arid and semi-arid areas where population growth is the highest.

According to Brown (1999) this led to the concept of water use efficiency, which is a useful index to determine seasonal water requirements of a crop with the intention of increasing yield.

Moreover, according to Howell *et al*. (1998); Trooein *et al*. (1999) the choice of suitable varieties relies on a balance between water requirements, which is directly related to the yield potential, and water availability.

Kafkafi (1997) found that the term water use efficiency originates in the economic concept of productivity which measures the amount of any given resource that must be expended to produce a unit of output. In simplest term, improved water use efficiency means lowering the water needs to achieve a unit of production. Therefore, in agricultural systems optimum water management should be established to maximize the water use efficiency which is associated with the economic yield produced with the corresponding total amount of water consumed.

Howell *et al*. (1996) found the seasonal ET amount of an early maturing cultivar to be almost 120 mm less than that of late maturing cultivar. Stress during a particular crop growth phase is one of the plant factors that affect WUE, because each plant has a characteristic water use pattern throughout the growing season. As water use is minimal during germination and early growth of seedlings it increases during the vegetative phase and reaches a maximum during flowering to grain filling stages and decreases at maturity.

Maddonni and Otegui (1996), Westgate *et al*. (1997) stated that differences in canopy structure may affect WUE by affecting the amount of light intercepted and attenuated. Variations in canopy architecture have concomitant effects on light in interception and attenuation and affect the crop's response to plant spatial arrangement.

Hence, Saeed (1994) indicated that soil water utilization is an important limiting factor to crop production since it is essential for every growth and development phase starting from seed germination to maturation. Yield potential in maize is closely related to water availability, either from rainfall or irrigation. The amount of water effectively utilized by the crops is less than 20% of the total water applied.

According to Payne *et al.* (1991) soil water management is an important and integral part of the overall cropping system. Detailed information is therefore needed in order to develop efficient methods of soil water management that reduce the wastage of water in some of these irrigation schemes, which tend to accelerate their deterioration and reduce output. Such losses can be as a result of under or over irrigation, which leads to retardation of crop growth and development and consequently, yield reduction. This results in rapid deterioration of such schemes as a result of deleterious irrigation practices. One of the important ways of avoiding this is to apply only the necessary quantity of water at each irrigation. It is often assumed that water supply constitutes the primary limiting constraint to production.

According to Jensen *et al.* (1990) the most common WUE expression is related to the ratio of crop yield, usually economic yield per unit area, to the water consumed by ET from planting to crop physiological maturity.

According to Gregory (1989); Khan *et al*. (2001) generally, the term water use efficiency (WUE) (kg ha-1 mm-1) has been used very loosely by plant scientists and agronomists to refer to observations ranging from gas exchange by individual leaves for a few minutes, to grain yield response to irrigation treatments through an entire season.

Baggett and Kean (1989) observed that temperature and photoperiod may influence stalk height by affecting the number of internodes. However, other factors include water, nutrition, temperature, pest, diseases, light quality and quantity. Moisture stress might simply affect the length of internodes by inhibiting the elongation of developing cells. Clearly water use efficiency can be maximized by decreasing unproductive losses (evaporation, runoff, deep percolation) or increasing transpiration of crops. Improving water use efficiency is therefore, a twofold task. It requires that (a) water be conserved by avoidance of waste and (b) growth be maximized by using high yielding crop varieties, well adapted to local soil and climate and by optimizing agronomic practices.

Turner *et al*. (1986) stated that any strategic crop management that increases canopy closure favours the proportion of transpiration relative to evaporation and thereby increase dry matter production with corresponding maximization of water use efficiency.

Morgado and Rao (1985) revealed that applying 75% of the moisture requirement at all the growth stages resulted in moderate water use efficiency values.

Pearson *et al*. (1984) revealed that greater leaf area results in more rapid ground cover and reduced penetration of radiated energy to the soil surface for evaporation of water. hypothesized that: (i) cultivar differences in carbon dioxide exchange rate (CER) were the greatest during grain filling, i.e. they were related to sink mediation of CER; (ii) manipulation of source-sink relations should produce changes in CER within hours, not days, if the effect is primarily on stomatal metabolism; but (iii) the changes in CER would be relatively small, at least in the field. They also concluded that the differences among the genotypes in leaf CER was most likely due to stomatal conductance, because the genotypes had the same CO_2:H_2O exchange ratio.

Taylor *et al*. (1983) revealed that the main emphasis of enhancing water use efficiency in irrigated cropping is to increase crop yield per unit of water applied. Therefore, irrigation scheduling can be an effective technique of improving water use efficiency of crops by increasing yield. Water requirements of a crop vary with genotype and environmental conditions. Basically water used by crops is related to the total dry matter production or economic yield.

Tanner and Sinclair (1983) stated that water use efficiency during a specific growing season, therefore, expresses the efficiency with which a particular crop converted the available water into biomass. Water use efficiency measurements can be made on plants in containers, on individual plants in the field or even on crop communities. It is important to emphasise that water use efficiency can be based either on evapotranspiration (ET, efficiency) or on crop transpiration (T, efficiency). The difference is important since suppression of soil evaporation and prevention of weed transpiration can improve the T efficiency, which is a measure of crop performance. These two water use efficiencies may be used either on the total dry matter production or the marketable yield, and thus the yield base should be given.

Tanner and Sinclair (1983) also found that the water use efficiency expressed as dry matter production per unit evapotranspiration reflects on both genetic and environmental factors.

Waldren (1983) found that water stress at tasseling not only hinders the plant's ability to flower and shed pollen, but can also greatly affect the viability of maize pollen, especially when the drought is accompanied by high temperatures, as is usually the case. Water stress at silking can impair extrusion of the silks from the husks and cause desiccation of the silks, reducing the number of seeds set on the ear. Water stress before floral initiation can reduce the number of kernels that can potentially be produced by the plant and stress after floral initiation can reduce the potential size of the kernels. Hence, matching of plant density with corresponding available soil water may maximize the efficient use of water by maize.

Loomis (1983) found that plant factors that affect WUE encompasses stomatal closure, number and size of stomata, leaf surface area, leaf rolling or folding, and root depth and proliferation. Plant factors modify the ET rate by affecting the resistance to water movement from soil to plant and from plant surface to the surrounding atmosphere. Variation in the length or duration of the growing season is one of the most obvious means for matching seasonal transpiration or evapotranspiration to water supply.

Hillel (1980); Botha *et al*.(1983); Fanadzo *et al*. (2010) summarized that allowing a crop to transpire freely appears to be the most promising option for increasing its water use efficiency. Thus, higher water use efficiencies can be achieved by preventing any shortage of water during the growing season, while avoiding the wastage of water and obviating all other environmental constraints. This will ensure the attainment of the maximum possible production of the crop. These considerations are particularly important for new and superior cultivars, which have been developed in recent years for a better yield and water use.

Results showed by Damdroth and Bramm (1979); Mbagwu and Osuigwe (1985); Briggs and Shantz (1913); Hillel (2004) that water use efficiency is the result of any measure that reduces the amount of water used per unit of any given activity. Most of the water taken up by plants in the field is transpired (in arid regions, as much as 99%) only a small amount is retained. Plant water use efficiency is in effect the reciprocal of what is known as the transpiration ratio.

Field experiments were conducted by Ma *et al*. (2002) to evaluate maize response to row spacing and N fertility over a 4-yr period (1997–2000). Row spacing of 0.51 m, 0.76 m and 0.76 m paired row alone or in combination with hybrid were tested in the subplot whereas combination of fertilizer N by population density (1997 and 1998) or N alone was assigned to the main plot. In 1997 and 1998, combinations of N by density consisted of 0, 60, 120, 180 and 240 kg N ha^{-1} at 89 000 plants ha^{-1}, and 60 and 180 kg N ha^{-1} at 69 000 plants ha^{-1} using a single hybrid, Pioneer 3893. In 1999 and 2000, N fertility levels of 0, 80 and 180 kg N ha^{-1} were the main plots and six combinations of hybrids (Pioneer 3893 and Pioneer 38P06 Bt) by row spacing were grown in the subplots at 69 000 plants ha^{-1}. They reported that there were significant interactions between row spacing and N rates ($P < 0.01$); grain yield of Pioneer 38P06 Bt maize with the 80 kg N ha^{-1} fertilizer treatment was significantly greater (14.6%) at the 0.51 m row spacing than at the conventional 0.76 m row spacing. Yield of Pioneer 3893 was only 1.5% greater at the 0.51 m row spacing than at the 0.76 m row spacing. In 2000, yields were less than half those recorded in 1997-1999. Paired rows (0.76 m pair) showed significantly lower yields than either single 0.76 m spacing or 0.51 m spacing.

Fischer and Turner (1978); Boyer (1982) found that water has always been a fundamental building block for a healthy economy. With the exception of soil fertility no other environmental factor limits crop productivity more severely than water deficits.

Laing and Fischer (1977) revealed that with a crop such as wheat, early maturing varieties generally yield better than late maturing varieties where the supply of water is limiting. Although early maturing maize varieties produce less dry matter and grain yields, compared to late maturing ones, they have nearly the same grain water use efficiency while the seasonal evapotranspiration amount was less.

On the other hand, Thomas *et al*. (1975); Smith (2000) stated that water use also termed seasonal evapotranspiration (ET), refers to the quantity of water used in transpiration or building of plant tissue and that evaporated from the soil or from intercepted precipitation during a specific period of time. The total ET requirement for a crop is usually taken from planting to crop physiological maturity.

Mitchell (1970) revealed that reduction of row spacing can maximize water use efficiency, because narrower rows can increase light interception and grain yield, and decrease ET, the net result is an indirect increase in transpiration and water use efficiency. Water use does not significantly change but the yield of grain per unit of water does increase significantly. On the other hand, under less than optimal moisture, narrow rows do not necessarily result in yield increases even though soil evaporation may be reduced with narrow rows and water use efficiency may increase.

Moreover, Salter and Good, (1967); Saini, (1997) stated that the sensitivity to water deficits is particularly acute during the reproductive development because reproduction involves several processes that are extremely vulnerable to a change in the plant water status

Viets (1962) stated that any concept of efficiency is a measure of the output obtainable from a given input. Water use efficiency can be defined in different ways depending on the nature of the inputs and outputs considered. A widely applicable expression of efficiency is the agronomic or crop water-use efficiency, which has been defined as the amount of vegetative dry matter produced per unit volume of water taken up by the crop from the soil.

Denmead and Shaw (1960) mentioned that although maize has high water requirements, it is still one of the most water efficient crops in producing dry matter. Water use efficiency in maize increases as yield increases, and higher plant densities result in a decreased efficiency during seasons of water deficits. The peak water use by maize occurs at the time of silking or shortly thereafter. Research has shown that water deficits at the time of tasseling and silking also cause the greatest reduction in yield. Water stress prior to silking reduces grain yield by 25%, 50% at silking and 21% after silking.

De Wit (1958) found that only the transpiration portion of evaporation directly influences crop production.

Thornthwaite (1948) stated that WUE is the ratio of production to water used while production is the amount of marketable, total or above ground biomass and carbon dioxide fixed. Similarly, water use can be defined in terms of applied irrigation water, plant or leaf transpiration, or the sum of transpiration and evaporation from the soil surface.

Thornthwaite (1948) also mentioned that crops consume water in the process of transpiration and water evaporates from the soil. Transpiration and evaporation are the combination of two separate processes, whereby water is lost from land. Evaporation is the process by which liquid water is converted to water vapour, while transpiration consists of the vaporization of liquid water contained in plant tissues and vapour removal to the atmosphere. Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes and they are collectively termed evapotranspiration.

Pendleton (1966), Mitchell (1970) and Choy and Kanemasu (1974) reported that studies on sorghum have shown that shading the soil sooner with narrow rows can reduce the sensible heat load, and subsequently lower the evaporation component of evapotranspiration (ET). This is probably also true for maize canopies where a more uniform distribution of plants will also assist in reducing the negative effect of rainfall impact on soil structure deterioration by intercepting more drops with leaves. This results in higher infiltration rates and more effective rainfall utilization with a positive impact on final grain yield.

CHAPTER III

MATERIALS AND METHODS

3.1. Description of the experimental locations

To meet research objectives of the present study, ten field experiments were carried out at three different locations of Bangladesh namely, Sher-e-Bangla Agricultural University (SAU), Suapur of Dhamrai Upazilla of Dhaka and Thakurpara of Rangpur Sadar Upazilla of Rangpur district in three consecutive rabi seasons of 2015-16, 2016-17 and 2017-2018.

3.2. Geographical position

These locations had distinct soil series. One location was Sher-e-Bangla Agricultural University (SAU) farm which was situated at Dhaka (central Bangladesh) which has the soil series – Chiatta. The second location was the farmer's field at Suapur Union of Dhamrai Upazilla which was about forty kilometers away from Dhaka having soil series - Dhamrai and the third location was at the Thakurpara village of Rangpur Sadar in the northern Bangladesh having soil series - Gangachara.

Sher-e-Bangla Agricultural University Farm is situated at $23^{0}41'$ N latitude, 90^{o} 22´ E longitude, 8.6 m altitude above the sea level (Bay of Bengal), belonging to the Agro-ecological Zone "AEZ-28" of Madhupur Tract having brown terrace soil (FAO/UNDP, 1988). Location map have been given in appendix-I

Dhamrai's geographical position is within 23°49' and 24°03' north latitudes and in between 90°01' and 90°15' east longitudes under the agro ecological zone (AEZ 8) of 'Young Brahmaputra Jamuna Floodplain' having predominantly alluvium *soil* of the Bongshi and Dholesshori rivers. (BBS, 2016; FAO 1988). One of the major cropping pattern of this location is Rabi- jute-T. aman wherein the test was made during the winter season of 2015-16.

Rangpur (central) location is located in between 25°39' and 25°50' north latitudes and in between 89°05' and 89°20' east longitudes. Its AEZ-3 is 'Tista Meander Floodplain' having the *soil* composition of mostly alluvial (80%) of the Teesta River basin.

3.3. Climate of the experimental areas

In Bangladesh the winter season's temperature is generally low and there is a plenty of sunshine. The temperature tends to increase from February as the season proceeds towards summer season. Rainfall seldom occurs during winter in the period from November to January and scanty in February to March (Figure 3.1).

The rainfall of Dhaka was 3, 14, 83, 26, 215, 210 and 406 millimeter, whereas that at Rangpur was 12, 0, 152, 20, 313, 451 and 707 millimeter respectively in the months of January, February, March, April, May, June and July of 2016. Dhamrai is about 39 kilometer away from Dhaka and its rainfall data are not separately available.

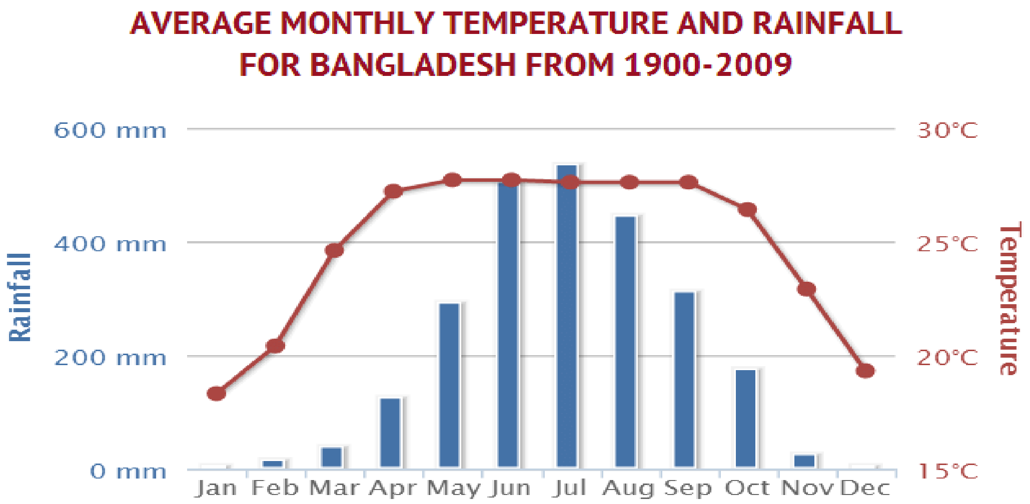


Fig. 3.1. Average monthly temperature and rainfall for Bangladesh from 1900-2009 (source: www. research gate. net)

3.4. Soil

The soil samples of SAU, Dhamrai and Rangpur locations were collected and analyzed at the Soil Resource Development Institute (SRDI) laboratory, Dhaka prior to the initiation of the experimentations. From the soil analysis reports (Table 1, 2,3), it was observed that the soil of Dhaka and Dhamrai were silt loam having sand, silt and clay 27, 63,10% respectively at Dhaka, while 12,78,10% respectively at Dhamrai, That is the soil of the Dhaka was heavier than that of that at Dhamrai. The soil of Dhaka was more acidic having pH of 4.8 as compared to that at Dhamrai (5.1). There was more organic matter at Dhaka (an urban area) soil (1.48%) as compared to that of rural area of Dhamrai (1.08%). Although it is an obvious fact that organic maters are more available in the rural areas compared to those at the unban areas. However, Sher-e-Bangla Agricultural University have enough funds to collect its organic matter from the surrounding areas where a number of dairy farms are established. The lesser soil organic matter at Dhamrai may be attributed to the reduction in the livestock resources in the rural areas and also using dried cow dungs as fuel for kitchen purpose. In Bangladesh the cow dung is the main source of the organic matter which is applied in the soil in decomposed form. Likewise, the N status at Dhaka soil (0.074) was higher than that at Dhamrai soil (0.054%) which was obvious as the Dhaka soil had more added organic matter than that at Dhamrai soil.

The soil status at SAU was low in terms of potassium and boron (0.16% and 0.06 ppm respectively), optimum in terms of calcium (4.52%), medium in terms of magnesium and Sulphur (0.85% and 15.70 ppm) but higher in terms of phosphours (37.12 ppm), copper (4.21 ppm), iron (236.85 ppm), manganese (42.20 ppm) and Zinc (4.07 ppm). The soil status at Dhamrai was low in potassium (0.12%), phosphorus (3.13 ppm), Sulphur (7.95 ppm) and Boron (0.22 ppm), whereas was high in calcium (9.45%), magnesium (2.21%), copper (2.56 ppm), iron (200 ppm) and manganese (20 ppm). That is in terms of phosphorus, the Dhaka soil had extremely higher content which was in deficient in Dhamrai soil. Similar case was with Sulphur which was higher (medium) at Dhaka but lower at Dhamrai soil. Zinc was very high (like phosphorus) at Dhaka soil but its status at Dhamrai was optimum.

Table 3.1. Soil analysis results of the SAU farm during pre-rabi season of 2016-17

Texture	**Sand**	**Silt**	**Clay**			
Silt loam	27%	63%	10%			
PH	**Organic matter %**	**Total N %**	**Potassium %**	**Calcium %**	**Magnesium %**	**Phosphorus (mg/g)**
4.8 Strongly acidic	1.48 Low	0.074 Very low	0.16 Low	4.52 Optimum	0.85 Medium	37.12 Very high
Sulphur (mg/g)	**Boron (mg/g)**	**Copper (mg/g)**	**Iron (mg/g)**	**Manganese (mg/g)**	**Zinc (mg/g)**	
15.70	0.06	4.21	236.85	42.2	4.07	
medium	Very low	Very high	Very high	Very high	Very high	

Source: SRDI, Farmgate, Dhaka

Table 3.2. Soil analysis results of Dhamrai farm during pre-rabi season 2016-17						
Texture	**Sand %**	**Silt %**	**Clay %**			
Silt loam	12	78	10			
PH	**Organic matter %**	**Total N %**	**Potassium %**	**Calcium %**	**Magnesium %**	**Phosphorus (mg/g)**
5.1	1.08	0.054	0.12	9.45	2.21	3.13
Strongly acidic	Low	Very low	Low	Very high	Very high	Very low
Sulphur (mg/g)	**Boron(mg/g)**	**Copper (mg/g)**	**Iron (mg/g)**	**Manganese (mg/g)**	**Zinc (mg/g)**	
7.95	0.22	2.56	200.07	20.00	1.8	
Low	low	Very high	Very high	Very high	optimum	

Source: SRDI, Farmgate, Dhaka

The soil of Rangpur (AEZ 3) was sandy loam in texture having sand, silt and clay of 51, 27 and 22% respectively which was much lighter than those of the other two locations. The pH was 4.9 and organic matter 1.3% which was remarkably higher than SAU. The Rangpur location was basically in a rural area although was nearby a city corporation area ‘Rangpur’ wherein a number of poultry and dairy farms are established. Probably these two factors made an easy availability of organic matter to the farmers. The Rangpur soil had total N of 0.08% with available P of 42.39 mg/g and these two nutrients were also higher in comparison to those at Dhamrai. The Sulphur content at Rangpur was 10.96 mg/g. The amount of the exchangeable bases such as K, Ca, Mg and Sodium were 0.16, 2.50, 0.57 and 0.36 meq /100 g soil, respectively. It may be mentioned here that N, P, K. S, Zinc and Boron is deficient in most of the Bangladesh soil which are added to the soil from different fertilizer sources.

Table 3.3. Soil analysis results of the Rangpur farm during pre-rabi season of 2016-17						
Texture	**Sand**	**Silt**	**Clay**			
Sandy loam	51%	27%	22%			
PH	**Organic matter%**	**Total N%**	**Potassium %**	**Calcium %**	**Magnesium %**	**Phosphorus (mg/g)**
4.9 Strongly acidic	1.30 Low	0.08 Very low	0.16 Low	2.50 Optimum	0.57 Medium	42.39 Very high
Sulphur (mg/g)	**Boron (mg/g)**	**Copper (mg/g)**	**Iron (mg/g)**	**Manganese (mg/g)**	**Zinc (mg/g)**	
10.96	0.06	4.21	236.85	42.2	4.07	
medium	Very low	Very high	Very high	Very high	Very high	

Source: SRDI, Farmgate, Dhaka

3.5. Experimental details

3.5.1. Experiment 1: Growth and yield assessment of different varieties of Chinese white maize under varying planting geometry at SAU, Dhaka (rabi 2015-16)

3.5.1.1 Experimental location

The experimental field was in upland soil of Sher-e- Bangla Agricultural University farm, Dhaka. Detailed has been described in section 3.2

3.5.1.2 Experimental period

The experiment was undertaken during the period from November, 2015 to April, 2016 in rabi or winter season.

3.5.1.3 Experimental materials

3.5.1.3.1 Seeds

The four exotic white maize varieties were used as a plant materials. The varieties Changnau-1, Q-Xiangnau-1, Changnau-6 and Youngnau-7 were collected from China.

3.5.1.4 Methods

3.5.1.4.1 Experimental Treatments

In this experiment there were four varieties and two planting geometry which constituted the treatments. For better understanding their interactions were also evaluated. So the treatment combinations in the entire experiment were as follows:

Factor - A (4 -Varieties)

(i) V_1 = Changnau -1

(ii) V_2 = Q-Xiangnau -1

(iii) V_3 = Changnau - 6

(iv) V_4 = Youngnau - 7

Factor -B (2-spacings)

(i) S_1 = 70 cm × 25 cm

(ii) S_2 = 60 cm × 25 cm

Interactions of variety and spacing were as follows

(i) $V_1 S_1$

(ii) $V_1 S_2$

(iii) $V_2 S_1$

(iv) $V_2 S_2$

(v) $V_3 S_1$

(vi) $V_3 S_2$

(vii) $V_4 S_1$

(viii) $V_4 S_2$

3.5.1.5. Preparation of experimental land

The land was prepared with power tiller ploughed for several times until it got the desirable tilth condition. The stubble and weeds were removed. Then experimental land was divided into unit plots following the design of experiment.

3.5.1.6. Experimental design and layout

The experiment was laid out in a factorial RCBD design with three replications. The experimental area was divided into three blocks and each blocks was again divided into eight plots. The unit plot size was 4.8 m^2 (2.4 m × 2 m) with 80 cm border between two adjacent plots and 1 m between adjacent replications (block). As such the total numbers unit plots were 24 in the experiment. Row to row distance and plant to plant distance were according to the treatments.

3.5.1.7 Fertilizer and manure application

The amount of fertilizer in the form of Urea, Triple Super Phosphate, Muriate of Potash, Gypsum, Zinc Sulphate, and Boric acid @ 550 kg/ha, 250 kg/ha, 220 kg/ha, 220 kg/ha, 12.5 kg/ha, and 6 kg/ha [253, 49.1, 132, 39.6, 31.25 and 0.9 kg of N, P, K, S, Zn and B respectively] (BARI, 2014) were calculated for the each plots. All the fertilizers and 1/3rd of urea were broadcasted and incorporated in a plot at the final land preparation. The rest of the urea were top dressed in 2 installments: at 8-10 leaf stage (20-30 DAS) and pre tasselling stage (BARI, 2014). Cow dung was also applied @ 5 ton/ha at the time of final land preparation.

3.5.1.8. Sowing of seeds

Seeds were sown on 30 November, 2015 as per treatments by opening 3-4 cm deep furrows and covered by the soil on the ridge beside each furrow putting two seeds in each hill^{-1}. Seeds were treated with Sevin power @ 2.5-3 g/kg before sowing to control ant, termite and seed borne diseases.

3.5.1.9. Intercultural operations

Intercultural operations such as thinning, weeding, watering, earthing up etc. were done as follows:

3.5.1.9.1. Thinning

One healthy seedling hill^{-1} was kept and the rest one was thinned out before 30 DAS (BARI, 2014).

3.5.1.9.2. Weed control

Crop field was weed free before 30 DAS (BARI, 2014).

3.5.1.9.3. Earthing up

One earthing up operations was done by 30 DAS.

3.5.1.9.4. Irrigation and drainage

Irrigation was done at four different growth stages to meet up crop's water demand providing at 15-20 DAS, 30-35 DAS, 60-70 DAS and 85-89 DAS respectively (BARI, 2014). Proper drainage system was also developed for draining out excess water.

3.5.1.9.5. Crop protection

The crop was infested by leaf borer and aphid during the growing period. Therefore, selective insecticide (Marshal @ 10 ml per 10 liters of water) was given two times. During the entire growing period the crop was observed carefully to take protection measures.

3.5.1.10. Sampling and harvesting

Ten plants were randomly selected from the central two rows of each plot for collecting data on yield attributes and yield. Cobs were dried in bright sunshine, shelled and the grains were cleaned properly, then grains were oven-dried to kept 12% moisture and weighed with digital balance and ten cobs grain were recorded in gram and converted into metric tons per hectare. Stalks obtained from ten plants were oven-dried and final stalk weight were recorded in gram and converted into metric tons per hectare.

3.5.1.11. Collection of experimental data

The details procedures to determine the growth, phenology, yield and yield attributes were discussed below:

3.5.1.11.1. Growth and growth indicating parameters

From the ten harvested plants following data were collected:

(iv) **Plant height (cm)**

Plant height was measured at 30 DAS, 60 DAS, 90 DAS and harvest by measuring tape from soil surface to the highest tip of the tassel. Plant height was measured in cm.

(v) **Stalk base circumference (cm)**

The basal stalk circumference was measured at harvest about 1 cm from the soil surface using measuring tape.

(vi) **Leaf number per plant**

Total number of leaves of each plant was counted at harvest excluding those under soil. All leaves were counted including those that were senesced as long as they were identifiable.

(vii) **Leaf area per plant (cm^2)**

Leaf area of sample plants was measured measuring lamina length and breadth (at the middle). The leaf area was then calculated multiplying length and breadth and also by a K-co-efficient of 0.75 as per Musa *et al*. (2016). Leaf area was measured at 30 DAS, 60 DAS, 90 DAS and harvest.

(v) Leaf area index (LAI)

It is the ratio of leaf area and ground area of a plant. The information used to determine leaf area per plant was also the input here to measure the leaf area index. Leaf area was also measured at 30 DAS, 60 DAS, 90 DAS and harvest.

LAI was calculated using the following equation below:

$$LAI = \frac{1}{P} LA$$

Where, LA = Total leaf area, P = Ground area

(vi) Total dry matter per plant (g)

The respective plant parts (stem, leaves, cobs) were separated from the ten harvested plants and dried in an electric oven at 70˚c for 72 hours until a constant weight was reached. Then dry weights were taken by an electric balance. Weight of TDM was express as grams per plant. Total dry matter was the sum of dry weight of stems, leaves and cob. Then TDM weights data were used for determination of CGR, RGR and NAR etc.

(vii) Crop growth rate (CGR)

Crop growth rate is the rate of dry matter production per unit time per unit land area. After leaf area measurement the whole above ground plants at 30 DAS, 60 DAS, 90 DAS and harvest, then dried in an oven at 70˚ C for 72 hrs. (until constant weight was reached). Total dry matter (TDM) was recorded from the five harvested plant sample and converted to per m^2 basis. CGR was calculated from the TDM data using the following equation and expressed in $g/m^{-2}/ day^{-}$.

$$CGR = (W_2 – W_1) / (T_2 – T_1) \times GA$$

Where,

W_1 = Total dry weight at time T_1

W_2 = Total dry weight at time T_2
GA = Ground area (m^2)

(viii) Relative growth rate (RGR)

Relative crop growth (RGR) is the rate of dry matter increase in per unit of total dry matter (TDM) per unit of time. RGR was measured at 60 DAS, 90 DAS and harvest. RGR was calculated by using the following equation.

$$RGR = (LnW_2 - LnW_1) / (T_2 - T_1)$$

Where,

Ln = Natural logarithm
T_1 = The period of previous observation
T_2 = The period of final observation
W_1 = Total dry weight at time T_1
W_2 = Total dry weight at time T_2

(ix) Net assimilation rate (NAR)

Net assimilation rate is define as the increase in dry weight per unit of time per unit of leaf area present (Haloi and Baldev, 1986). It is expressed by following formula:

$$NAR = \frac{(\ln LA2 - \ln LA1)}{(LA2 - LA1)} \text{ X } \frac{(W2 - W1)}{(T2 - T1)} \; (g/m^2/days^{-1})$$

Where,
Ln = Natural logarithm
LA_1 = Leaf area at time T_1
LA_2 = Leaf area at time T_2
W_1 = Total dry weight at time T_1
W_2 = Total dry weight at time T_2

3.5.1.10.2. Phenological parameters

(iv) Days to first tasseling

The days to first flowering was recorded by visual observation. The number of days from sowing to first tasseling in any plant of the plot was recorded.

(v) Days to first silking

The days to first silking was recorded by visual observation. The number of days from sowing to first silking in any of the plant in the plot was recorded.

(vi) Days to maturity

The days to maturity was recorded when the cob turned to straw in color (also observing the black layer of the grain within the shell or rachis).

3.5.1.10.3. Yield and yield contributing parameters:

(x) **Cob length without husk**

Length of ten randomly selected cobs from each plot was measured by measuring tape and then average cob length (cm) was calculated. While measuring the length, length from basal seed location to the tip of the cob was considered excluding the length of the ear stalk.

(xi) **Cob diameter (cm)**

Cob diameter was measured by means of measuring tape (cm) at the middle of each cob from ten randomly selected plants per plot and averaged.

(xii)**Number of rows per cob**

Numbers of rows per cob was calculating by selecting ten cobs randomly from each plot and counted individually and then average was taken to get information about the numbers of rows per cob.

(xiii) **Number of grains per row**

Number of grains per row of each cob from ten randomly selected cobs was counted individually and then average was calculated.

(xiv) **Total grains per cob**

Total grains per cob was calculated by selecting ten cobs randomly from each plot and counted individually and then average was taken to get information about the total grains cob.

(xv) **100-grains weight (g)**

Three samples of 100-grains were taken randomly from the seeds lot of each plot, weighted separately and then averaged. Grains weight per plant was calculated as gram.

(xvi) **Grain yield**

From each plot ten plants were harvested randomly, cobs were removed and kernels were separated from the cobs and oven dried (at 70 ºC for 48 hours) up to a constant weight and grains dry weights was taken by an digital balance. Weight of grains was expressed as gram per plant, which was later converted into tons per hectare.

(xvii) **Stover yield**

From each plot ten plants were harvested randomly. Stover weight was determined after plants was oven dried (at 70° C for 72 hours) up to a constant then final dry weight was taken by an digital balance and recorded. Weight of stover was expressed as gram per plant, which was later converted into ton per hectare.

(xviii) **Biological yield**

Biological yield of a crop is defined as the sum of grain yield and stover yield. The biological yield of maize was measured for each plant and express in t ha^{-1}. The biological yield was estimated with the following formula:

Biological yield = Grain yield + Stover yield

(xix) **Harvest index (HI)**

The harvest index (HI) was computed as the ratio of grain yield to the total above ground dry matter yield. The following formula was used to calculate harvest index.

(%) HI = (Grain yield / Total biological yield) × 100

3.5.1.11 Statistical analysis

Data recorded for growth, phenology, yield and yield contributing characters were compiled and tabulated using MS excel. The collected data were analyzed statistically using the MSTAT-C computer package. Least Significant Difference (LSD) technique at 5% level of significance was used to compare the mean differences among the treatments (Gomez and Gomez, 1984).

3.5.2. Experiment 2. Growth and yield assessment of different varieties of Indian white maize under varying planting geometry at SAU, Dhaka (rabi 2015-16)

3.5.2.1. Experimental location

The research field was located at SAU farm, Dhaka. Details has been described in the beginning of this chapter in section 3.2.

3.5.2.2. Experimental period

The experiment was accomplished during the period from November, 2015 to April, 2016. It was Rabi season.

3.5.2.3. Species description

Two species usually PSC-121 and KS-510 were used as white maize variety. These two varieties were imported from India.The varieties have been developed by Proline Seed Company (India).

3.5.2.4. Experimental treatments

There were two varieties and three different planting geometry were evaluated and also their combined performance. The treatments throughout the experiment were as follows;

Factor A. (2-maize varieties)

(i) V_1 = PSC -121

(ii) V_2 = KS -510

Factor B. (3 -planting geometry)

(i) S_1 = 50 cm × 25 cm

(ii) S_2 = 60 cm × 25 cm

(iii) S_3 = 70 cm × 25 cm

Interactions of variety and spacing were as follows

(i) $V_1 S_1$

(ii) $V_1 S_2$

(iii) $V_1 S_3$

(iv) $V_2 S_1$

(v) $V_2 S_2$

(vi) $V_2 S_3$

3.5.2.5. Design and layout

The experiment was laid out in a factorial RCBD design with three replications. The experimental area was divided into three blocks and each blocks was again divided into six plots. The unit plot size was 6 m^2 (3 m × 2 m) with 80 cm border between two adjacent plots and 1 m between adjacent replications (block). As such the total numbers unit plots were 18 in the experiment. Row to row distance and plant to plant distance were according to the treatments.

3.5.2.6. Land preparation

As described in experiment 1.

3.5.2.7. Fertilizer and manure application

As described in experiment 1.

3.5.2.8. Sowing of seeds

Seeds were sown on 24 November, 2015 as per treatments. Other practices were done as described in experiment number- 1.

3.5.2.9. Intercultural operations

Intercultural operations were done as described in experiment number -1.

3.5.2.10. Sampling and harvesting

As described in experiment -1.

3.5.2.11 Data collection

Data on plant height, days to tasseling, days to silking, days to maturity, cob length, cob breadth, number of rows per cob, number of grain per row, number of grains per cob,100-grain weight, stover weight per plant, stover weight per hectare, grain yield per plant, grain yield per hectare, biological yield and harvest index were taken. The detailed methodology has been described in experiment -1.

3.5.2.12. Statistical analysis

As described in experiment- 1.

3.5.3. Experiment 3: Growth and yield assessment of different varieties of Indian white maize under varying planting geometry at Dhamrai Upazila, Dhaka during rabi 2015-16

3.5.3.1 Experimental location

The research field was located at Dhamrai Upazilla, Dhaka. Details has been described in the beginning of this chapter in section 3.2

3.5.3.2 Experimental period

The experiment was accomplished during the period from December, 2015 to April, 2016 of rabi season.

3.5.3.3 Species description

As described in experiment 2.

3.5.3.4. Experimental treatments

As described in expt. 2.

3.5.3.5 Design and layout

As described in experiment 2.

3.5.3.6. Land preparation

As described in experiment 1.

3.5.3.7. Fertilizer and manure application

As described in experiment 1.

3.5.3.8 Sowing of seeds

Seeds were sown on 07, December, 2015 as per treatments. The detailed methodology of sowing has been described in experiment number 1.

3.5.3.9. Intercultural operations

Intercultural operations were done as described in experiment number 1.

3.5.3.10. Sampling and harvesting

As were done in experiment number 1.

3.5.3.11 Data collection

Data on plant height, days to tasseling, days to silking, days to maturity, cob length, cob breadth, number of rows per cob, number of grain per row, number of grains per cob,100-grain weight, stover weight per plant, stover weight per hectare, grain yield per plant, grain yield per hectare, biological yield and harvest index were taken. The detailed methodology has been described in experiment 1.

3.5.3.12. Statistical analysis

As were done in experiment number 1.

3.5.4 Experiment 4: Growth and yield assessment of different varieties of Indian white maize under varying planting geometry at Rangpur district (rabi 2015-16)

3.5.4.1 Experimental location

The research field was located at Sadar Upazilla, Rangpur district. Details has been described in the beginning of this chapter in section 3.2

3.5.4.2 Experimental period

The experiment was accomplished during the period from December, 2015 to April, 2016. It was Rabi season.

3.5.4.3 Species description

As described in experiment 2

3.5.4.4. Experimental Treatments

As described in experiment 2.

3.5.4.5 Design and layout

As described in experiment 2.

3.5.4.6. Land preparation

As has been described in expt 1.

3.5.4.7. Fertilizer and manure application

As has been described in expt 1.

3.5.4.8 Sowing of seeds

Seeds were sown on 10 December, 2015 as per treatments. The detailed methodology of sowing has been described in experiment number 1.

3.4.5.9. Intercultural operations

Intercultural operations were done as described in experiment number 1.

3.5.4.10. Sampling and harvesting

As has been described in expt 1.

3.5.4.9 Data collection

Data on plant height, days to tasseling, days to silking, days to maturity, cob length, cob breadth, number of rows per cob, number of grain per row, number of grains per cob,100-grain weight, stover weight per plant, stover weight per hectare, grain yield per plant, grain yield per hectare, biological yield and harvest index were taken. The detailed methodology has been described in experiment 1.

3.5.4.10 Statistical analysis

As has been described in expt 1.

3.5.5 Experiment 5: Performance of white maize (var. PSC-121) under varying planting geometry at SAU, Dhaka (rabi 2016-17)

3.5.5.1 Experimental location

The research field was located at SAU farm, Dhaka. Detailed has been described in the beginning of this chapter in section 3.2

3.5.5.2. Experimental period

The experiment was accomplished during the period from November, 2016 to April,, 2017. It was Rabi season.

3.5.5.3. Species description

PSC-121 was used as maize variety as described in expt. 2.

3.5.5.4. Experimental Treatments

There was one white maize variety and four different planting geometry were evaluated. The treatments throughout the experiment were as follows:

(i) Variety: PSC - 121

(ii) Planting geometry: 04

S_1 = 50 cm × 20 cm

S_2 = 50 cm × 25 cm

S_3 = 60 cm × 20 cm

S_4 = 60 cm × 25 cm

3.5.5.5. Design and layout

A Randomized Complete Block Design (RCBD) with three replications was used to conduct the experiment. Four different planting geometry were used, so that the total numbers of experimental units were 12. Each plot was 6 m^2 (3 m × 2 m) in size. Spacing between the replications was 1 m. Experimental plots were separated from each other by 80 cm. Row to row distance and plant to plant distance were maintained 60 cm x 20 cm.

3.5.5.6. Land preparation

The land was prepared with power tiller ploughed on 20 November, 2016. Other land preparation practices were done as described in experiment number 1.

3.5.5.7. Fertilizer and manure application

As described in experiment number 1.

3.5.5.8. Sowing of seeds

Seeds were sown on 27 November, 2016 as per treatments. Other practices were done as described in experiment number 1.

3.5.5.9. Intercultural operations

Intercultural operations were done as described in experiment number 1.

3.5.5.10. Sampling and harvesting

As described in experiment number 1

3.5.5.11. Data collection

Data on plant height, days to tasseling, days to silking, days to maturity, cob length, cob breadth, number of rows per cob, number of grain per row, number of grains per cob,100-grain weight, stover weight per plant, stover weight per hectare, grain yield per plant, grain yield per hectare, biological yield and harvest index were taken. The detailed methodology has been described in experiment 1.

3.5.5.12 Statistical analysis

As has been described in expt 1.

3.5.6. Experiment 6: Performance of white maize (var. PSC-121) under varying planting geometry at Dhamrai Upazilla, Dhaka during rabi 2016-17

3.5.6.1. Experimental location

The research field was located at Dhamrai Upazilla, Dhaka. Detailed has been described in the beginning of this chapter in section 3.2

3.5.6.2 Experimental period

The experiment was accomplished during the period from December, 2016 to April, 2017. It was Rabi season.

3.5.6.3. Species description

PSC-121 was used as maize variety as described in expt. 2.

3.5.6.4. Experimental Treatments

As described in experiment 5

3.5.6.5. Design and layout

A Randomized Complete Block Design (RCBD) with three replications was used to conduct the experiment. Four different planting geometry were used, so that the total numbers of experimental units were 12. Each plot was 7 m^2 (3.5 m × 2 m) in size. Spacing between the replications was 1 m. Experimental plots were separated from each other by 80 cm. Row to row distance and plant to plant distance were according to the treatments.

3.5.6.6. Land preparation

The land was prepared with power tiller ploughed on 01, December 2016. Other land preparation practices were done as described in experiment number 1.

3.5.6.7. Fertilizer and manure application

As described in experiment number 1.

3.5.6.8. Sowing of seeds

Seeds were sown on 07, December, 2016 as per treatments. Other practices were done as described in experiment number 1.

3.6.5.9. Intercultural operations

Intercultural operations were done as described in experiment number 1.

3.5.6.10. Sampling and harvesting

As described in experiment number 1.

3.5.6.11 Data collection

Data on plant height, days to tasseling, days to silking, days to maturity, cob length, cob breadth, number of rows per cob, number of grain per row, number of grains per cob,100-grain weight, stover weight per plant, stover weight per hectare, grain yield per plant, grain yield per hectare, biological yield and harvest index were taken. The detailed methodology has been described in experiment 1

3.5.6.12. Statistical analysis

As described in experiment 1.

3.5.7 Experiment 7: Performance of white maize (var. PSC-121) under varying planting geometry at Rangpur district (rabi 2016-17)

3.5.7.1 Experimental location

The research field was located at Sadar Upazilla, Rangpur district. Detailed has been described in the beginning of this chapter in section 3.2

3.5.7.2 Experimental period

The experiment was accomplished during the period from December 2016 to April, 2017. It was Rabi season.

3.5.7.3. Species description

PSC-121 was used as white maize variety

3.5.7.4. Experimental treatments

As described in experiment 5

3.5.7.5. Design and layout

A Randomized Complete Block Design (RCBD) with three replications was used to conduct the experiment. Four different planting geometry were used, so that the total numbers of experimental units were 12. Each plot was 8.75 m^2 (3.5 m × 2.5 m) in size. Spacing between the replications was 1 m. Experimental plots were separated from each other by 80 cm. Row to row distance and plant to plant distance were according to the treatments.

3.5.7.6. Land preparation

The land was prepared with power tiller ploughed on 15 November, 2016. Other land preparation practices were done as described in experiment number 1.

3.5.7.7. Fertilizer and manure application

As described in experiment number 1.

3.5.7.8 Sowing of seeds

Seeds were sown on 22 November, 2016 as per treatments. Other practices were done as described in experiment number 1.

3.5.7.9. Intercultural operations

Intercultural operations were done as described in experiment number 1.

3.5.7.10. Sampling and harvesting

As described in experiment number 1.

3.5.7.11 Data collection

Data on plant height, days to tasseling, days to silking, days to maturity, cob length, cob breadth, number of rows per cob, number of grain per row, number of grains per cob,100-grain weight, stover weight per plant, stover weight per hectare, grain yield per plant, grain yield per hectare, biological yield and harvest index were taken. The detailed methodology has been described in experiment 1.

3.5.7.12 Statistical analysis

As described in experiment 1

3.5.8 Experiment 8: Performance of different white maize varieties as influenced by different levels of irrigation at SAU, Dhaka (rabi 2016-17)

3.5.8.1. Experimental location

The research field was located at SAU farm, Dhaka. Detailed has been described in the beginning of this chapter in section 3.2

3.5.8.2. Experimental period

The experiment was accomplished during the period from November, 2016 to April, 2017. It was Rabi season.

3.5.8.3. Species description

PSC-121, Changnuo –1, Youngnuo –30 and Changnuo -6 were used as white maize varieties.

3.5.8.4 Experimental Treatments

Four different varieties and four irrigation levels were evaluated separately and also with their combinations. The treatments throughout the experiment were as follows:

Factor A. Main plots (4-irrigation levels)

(i) I_2 = Two irrigations (25 DAS + 75 DAS)

(ii) I_3 = Three irrigations (25 DAS + 50 DAS +75 DAS)

(iii) I_4 = Four irrigations (25 DAS + 50 DAS +75 DAS + 100 DAS)

(iv) I_{wr} = Irrigation when required

Factor B. Sub plots (4-maize varieties)

(i) V_1 = PSC-121

(ii) V_2 = Changnuo -1

(iii) V_3 = Changnuo -6

(iv) V_4 = Youngnuo -30

Combinations of irrigation levels and variety

(i) $I_2 V_1$

(ii) $I_2 V_2$

(iii) $I_2 V_3$

(iv) $I_2 V_4$

(v) $I_3 V_1$

(vi) $I_3 V_2$

(vii) $I_3 V_3$

(viii) $I_3 V_4$

(ix) $I_4 V_1$

(x) $I_4 V_2$

(xi) $I_4 V_3$

(xii) $I_4 V_4$

(xiii) $I_{wr} V_1$

(xiv) $I_{wr} V_2$

(xv) $I_{wr} V_3$

(xvi) $I_{wr} V_4$

3.5.8.5 Design and layout

The field experiment was laid out in split plot design keeping irrigation levels in main plots and variety in sub plots with three replications. Each treatment combination was replicated three times and as such there were 48 unit plots in this study. Each plot was 7 m^2 (3.5 m × 2 m) in size. Spacing between the replications was 1 m. Experimental plots were separated from each other by 80 cm. Row to row distance and plant to plant distance were maintained 60 cm x 20 cm.

3.5.8.6 Land preparation

The land was prepared with power tiller ploughed on 20 November, 2016. Other land preparation practices were done as described in experiment number 1.

3.5.8.7. Fertilizer and manure application

As described in experiment number 1.

3.5.8.8 Sowing of seeds

Seeds were sown on 27 November, 2016 by maintaining (60 cm x 20 cm) planting geometry. Other practices were done as described in experiment number 1.

3.5.8..9. Intercultural operations

Intercultural operations were done as described in experiment number 1.

3.5.8.10. Sampling and harvesting

As described in experiment number 1.

3.5.8.11 Data collection

Data on plant height, days to tasseling, days to silking, days to maturity, cob length, cob breadth, number of rows per cob, number of grain per row, number of grains per cob,100-grain weight, stover weight per plant, stover weight per hectare, grain yield per plant, grain yield per hectare, biological yield and harvest index were taken. The detailed methodology has been described in experiment 1

3.5.8.12. Statistical analysis

As described in experiment 1

3.5.9. Experiment 9: Performance of different white maize varieties as influenced by different levels of fertilizer at SAU, Dhaka (rabi 2016-17)

3.5.9.1 Experimental location

The research field was located at SAU farm, Dhaka. Detailed has been described in the beginning of this chapter in section 3.2

3.5.9.2 Experimental period

The experiment was accomplished during the period from November, 2016 to April, 2017. It was Rabi season.

3.5.9.3. Species description

PSC-121, Changnuo-1, Q -Xiangnuo-1, Youngnuo-30 and Changnuo-6 were used as white maize variety.

3.5.8.7 Experimental Treatments

Five different varieties and four various fertilizer dose treatments were evaluated separately and also with their combinations. The treatments throughout the experiment were as follows:

Factor A. Main plots (Fertilizer levels)

(i) F_1 = Recommended fertilizer dose

(ii) F_2 = Half of recommended fertilizer dose

(iii) F_3 = 25% more of recommended fertilizer dose

(iv) F_4 = 25% less of recommended fertilizer dose

Factor B. Sub plots (maize varieties)

(i) V_1 = Changnuo -1

(ii) V_2 = Q-Xiangnuo-1

(iii) V_3 = PSC-121

(iv) V_4 = Youngnuo -30

(v) V_5 = Changnuo - 6

Combinations of fertilizer levels and variety

(i) $F_1 V_1$

(ii) $F_2 V_2$

(iii) $F_2 V_3$

(iv) $F_1 V_4$

(v) $F_1 V_5$

(vi) $F_2 V_1$

(vii) $F_2 V_2$

(viii) $F_2 V_3$

(ix) $F_2 V_4$

(x) $F_2 V_5$

(xi) $F_3 V_1$

(xii) $F_3 V_2$

(xiii) $F_3 V_3$

(xiv) $F_3 V_4$

(xv) $F_3 V_5$

(xvi) $F_4 V_1$

(xvii) $F_4 V_2$

(xviii) $F_4 V_3$

(xix) $F_4 V_4$

(xx) $F_4 V_5$

3.5.9.5. Design and layout

The field experiment was laid out in split plot design keeping fertilizer in main plots and variety in sub plots with three replication. Each treatment combination was replicated three times and as such there were 60 unit plots in the study. Each plot was 7.5 m^2 (3 m × 2.5 m) in size. Spacing between the replications was 1 m. Experimental plots were separated from each other by 80 cm.

3.5.9.6. Land preparation

The land was prepared with power tiller ploughed on 20 November, 2016. Other land preparation practices were done as described in experiment number 1.

3.5.9.7. Fertilizer and manure application

The experimental plots were fertilized with manures and fertilizers (Urea, TSP, MoP, Gypsum, Zinc Sulphate and Boric acid) as per treatments. Other fertilization practices were done as described in experiment number 1.

3.5.9.8. Sowing of seeds

Seeds were sown on 27 November, 2016 by maintaining (60cm x 20cm) planting geometry. Other practices were done as described in experiment number 1

3.5.9.9. Intercultural operations

Intercultural operations were done as described in experiment number 1.

3.5.9.10. Sampling and harvesting

As described in experiment number 1.

3.5.9.11. Data collection

Data on plant height, days to tasseling, days to maturity, cob length, number of rows per cob, number of grain per row, number of grains per cob,100-grain weight, stover weight per plant, stover weight per hectare, grain yield per plant, grain yield per hectare, biological yield and harvest index were taken. The detailed methodology has been described in experiment 1.

3.5.9.12 Statistical analysis

As described in experiment 1

3.5.10. Experiment 10: Performance of white maize (var. PSC-121) under different fertilizer levels and planting geometry at SAU, Dhaka (rabi 2017-18)

3.5.10.1. Experimental location

The research field was located at SAU farm, Dhaka. Detailed has been described in the beginning of this chapter in section 3.2.

3.5.5.10.2. Experimental period

The experiment was accomplished during the period from, December 2017 to April, 2018. It was Rabi season.

3.5.10.3. Species description

PSC-121 was used as white maize variety.

3.5.10.4. Experimental Treatments

There was an one variety, four planting geometry and two fertilizer levels evaluated separately and also evaluated with their combined performance. The treatment throughout the experiment were as follows:

Factor A. Main plots (2 -fertilizer levels)

(i) F_1 = Recommended fertilizer dose

(ii) F_2 = 25% more of recommended fertilizer dose

Factor B: Sub plots (4-spacings)

(i) S_1 = 50 cm × 20 cm

(ii) S_2 = 50 cm × 25 cm

(iii) S_3 = 60 cm × 20 cm

(iv) S_4 = 60 cm × 25 cm

Treatment combinations of fertilizer and spacing

(i) $F_1 S_1$

(ii) $F_1 S_2$

(iii) $F_1 S_3$

(iv) $F_1 S_4$

(v) $F_2 S_1$

(vi) $F_2 S_2$

(vii) $F_2 S_3$

(viii) $F_2 S_4$

3.5.10.5 Design and layout

The field experiment was laid out in split plot design keeping fertilizer in main plots and spacing in sub plots with three replication. Each treatment combination was replicated three times and as such there were 24 unit plots in the study. Each plot was 6 m^2 (3 m × 2 m) in size. Spacing between the replications was1 m. Experimental plots were separated from each other by 80 cm. Row to row distance and plant to plant distance were according to the treatments.

3.5.10.6. Land preparation

The land was prepared with power tiller ploughed on 22 November, 2017. Other land preparation practices were done as described in experiment number 1.

3.5.10.7. Fertilizer and manure application

The experimental plots were fertilized with manures and fertilizers (Urea, TSP, MoP, Gypsum, Zinc Sulphate and Boric acid) as treatment wise. Other fertilization practices were done as described in experiment number 1.

3.5.10.8 Sowing of seeds

Seeds were sown on 2nd December, 2017 by maintaining (60cm x 20cm) plant geometry. Other practices were done as described in experiment number 1.

3.5.10.9. Intercultural operations

Intercultural operations were done as described in experiment number 1

3.5.10.10. Sampling and harvesting

As described in experiment number 1.

3.5.10.9 Data collection

Data on plant height, number of leaves per plant, stem diameter, leaf area per plant, leaf area index (LAI), total dry matter per plant (TDM), Crop growth rate (CGR), Relative growth rate (RGR), Net assimilation rate (NAR), days to tasseling, days to silking, days to maturity, cob length, cob breadth, number of rows per cob, number of grain per row, number of grains per cob,100-grain weight, stover weight per plant, stover weight per hectare, grain yield per plant, grain yield per hectare, biological yield and harvest index were taken. The detailed methodology has been described in experiment 1

3.5.10.10 Statistical analysis

As described in experiment 1

CHAPTER IV

RESULTS AND DISCUSSION

4.1. Experiment 1: Growth and yield assessment of different varieties of Chinese white maize under varying planting geometry at SAU, Dhaka (rabi 2015-16)

4.1.1. Growth parameters

4.1.1.1. Plant height

Almost all the growth parameters were significantly affected by maize varieties and plant densities. Plant height is an important component which helps in the determination of growth attained during the growing period. Various treatments such as variety, plant spacing and their combination were used to observe their effects on plant height of white maize and the result was represented in figure 4.1.1, 4.1.2, and 4.1.3.

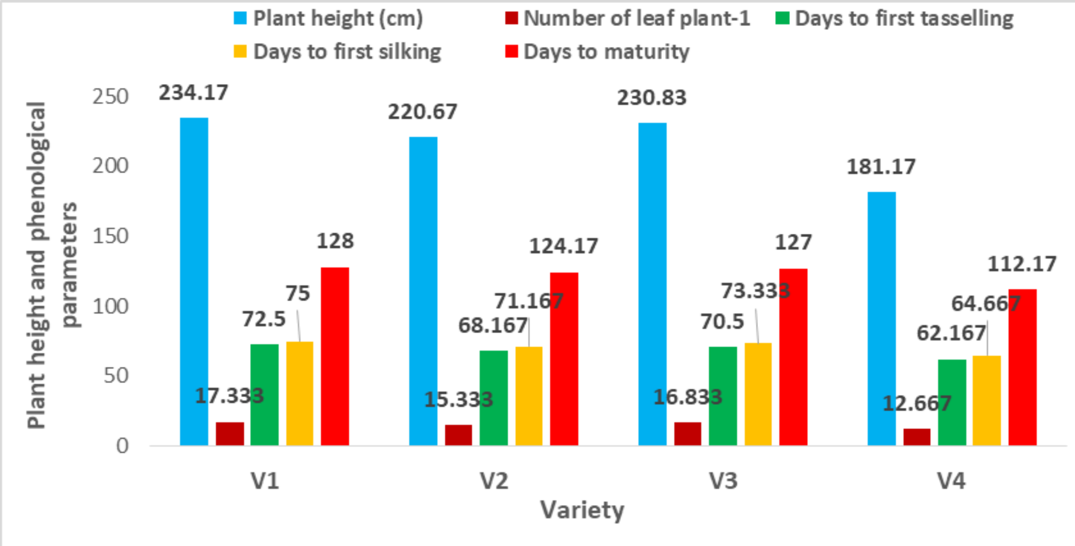
It was revealed from the results that plant height was significantly influenced by four examined white maize hybrid varieties. Among the varieties, V_1 showed significantly the tallest plant (234.17 cm) and V_4 produced significantly the shortest (181.17 cm) plants. Likewise, V_3 had significantly longer plants (230.83 cm) than that of V_2 (220.67 cm) (Figure 4.1.1).

Among the plant spacing treatments, S_1 had the tallest plants (219.50 cm) while S_2 showed the shortest (213.9 cm) plants (Figure 4.1. 2).

For their various combination among the above stated treatments, V_1S_1 produced significantly the tallest plants (236.67 cm) which was statistically similar to V_3S_1 (233.6 cm) whileV_4S_2 showed significantly the shortest (179.00 cm) plants. Likewise, V_1 S_2 had significantly longer plants (231.6 cm) than that of V_3 S_2 and V_2 S_1 (228.0 cm and 224.0 cm respectively) (Figure 4.1.3)

These results are in the line with Gozubenli *et al.* (2001) and Konuskan (2000) who found that there was a considerable varietal variation for the plant height. Dawadi and

Sah (2012) also observed that plant height was significantly influenced by the densities and varieties.



Here, V_1 = Changnuo-1, V_2 = Q- Xiangnuo-1, V_3 = Changnuo-6, V_4 = Yangnuo-7

Figure 4.1.1. Effect of variety on plant height, number of leaves per plant, days to first tasseling, days to first silking and days to maturity of white maize

4.1.2. Number of leaves plant^{-1}

Total number of leaves plant^{-1} was significantly influenced by varieties, plant spacing and their combinations (Figure 4.1.1, 4.1.2 and 4.1.3).

Significantly the maximum number of leaves plant^{-1} (17.333) was produced by the variety V_1 followed by V_3 (16.833) variety while V_4 variety was significantly the lowest leaves producer (12.667). Likewise, V_2 produced medium number of leaves plant^{-1} (15.333) Figure 4.1.1).

Among the various plant spacing treatments, S_1 produced significantly highest number of leaves plant^{-1} (16.083) whereas S_2 produced significantly the least number of leaves plant^{-1} (15.000) (Figure 4.1.2).

Their combinations revealed that, V_1S_1 (18.000) showed significantly the highest number of leaves plant^{-1} (18.000) followed by V_3S_1 (17.330) while V_4 S_2 showed significantly lowest number of leaves plant^{-1} (12.333) which was statistically at par with V_4S_1 (13.000). Likewise, V_1S_2 had significantly medium number of leaves plant^{-1}(16.667) than that of V_3 S_2, V_2 S_1 and V_2 S_2 (16.333,16.000 and 14.667 respectively) (Figure 4.1.3). Leaf number was greater at the low population density than at high population density. This decrease number of leaves resulted from greater inter competetion at higher plant densities (Fakorede MAB, Mock JJ, 1978), Similar result was also reported by (Bahadur *et. al*, 1999) and (Shafshak *et. al*, 1984).

4.1.2. Phenological parameters

4.1.2.1. Days to first tasselling

Varieties and plant spacing treatments separately and their combinations were used to observe their effects on days to tasseling (Figure 4.1.1, 4.1.2 and 4.1.3). It was found that days to tasseling was significantly influenced by varieties.

Among the treatments, V_1 variety significantly took the maximum days to first tasselling (72.500 days) followed by V_2 and V_3 (68.167 days and 70.500 days), while V_4 significantly took minimum days to tasselling (62.1670 days) (Figure 4.1.1).

Plant spacing treatments were non-significant effect on days to first tasseling (Figure 4.1.2). Although having non-significant effect, S_1 took to reach maximum days to first tassel (68.500 days) while S_2 took to reach minimum days to first tassel (68.167 days) (Figure 4.1.2).

On the other hand, for the combination of varieties and plant spacing treatment it was found that, V_1S_1 combination significantly took more days to first tassel (72.667 days) followed by V_1S_2 (72.333 days) whereas V_4S_1 took the lowest days to first tassel (62.333 days) which was statistically at par with V_4S_2 (62.000 days) (Figure 4.1.3).

Significantly earlier tasseling and silking and shorter physiological maturity was observed in the variety Yangnuo-7. Early tasseling, silking and short physiological maturity of Yangnuo-7 might be due to its genetic characteristics.

Late maturing varieties took more days to tassel and hence had a better chance to utilize more nutrients and more photosynthetic activity, which utimately resulted in late maturity. The earliest tasselling observed in the highest plant density of 66,666 plants ha^{-1} was due intra-specific competition for soil nutrients, water and sunlight among the plants which utimately triggers the plants to earily reproductive phase while lower plant density utilized soil nutrients, water and solar radiation efficiently thereby prolonged the tasselling dates. Park *et al*., (1987) reported that plant density did not affect days to tasseling and silking. Dawadi and Sah, (2012) also reported that tasseling, silking and physiological maturity were not significantly influenced by plant density. However, there was a lower number of days to silking, tasseling and physiological maturity with increases in plant density. Azam *et al.*, (2007) reported different tasseling days for different maize varieties.

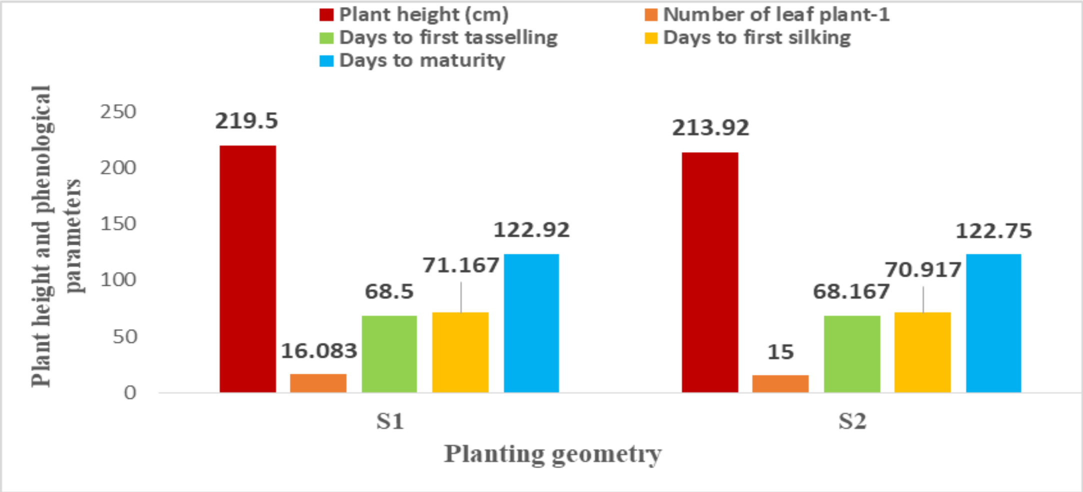
4.1.2.2. Days to first silking

White maize varieties and plant spacing treatment separately and their combinations were used to observe their effects on days to silking of white maize (Figure 4.1.1, 4.1.2 and 4.1.3). It was found that days to silking was significantly influenced by varieties.

Among the varieties, V_1 variety took significantly maximum number of days for silking (75.000 days) followed by V_4 (64.667 days) which was significantly took minimum number of days for silking (64.667 days)(Figure 4.1.1). It could be due to differences in genetic makeup of these varieties.

Plant spacing treatments were non- significant effect on days to first silking of white maize. Although having non-significant effect, S_1 took the highest number of days to first silking (71.167 days) while S_2 took the lowest number of days to first silking (70.917 days) (Figure 4.1.2).

On the other hand, for the combination of variety and plant spacing treatment it was found that V_1S_1 significantly took more days for silking (75.000 days), which were statistically similar to V_1S_2 (75.000 days). V_4S_1 took the lowest days to silking (64.667 days), which were statistically similar to V_4S_2 (64.667 days) (Figure 4.1.3). Hassan (1987) revealed that maize cultivars had significant differences in days to 50% silking.



Here, S_1 = 70 cm x 25 cm, S_2 = 60 cm x 25 cm

Figure 4.1.2. Effect of planting geometry on plant height, number of leaves per plant; days to first tasseling, days to first silking and days to maturity of white maize

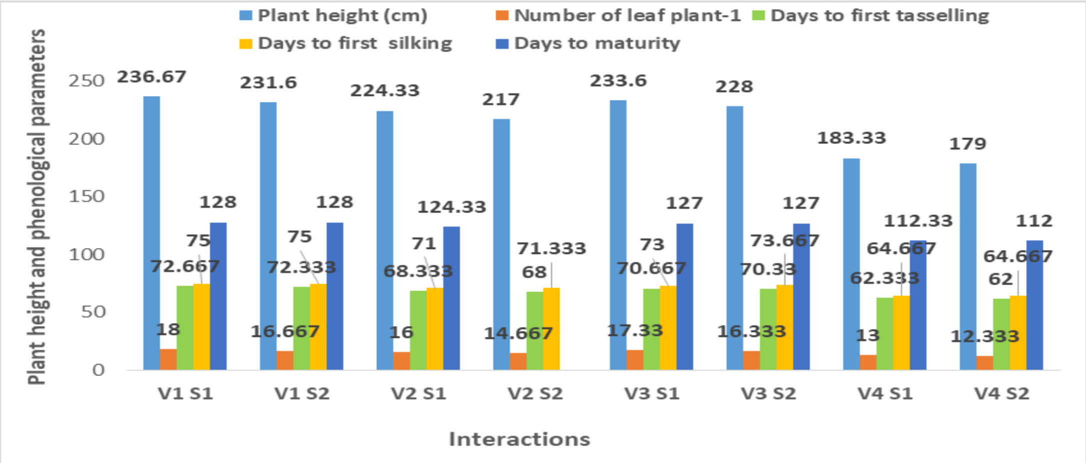
4.1.2.3. Days to maturity

Varieties, plant spacing and their combinations showed significant positive effect on days to maturity for the two tested cultivars (Figure 4.1, 4.2 and 4.3).

There was significant variations reported in plant maturity with the varieties. V_1 variety significantly took maximum days to be matured (128.00 days) followed by V_2 and V_3 (124.17 days, 127.00 days respectively) while V_4 variety significantly took very minimum days (112.17 days) to be matured (Figure 4.1).

Plant spacing treatments showed the non-significant effects on days to be matured of white maize (Figure 4.2). S_1 took the highest number of days to be matured (122.92 days) and S_2 took the lowest number of days to be matured (122.75 days) (Figure 4.1.2).

On the other hand, for the combination of variety and plant spacing it was found that V_1S_1 significantly took the highest days to be matured (128.00 days), which was statistically similar to V_1S_2 , V_3S_1 and V_3S_2 treatments (128.00 days,127 days and 127 days respectively) whereas V_4S_2 significantly took the lowest days to be matured (112.00 days) which was statistically similar to V_4S_1 (112.33 days) (Figure 4.1.3). Dawadi and Sah, (2012) also reported that tasseling, silking and physiological maturity were not significantly influenced by plant density. This might be due to the reason that different crop cultivars take their normal time to develop different vegetative and reproductive structure and attain maturity. These results were akin to that of Otegui *et al*., (1995).



Here, V_1 = Changnuo-1, V_2 = Q-Xiangnuo-1, V_3 = Changnuo-6, V_4 = Yangnuo -7 and S_1 = 70 cm x 25 cm, S_2 = 60 cm x 25 cm

Figure 4.1.3. Interaction effects of variety and planting geometry on plant height, number of leaves per plant, days to first tasseling, days to first silking and days to maturity of white maize

4.1.3. Yield contributing characters and yield

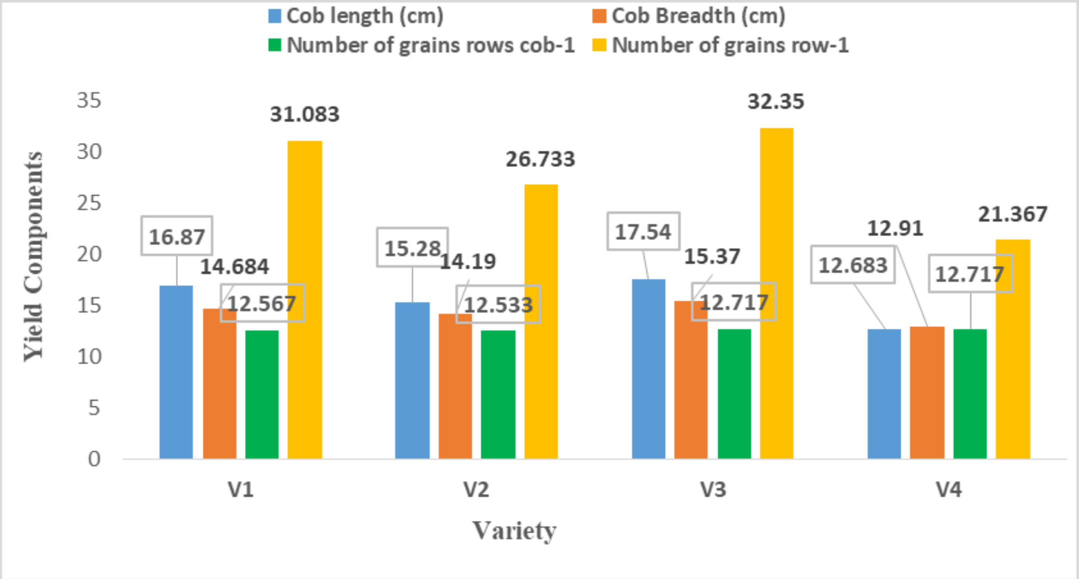
4.1.3.1. Cob length

Population density, white maize hybrids and the interactive effect of plant population density and hybrids had significant effects on cob length.

Maximum cob length (17.54 cm) was significantly achieved with V_3 variety followed by V_1 (16.87 cm) and V_2 variety (15.28 cm) while the minimum cob length was achieved with V_4 variety (12.683 cm) (Figure 4.1.4).

Cob length was increased with increasing plant spacing. Among the plant spacing treatments, S_1 spacing significantly produced the tallest cobs (16.097 cm) while S_2 significantly produced the shortest cobs (15.092 cm). (Figure 4.1.5).

Moreover, for the combinations of varieties and plant spacing, it was observed that V_3S_1 significantly showed the highest cob length (18.077 cm) which was statistically similar to V_3S_2 and V_1S_1 (17.07 and 17.300 cm). Among the other treatments, V_4S_2 significantly showed the lowest cob length (12.00 cm) (Figure 4.1.6). These results are in line with the findings of Karim *et al*. (1983), Kamel et al. (1983) and Akcin *et al*. (1993) who concluded that the cob length decreased linearly with increase in plant population. These results indicate that there is a positive relationship between plant spacing and cob length of maize, probably due to variable plant competition. Konuskan (2000) and Gozubenli *et al.* (2001) reported that variations in ear characteristics of maize depend upon genotype and environmental conditions. Similar results were also reported by Chakor & Awasthi (1983); Esechie (1992) and Hassan (2000). They observed that ear length decreased with increase in plant population. This may be due to the fact that available nutrients, moisture, space and light become limited in high plant population due to high competition of soil resources between plants. Ultimately plants produced relatively small ears.



Here, V_1 = Changnuo-1, V_2 = Q - Xiangnuo-1, V_3 = Changnuo-6, V_4 = Yangnuo-7

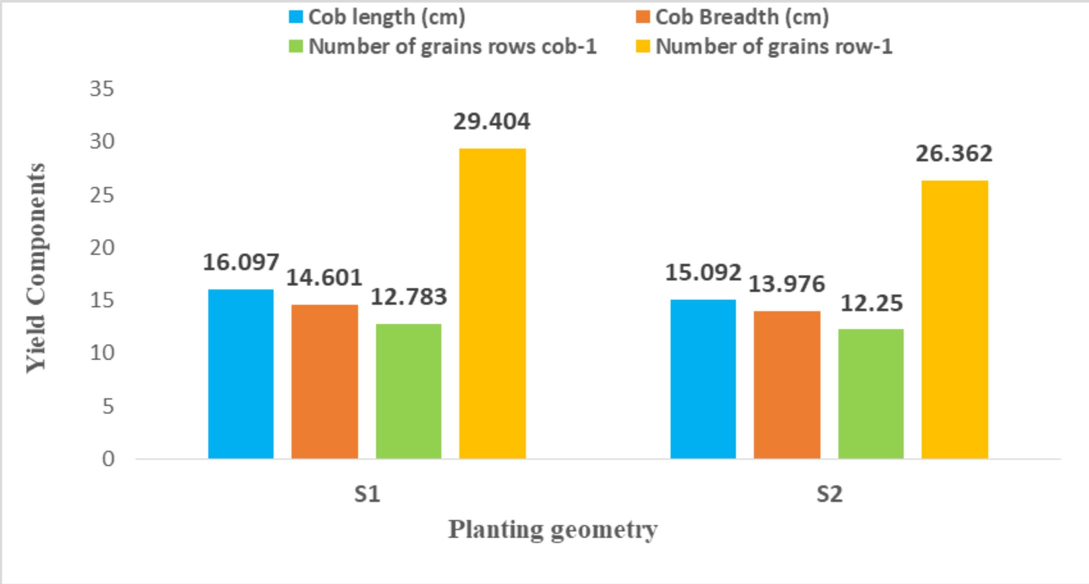
Figure 4.1.4. Effect of variety on cob length; cob breadth, number of grains rows per cob; number of grains per row of white maize

4.1.3.2. Cob breadth

Cob breadth was significantly affected by planting density, varieties and their combinations. Among the varieties significant difference was found on the production of cob breadth. Maximum cob breadth (15.370 cm) was significantly achieved with V_3 variety and the minimum (12.910 cm) was significantly achieved with V_4 variety (Figure 4.1.4).

Cob breadth was increased with increasing plant spacing. Among the plant spacing, S_1 produced the highest cob breadth (14.601 cm) and S_2 produced the lowest cob breadth (13.976 cm) (Figure 4.1.5).

Moreover, for the combination of varieties and plant spacing, it was observed that V_3S_1 treatment showed maximum cob breadth (15.607 cm), which was statistically similar to V_3S_2 (15.133 cm). Among the other treatments V_4S_2 showed minimum cob breadth (12.380 cm) (Figure 4.1.6).



Here, S_1 = 70 cm x 25 cm, S_2 = 60 cm x 25 cm

Figure 4.1.5. Effect of planting geometry on cob length; cob breadth, number of grains rows per cob; number of grains per rows of white maize

4.1.3.3. Number of rows cob^{-1}

Number of rows cob^{-1} was significantly influenced by varieties, plant spacing and their combinations (Figure 4.1.4, 4.1.5 and 4.1.6). Among the varieties, the maximum number of rows cob^{-1} was found in V_3 (12.717) which was statistically similar to V_1 and V_2 (12.567 and 12.533) whereas V_4 was the lowest performer (12.250) (Figure 4.1.4).

However, plant spacing treatments showed the significant effects on number of rows cob^{-1}. Among the various treatments, S_1 produced significantly the highest number of rows cob^{-1} (12.783) while the lowest (12.250) was produced from S_2 (Figure 4.1.5).

Moreover, their combination revealed that, V_3S_1 showed the highest number of rows cob^{-1} (13.067), which was statistically similar to V_3S_2, V_1S_1 and V_2S_1 respectively (12.867, 12.867 and 12.867 respectively). Again the treatment V_4S_2 showed the minimum number of rows cob^{-1} (12.167), which was statistically similar to V_2S_2 (12.200) (Figure 4.1.6).

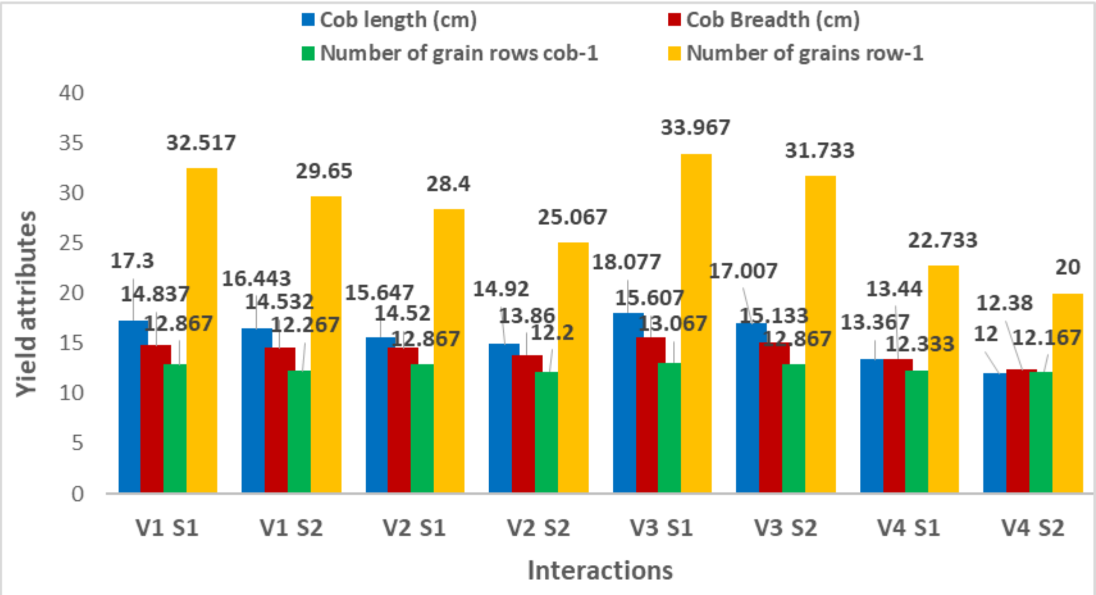
Hashemi *et al*. (2005) reported a linear decline in number of kernel rows/ear with increasing plant density.

4.1.3.4. Number of grains row^{-1}

Number of grains row^{-1} was significantly influenced by varieties, plant spacing and their combinations (Figure 4.1.4, 4.1.5 and 4.1.6). The maximum number of grains row^{-1} (32.350) was significantly reported from the treatments having V_3 variety which were statistically similar to V_1 (31.083) followed by V_2 (26.733) whereasV_4 had the lowest performer (21.367) (Figure 4.1.4).

However, plant spacing treatments showed the significant effects on number of grains row^{-1}. Among the various treatments, S_1 produced the highest number of grains row^{-1} (29.404) and the lowest (26.362) was produced from S_2 (Figure 4.1.5).

Moreover, their combination revealed that V_3S_1 showed significantly the highest number of grains row^{-1} (33.967) than the other combinations, which were statistically similar to V_1S_1 (32.517) and V_2S_2 (31.733) where V_4S_2 produced significantly the minimum number of grains row^{-1} (20.000) (Figure 4.1.6). Observed results were alike with the following results where it was stated that increased competition due to dense population may also lead to abortion of ovary and eventually producing lesser number of kernels increasing barrenness (Gozubenli *et al*., 2004). Comparing the response of old and modern maize varieties (Jacobs and Pearson, 1991), however, Sangoi and Salvador (1998) reported that high plant population decreased number of grains per ear of dwarf lines and did not affect this variable for modern varieties (Akbar *et al*., 2016).



Here, V_1 = Changnuo-1, V_2 = Q- Xiangnuo-1, V_3 = Changnuo-6, V_4 = Yangnuo-7, S_1=70 cm x 25 cm, S_2= 60 cm x 25 cm

Figure 4.1.6. Interaction effects of variety and planting geometry on cob length, cob breadth, number of rows cob,$^{-1}$ number of grains row^{-1} of white maize

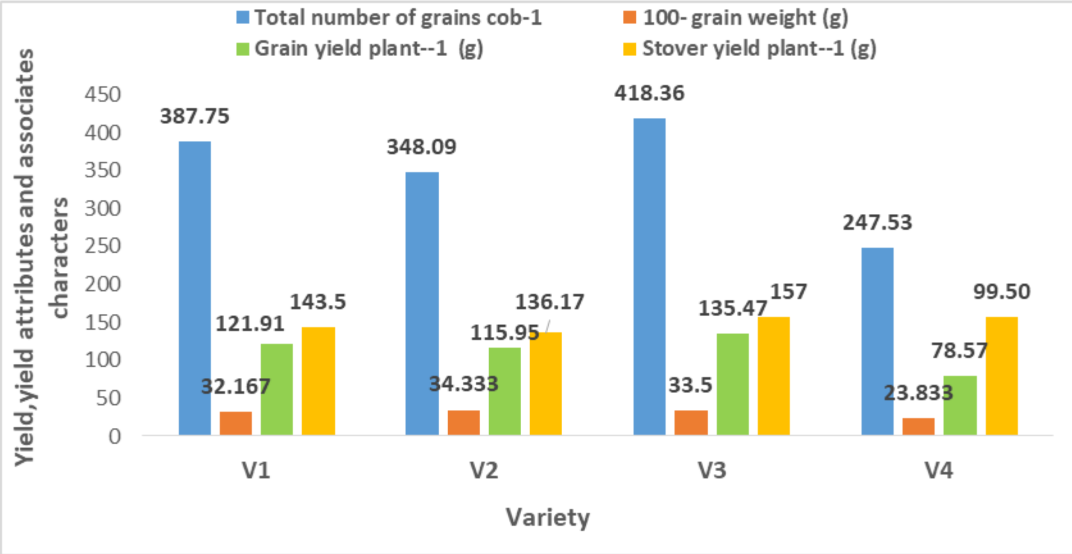
4.1.3.5. Total number of grains cob^{-1}

Total number of grains ear-^{1} contributes to the economic yield as well as represent the productive efficiency of any cereal crop or crop variety. Total number of grains cob^{-1} was significantly influenced by varieties, plant spacing and their combinations (Figure 4.1.7, 4.1.8 and 4.1.9).

The maximum number of grains cob^{-1} (418.36) was reported from the treatments having V_3 followed by V_1 (387.85) and V_2 (348.09) and V_4 was the lowest performer among others (247.53) (Figure 4.1.7).

However, in white maize plant spacing treatments showed the non-significant effects on number of grains cob^{-1}. Among the various treatments, S_1 produced highest number of grains cob^{-1} (367.64), which was statistically similar to S_2 (351.31) and it was the lowest (366.50) grain producer (Figure 4.1.8).

Moreover, their combination revealed that V_3S_1 showed the highest number of grains cob^{-1} (431.7) than the other combinations, which were statistically similar to V_3S_2, V_1S_1 and V_1S_2 (412.35, 405.49 and 380.66). Among the treatments V_4S_2 showed the very minimum number of grains cob^{-1} (275.28), which was statistically similar to V_4S_1 (277.12) (Figure 4.19). These results are in line with Esechie (1992) and Zada (1998) who found that the number of grains ear-^{1} decreased with increasing plant density. It may be due to source sink relationship and competition among maize plants for nutrients. The lowest number of kernels/ear at high plant density may be due to high competition for the resources such as light, moisture and fertilizer. The high barrenness (%) at high densities was due to the absence of the usual sink for the assimilate supply and limiting optimum conversion of light energy to grain in maize grown at high plant densities which inhibited the plants to produce viable ears. density. Tetio-kagho, Gardner and Andrade *et al*.(1986b) also reported that kernel number per plant declines sharply when the plant density increases which support our research finding.



Here, V_1 = Changnuo-1, V_2 = Q-Xiangnuo-1, V_3 = Changnuo-6 and V_4 = Yangnuo-7

Figure 4.1.7. Effect of variety on grain yield per plant, stover yield per plant, 100-grains weight and total number of grains per cob of white maize

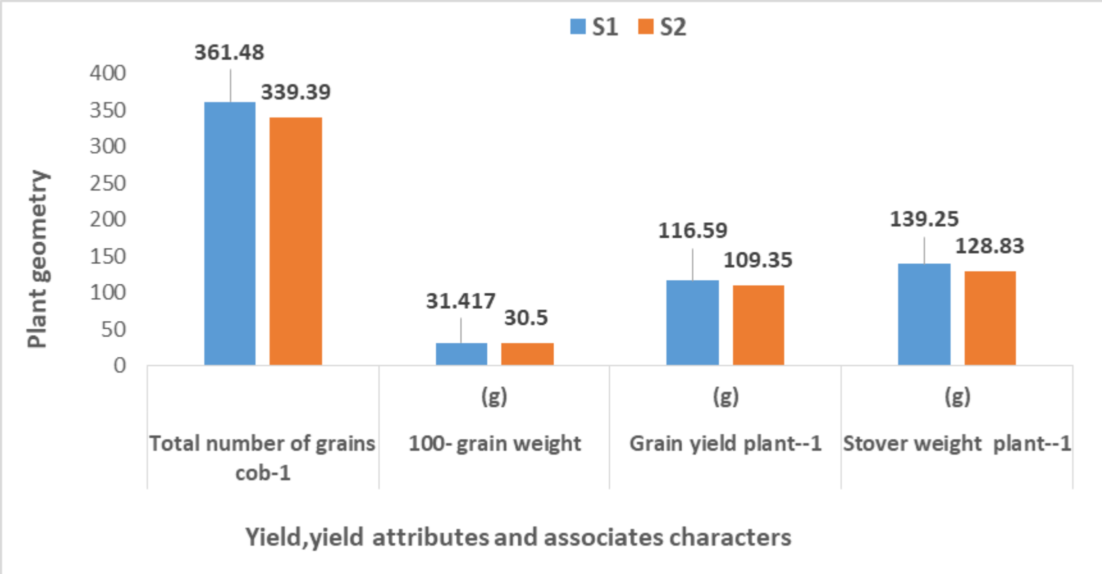
4.1.3.6. 100-grain weight

100-grain weight is an important yield contributing factor, which plays an important role in showing the potential of a variety. The varieties, plant spacing and their combination also influenced the weight of 100-grain in white maize (Figure 4.1.7, 4.1.8 and 4.1.9).

The highest 100-grain weight was produced with V_2 (34.333 g) followed by V_3 (33.500 g) and V_1 (32.16 g) while the lowest 100-grain weight was recorded fromV_4 (23.833 g) (Figure 4.1.7).

Plant spacing treatments showed the significant effects on 100- grain weight, where the maximum 100- grain weight (31.167g) was significantly found from S_1 and the minimum weight of 100-grain (30.750 g) was observed from S_2 treatment(Figure 4.1.8).

For their combination, the highest 100- grain weight (34.667 g) was produced with V_2S_2, which was statistically similar to V_2S_1, V_3S_1 and V_3S_2 (34.000, 34.00 and 33.667 g). The minimum weight of 100-grain (24.33 g) was produced by the V_4S_2 treatments, which was statistically similar to V_4S_2 (23.33 g) (Figure 4.1.9). White maize varieties showed significant effect on 100 grain weight (Ullah *et al*., 2016). Abuzar *et al.* (2011) reported increasing population density adversely affected the number of grains per ear and individual grain weight. Akcin *et al.* (1993) also reported that 100-grain weight increased with decreasing plant population density in maize. These results are in conformity with the findings of Rogers and Lomman (1988), Konuskan (2000) and Gozubenli *et al.* (2001) who stated that there were varietal differences in 100-grain weight, which increased with increasing plant spacing.



Here, S_1 = 70 cm x 25 cm, S_2 = 60 cm x 25 cm

Figure 4.1.8. Effect of planting spacing on grain yield per plant (g), stover weight per plant (g), 100-grains weight (g) and total number of grains per cob of white maize

4.1.3.7. Grain yield plant^{-1}

The varieties, plant spacing and their combinations remarkably influenced the grain yield plant^{-1} (g) in white maize (Figure 4.1.7, 4.1.8 and 4.1.9). Maximum grain yield plant^{-1} (135.47 g) was significantly achieved with the treatment V_3 and the minimum grain yield plant^{-1} (78.57 g) was significantly recorded from the treatment V_4 .Likewise, V_2 (121.91 g) had more grain producer than that of V_2 (115.95 g)

For plant spacing treatments, the maximum grain yield plant^{-1} (116.59 g) was significantly obtained with the treatment S_1 and the minimum per plant grain yielder was S_2 (109.35 g).

For their combinations, maximum grain yield plant^{-1} (139.46 g) was recorded from treatment V_3S_1. From others treatments applications the minimum grain yield plant^{-1} was significantly observed from V_4S_2 (75.07 g) and it was statistically similar to V_4S_1 (82.06 g). Likewise, V_3S_2 (131.47 g) had significantly more grain achiever than that of V_3S_2 (125.92 g).

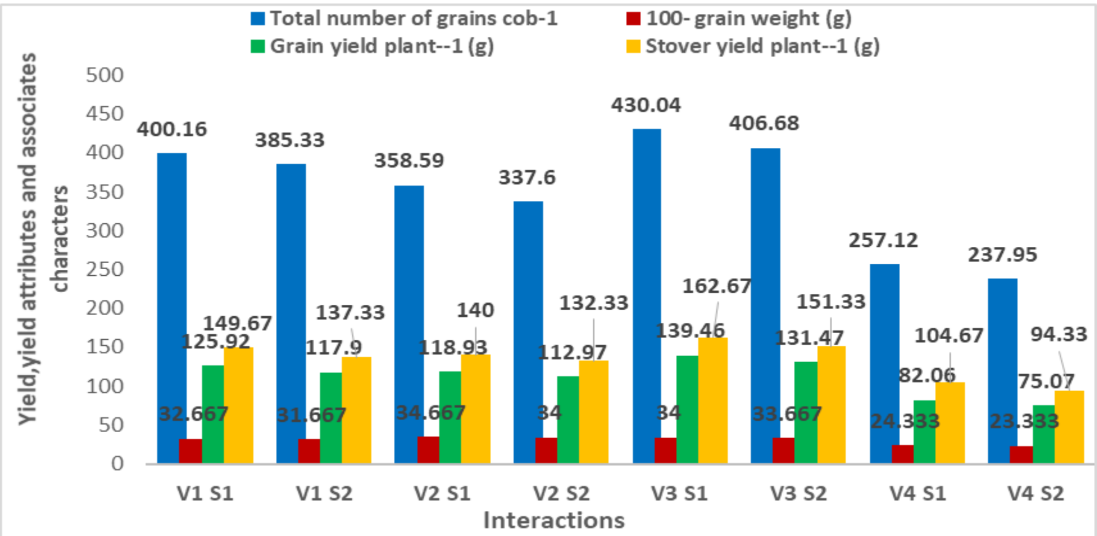
These results are in agreement with Sharma and Adamu (1984) who reported that grain weight ear-^{1} was highest at lowest plant population. It may be due to source sink relationship and competition among maize plants for nutrients.

4.1.3.8. Stover weight plant^{-1}

The varieties, plant spacing and their combinations remarkably influenced the Stover weight Plant^{-1} (g) in white maize (Figure 4.1.7, 4.1.8 and 4.1.9). The maximum stover weight plant^{-1} (157.0 g) was significantly achieved with the treatment V_3 and the minimum stover weight plant^{-1} (99.50 g) was significantly found the treatment V_4 .Likewise, V_2 (143.50 g) had significantly more stover producer than that of V_2 (136.17 g)

For plant spacing treatments, the maximum stover weight plant^{-1} (139.25 g) was observed from the treatment S_1 and the minimum per plant stover yielder was S_2 (128.83 g). For their combinations, maximum stover weight plant^{-1} (162.67 g) was recorded from treatment V_3S_1 followed by V_3S_2 (151.33 g) and V_1S_1 (149.67 g) which were statistically similar to each other. From others treatments, the minimum stover weight plant^{-1} was significantly found from V_4S_2 (94.33 g). Likewise, V_2S_1 (140.00 g) had significantly more stover producer than that of V_2S_2 (132.33 g).

These results are in agreement with Sharma and Adamu (1984) who reported that grain weight ear-^{1} was highest at lowest plant population. It may be due to source sink relationship and competition among maize plants for nutrients.



Here, V_1 = Changnuo-1, V_2 = Q- Xiangnuo-1, V_3 = Changnuo-6, V_4 = Yangnuo-7 and

S_1 =70 cm x 25 cm, S_2 = 60 cm x 25 cm

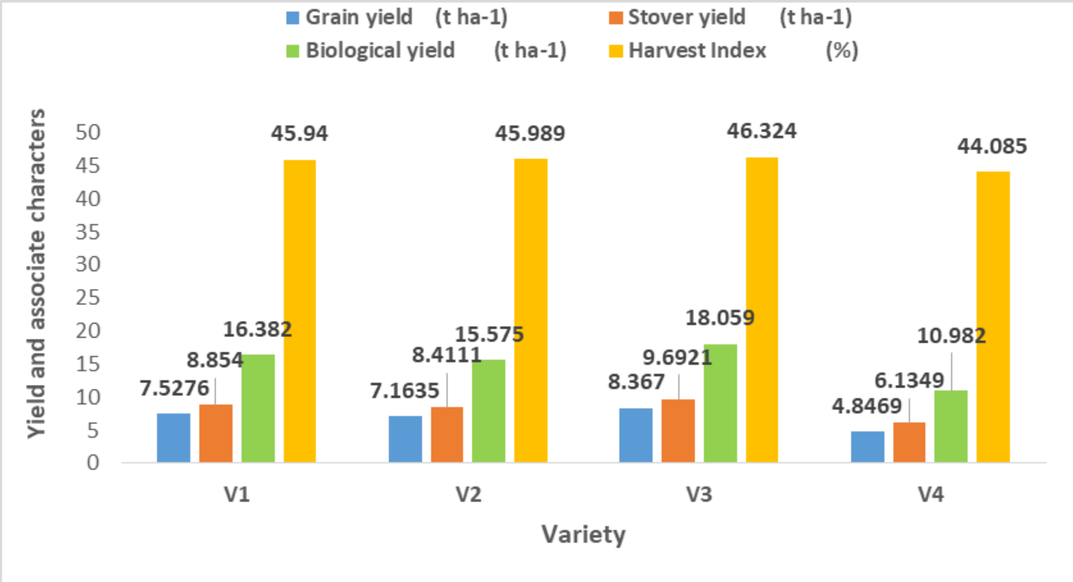
Figure 4.1.9. Interaction effect of variety and planting geometry on grain yield per plant, stover weight per plant, 100-grain weight and total number of grains per cob of white maize

4.1.3.9. Grain yield

Grain yield or economic yield is an important characteristic and ultimate objective for which most of crops are grown. The varieties, plant spacing and their combinations significantly influenced the grain yield in white maize (Figure 4.1.10, 4.1.11 and 4.1.12). Maximum grain yield (8.3670 t ha^{-1}) was observed with the treatment V_3 and the minimum grain yield (4.8469 t ha^{-1}) was achieved with the treatment V_4. Likewise, V_2 (7.5276 t ha^{-1}) had significantly more grain producer than that of V_2 (7.1635 t ha^{-1}).

For plant spacing treatments maximum grain yield (7.2901 t ha^{-1}) was achieved with the treatment S_2 and the minimum grain yielder (6.6624 t ha^{-1}) was S_1.

For their combinations, maximum grain yield (8.7645 t ha^{-1}) was counted from treatment V_3S_1. From others treatments combinations, the minimum grain yield was observed for V_4S_2 (4.6893 t ha^{-1}), which was statistically similar to V_4S_1 (5.0045 t ha^{-1}) cm) with lowest plant population (50000 plants ha-1) (4.38 t ha-1). The higher grain yield in high plant density plots might be due to higher number of effective plants per hectare (66,666) compared to 53,333 effective plants per hectare. The superior performance of Changnuo-6 could be attributed to its inherent yield potential and its better response to the environmental stress created by the increased plant density. It could be argued that Changnuo-6 which is a medium maturing variety was less affected by seasonal fluctuations. Availability of improved varieties with shorter plants, lower leaf number, upright leaves, smaller tassels and reduced anthesis silking interval has enhanced the ability of maize to withstand high plant populations without showing excessive barrenness (Sangoi, 2001). The highest grain yield obtained with plant density of 66,666 ha^{-1} might be due to large number of plants per m2 which compensated the effects of decrease in other yield components. These components though decreased per seed, yet yield actually increased per unit area. Plants grown with wider spacing consume more nutrients and absorb more solar radiation for efficient photosynthesis and hence perform better at individual basis. The reason for deviation of this linearity in case of grain yield per unit area is that the yield does not solely depend on the performance of individual plant but rather depend on total number of grains per cob and other yield contributing characters. This study revealed that a density of 66,666 plants ha^{-1} would be the optimum for maximum grain production for the varieties tested. This is in agreement with Akbar *et al.*(1996) who reported that optimum plant density produced greater yield due to efficient utilization of available soil nutrients coupled with other growth factors. The lowest grain yield with highest density was due to smaller ear size, less number of ears plant-1due to more competition for growth factors. Porter *et al*.(1997) suggested that plant distribution was a yield limiting factors when other limiting factors such as nutrient deficiencies were eliminated. Grain yield depends upon various factors such as soil status, environmental factor, plant population and plant characteristics. Grain yield is a function of integrated effects of genetic makeup of cultivars and growing conditions on the yield components of a crop. Grain yield is the end result of many complex morphological and physiological processes occurring during the growth. The growing conditions are changed by different plant spacing. As hybrids are regarded, the hybrids differed significantly for grain yield. These differences in the grain yield of hybrids are due to the differences in their potential yields. The present results are in good agreement with the findings of Konuskan (2000), Gozubenli *et al*. (2001) and Farnham (2001). Interaction effect of the variety with the planting configuration showed that the varieties when transplanted at higher population densities showed significantly higher yield. At the closer spacing the number of plants in a given area is higher than at the sparse spacing. In general the closer spacing enhances the seed yield through increasing the potentials of yield attributes provided the population density at that level does not become competitive. (Ullah *et al*., 2016). Tollenaar *et al.* (1997) also reported that maize grain yield declines when plant density is increased beyond an optimum. Similar trend was also reported Dawadi and Sah (2012). They found that plant density of 66,666 plants/ha produced the higher grain yield (11.19 t/ha) compared to that of 55,555 plants/ha (9.52 t/ha). The reason of increased grain yield may be due to net crop assimilation rate and more number of ears unit-^{1} areas.



Here, V_1 = Changnuo-1, V_2 = Q- Xiangnuo-1, V_3 = Changnuo-6, V_4 = Yangnuo-7

Figure 4.1.10. Effect of variety on grain yield; stover yield; biological yield and harvest index of white maize

4.1.3.10. Stover yield

Stover yield was significantly affected by plant population, varieties and their interactions. (Figure 4.1.10, 4.1.11 and 4.1.12).

The highest stover yield (9.6921 t ha^{-1}) was significantly observed in V_3 and the minimum by V_4 (6.1349 t ha^{-1}) which were also statistically dissimilar to each other. Likewise, V_2 (8.8540 t ha^{-1}) had significantly more stover producer than that of V_2 (8.4111 t ha^{-1}).

In the plant spacing treatments, S_2 treatment was significantly the highest stover yielder (8.5889 t ha^{-1}), while S_1 treatment was significantly the lowest stover yielder (7.9571t ha^{-1}).

However, for the combination of variety and plant spacing it was observed that, the maximum stover yield (10.089 t ha^{-1}) was significantly produced by V_3S_2 and the minimum was revealed with V_4S_1 treatment (5.981 t ha^{-1}), which was statistically similar to V_4S_2 (6.289 t ha^{-1}). It is clear from the data that the straw yield was progressively decreased with each decrease in plant population. The variability in straw yield per hectare is the result of variation in the crop stand per unit area. These results are in line with the findings of Knapp and Reid (1981), Anjum (1987) and Tetio-Kagho and Gardner (1988 b). These results are in agreement with Rezuvaev (1981) and Roy and Biswas (1992) who reported that fodder yield increased with increasing plant density. Park *et al.*,(1989) reported that increasing plant density linearly increased stover yield. Scarsbrook and Doss (1973) reported that stover yields of hybrid maize usually increased with each increment of plant population up to 80,000 plants/ha.

4.1.3.11. Biological yield

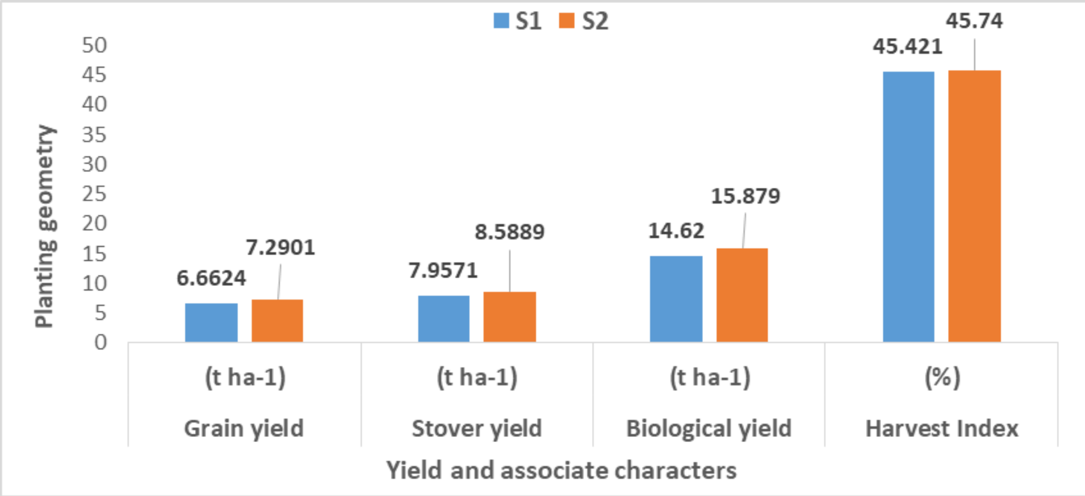
Biological yield is a major contributor to total output of any crop and dependent upon crop management, type of variety and various other factors.

Biological yield also varied significantly by the different varieties, plant spacing and their combination (Figure 4.1.10, 4.1.11 and 4.1.12).

Among the varieties V_3 significantly produced highest biological yield (18.059 t ha^{-1}). V_4 produced significantly the minimum biological yields (10.982 t ha^{-1}) (Figure 4.1.10). Likewise, V_2 (16.382 t ha^{-1}) had significantly more biological yield producer than that of V_2 (15.575 t ha^{-1}).

Between two spacing treatments, S_2 showed significantly the maximum biological yield (15.879 t ha^{-1}) and S_1 was significantly the lowest biological yield (14.620 t ha^{-1}) producer (Figure 4.1.11).

However, for the combination of varieties and plant spacing, it was observed that the maximum biological yield (18.853 t ha^{-1}) was significantly produced by V_3S_2 and the minimum was revealed with V_4S_1 treatment (10.670 t ha^{-1}) which was statistically similar to V_4S_2 (11.29 t ha^{-1}) (Figure 4.1.12). Abuzar *et al.*, (2011) observed that optimum planting space acquired optimum number of plants (60000 plants ha^{-1}), which produced the maximum biomass yield, grain yield and ultimately increased biological yield. Akbar *et al.*, (2002) reported that biological yield was significantly increased at 180000 plants ha-^{1}. These results are consistent with the findings of Plensicar & Kustori (2005) who reported that maximum biological yield was found at higher planting density.



Here, S_1 = 70 cm x 25 cm, S_2 = 60 cm x 25 cm

Figure 4.1.11. Effect of planting geometry on grain yield; stover yield; biological yield and harvest index of white maize

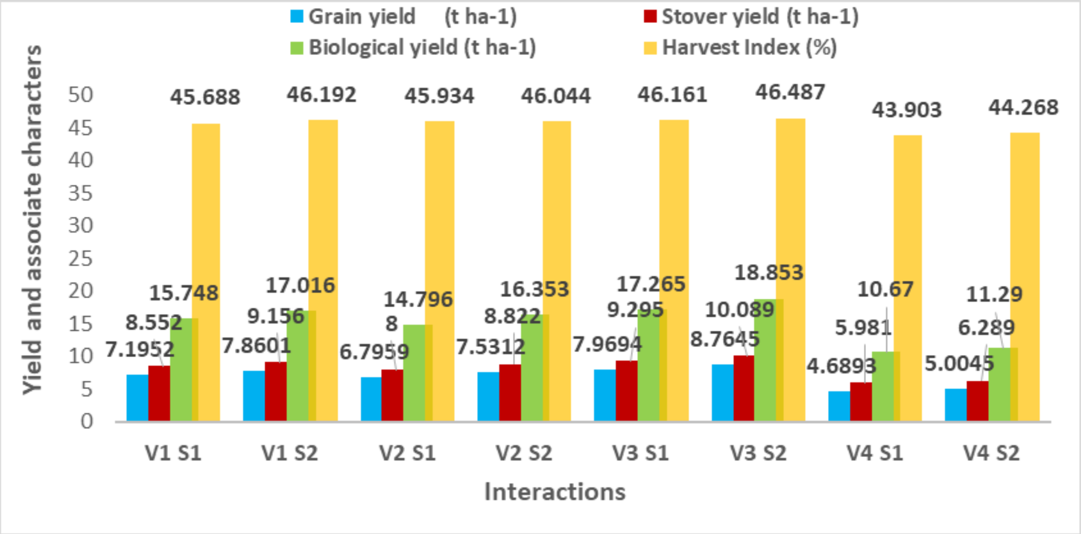
4.1.3.12. Harvest Index

Harvest index is the partitioning of dry matter by plant among biological and economic yield. Plant spacing did not affect significantly but varieties and their interactions had a significant effect on harvest index (Figure 4.1.10, 4.1.11 and 4.1.12).

Harvest index was varied significantly due to varieties, V_3 showed the highest harvest index (46.324 %), which was statistically similar to V_1 and V_2 (45.940 % and 45.989 %) while V_4 variety was the lowest (44.085 %) harvest indexer (Figure 4.1.10).

Plant spacing did not affect significantly on harvest index. Although having non–significant effect, S_2 had the highest harvest indexer (45.748 %), and S_1 showed the lowest harvest indexer (45.421 %) (Figure 4.1.11).

For the combinations of variety and plant spacing, it was observed that V_3S_2 treatment showed the highest harvest index (46.487 %), which was statistically similar to V_1S_2 , V_2S_1, V_2S_2 and V_3S_1 (46.192 %, 45.934 %, 46.044% and 46.161 % respectively).The minimum harvest index was revealed with V_4S_1 treatment (43.903%), which was statistically similar to V_4S_2 (44.268 %) (Figure 4.1.12). Ahmad & Khan (2002) reported that increase in plant density significantly increased harvest index. The reasons for such results could be better utilization of available nutrients by maize plants in highest plant population as compared to lowest plant population. In lowest plant population, weeds also compete with crop for nutrients. Similarly grain become a dominant sink at their maturity stage and the entire photo assimilate deposited in the grains as compared to other parts of the plant. Highest plant population produced more grain and thus resulted in maximum harvest index.



Here, V_1 = Changnuo-1, V_2 = Q- Xiangnuo-1, V_3 = Changnuo-6, V_4 = Yangnuo-7
S_1 = 70 cm x 25 cm and S_2 = 60 cm x 25 cm

Figure 4.1.12. Interaction effects of variety and planting geometry on grain yield, stover yield; biological yield and harvest index of white maize

4.2. Experiment 2: Growth and yield assessment of different varieties of Indian white maize under varying planting geometry at SAU (rabi 2015-16)

4.2.1 Growth parameters

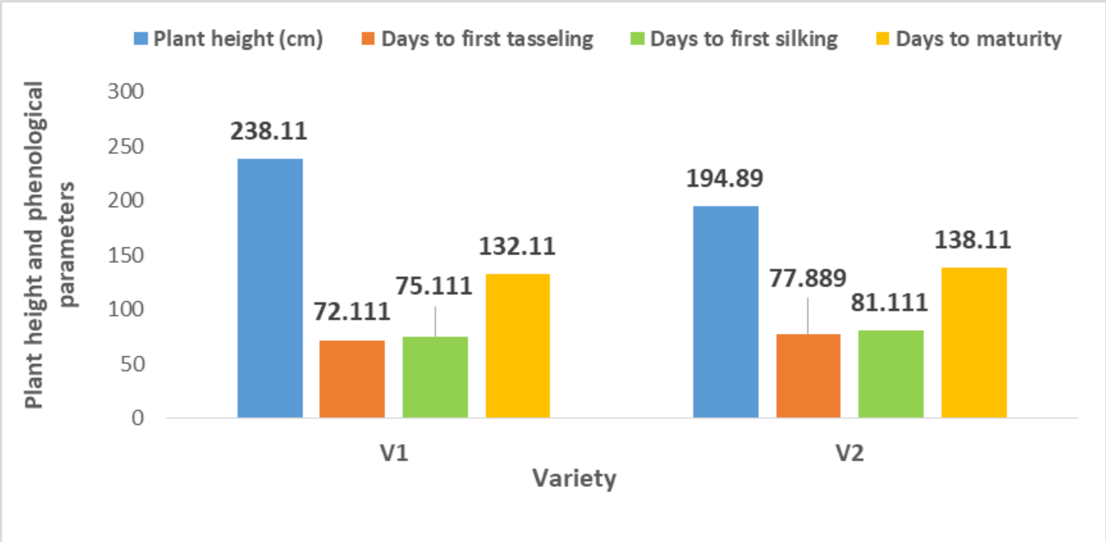
4.2.1.1 Plant height

Plant height is an important component which helps to determine the growth attained during the growth period. Various treatments such variety, plant spacing and their combination were used to observe their effects on plant height of white maize and the result was represented in figure 4.2.1, 4.2.2 and 4.2.3.

It was revealed from the mentioned figure that plant height was significantly influenced by variety. V_1 showed the longest plants (238.11 cm) followed by V_2 (194.89 cm), which was also the shortest.

Plant height was significantly influenced by plant spacing. Among the spacing treatments S_3 had significantly the longest plants (222.58 cm), which was statistically similar to S_2 (217.46 cm). Whereas S_1 had significantly the shortest plants (209.46 cm).

Their combination was significant effect on plant height. Among the observed treatments V_1S_3 showed significantly the tallest plant (244.50 cm) which was statistically similar to V_1S_2 (238.58 cm). However V_2S_1 had significantly the smallest plants (188.67cm) which was statistically similar to V_2S_2 (195.33 cm). Likewise, V_1S_1 had significantly longer plants (230.25 cm) than that of V_2S_3 (200.67cm).Similar result was also reported by Bahadur *et.al* (1999) where they noticed that higher plant height were recorded in higher spacing and lower plant height was found in lower plant spacing in maize. Plant height affected due to crowding effect of the plant and higher intra specific competition for resources. This trend explains that as the number of plants increased in a given area the competition among the plants for nutrients uptake and sunlight interception also increased (Sangakkara *et. al*, 2004)



Here, V_1 = PSC- 121, V_2 = KS -510

Figure 4.2.1. Effect of variety on plant height, days to first tasseling, days to first silking and days to maturity

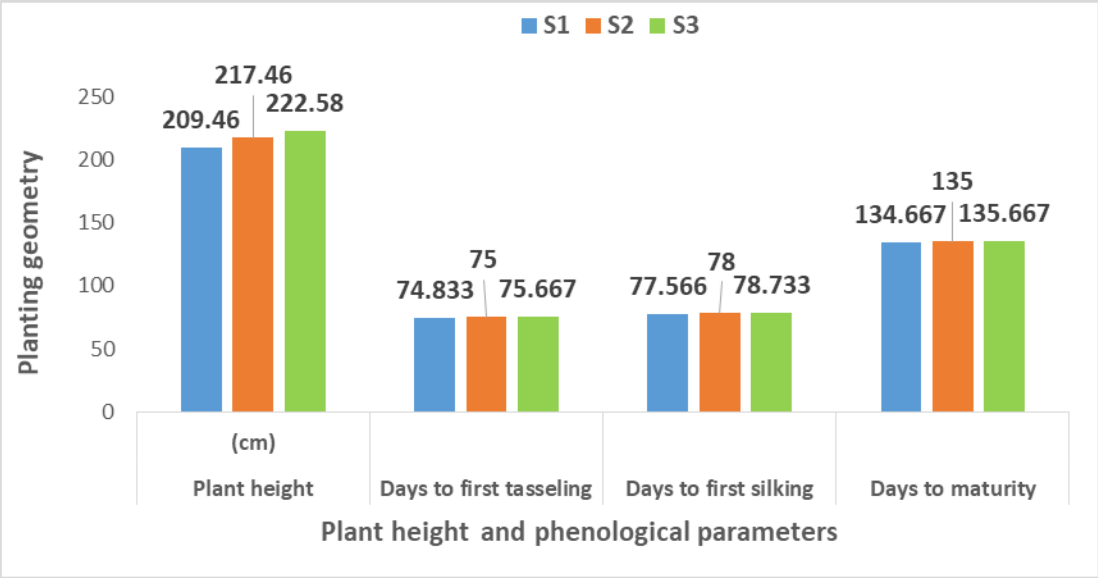
4.2.2. Phenological parameters

4.2.2.1. Days to tasseling

Days to tasseling was influenced by the variety, and their combinations but not plant spacing treatments, the result was represented in figure 4.2.1, 4.2.2 and 4.2.3.Variety V_2 took significantly maximum days for tasseling. (77.889 days). Whereas V_1 took significantly the lowest days for tasseling (72.111 days) (Figure 4.2. 1).

Days to tasseling was non-significantly influenced by different plant spacing. Among the plant spacing treatments, S_3 showed numerically highest day required for tasseling (75.167 days).While S_1 showed the lowest day required for tasseling (74.833 days) (Figure 4.2.2).

Among the combination treatments, V_2S_3 showed the significantly highest day required (78.000 days) for tasseling which was statistically similar to V_2S_2 and V_2S_1 (78.000 days and 78.000 days respectively). On the other hand, V_1S_1 showed significantly the lowest (72.000 days) day required for tasseling which was statistically similar to V_1S_2 V_1S_3 (72.000 days and 72.000 days respectively) (Figure 4.2.3). Gozubenli (2004) reported that the effect of inter and intra-row spacing did not significantly affect on tasseling and maturity period of maize. Similarly, Park *et al.*, (1989) reported that plant density did not affect days to tasseling and maturity.



Here, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm × 25 cm

Figure 4.2.2 Effect of planting geometry on plant height, days to first tasseling, days to first silking and days to maturity

4.2.2.2. Days to silking

Days to silking was influenced by the variety, and their combinations but not plant spacing treatments, the result was represented in figure 4.2.1, 4.2.2 and 4.2.3.Variety V_2 took significantly maximum days for silking. (81.111 days). Whereas V_1 took significantly the lowest days for tasseling (75.111 days) (Figure 4.2. 1).

Days to silking was non-significantly influenced by different plant spacing. Among the plant spacing treatments, S_3 showed numerically highest day required for silking (78.333 days).While S_1 showed the lowest day required for silking (78.000 days) (Figure 4.2.2).

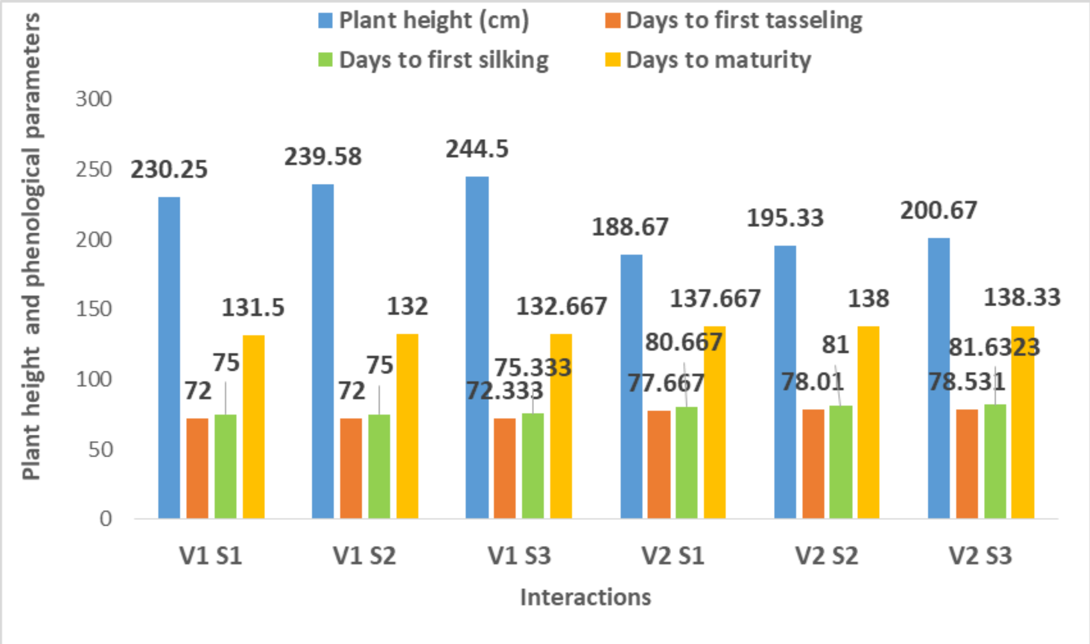
Among the combination treatments, V_2S_3 showed the significantly highest day required (81.333 days) for silking which was statistically similar to V_2S_2 and V_2S_1 (81.000 days and 81.000 days respectively). On the other hand, V_1S_1 showed significantly the lowest (75.333 days) day required for silking which was statistically similar to V_1S_2 V_1S_3 (72.000 days and 72.000 days respectively) (Figure 4.2.3).

4.2.2.3. Days to maturity

Days to maturity was influenced by the variety but not plant spacing treatments and their combinations, the result has been represented in figure 4.2.1, 4.2.2 and 4.2.3. For individual treatmentsV$_2$ took maximum days to be matured (138.11 days). On the other hand, V_1 took the lowest days to be matured (132.11 days).) (Figure 4.2. 1).

Days to maturity was non-significantly influenced by different plant spacing. Among the plant spacing treatments, S_3 showed numerically highest day required for matured (135.333 days).While S_1 showed the lowest day required for matured (135.000 days) (Figure 4.2.2).

Among the combination treatments, V_1S_3 took the significantly highest days (138.33 days) to be matured. Whereas V_2S_1 took the lowest days to be matured (132.00 days) (Figure 4.2.3). This result are in line with the findings of Dawadi and Sah (2012) and Ullah *et al* (2016), where they reported that, days to maturity is a non-significant matter in respect of plant spacing.



Here, V_1 = PSC -121, V_2 = KS -510, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm;

S_3 = 70 cm × 25 cm

Figure 4.2.3. Interaction effects of variety and planting geometry on plant height, days to first tasseling, days to first silking and days to maturity

4.2.3. Yield contributing characters and yield

4.2.3.1. Cob length

Cob length was significantly affected by the varieties, spacing and their combinations (Figure 4.2.4, 4.2.5 and 4.2.6). Significantly maximum cob length (15.456 cm) was achieved with variety V_1 and the minimum cob length (13.974 cm) was significantly achieved with V_2 variety (Figure 4.2.4). These results are in line with the findings of Konuskan (2000) and Gozubenli *et al.*(2001) who reported that variations in ear characteristics of maize depend upon genotype and environmental conditions.

Cob length was increased with increasing plant spacing (Figure 4.2.5). Among the various treatments, S_3 (15.375 cm) showed significantly the longest cob length, which was statistically similar to S_2 (14.892 cm)**,** while S_1 showed significantly the shortest **(**13.878 cm) cob length. (Figure 4.2.5).

The data showed that the cob length decreased as the plant population increased. These results are in line with the findings of Karim *et al.*(1983), Kamel *et al.*(1983) and Akcin et al. (1993) who concluded that the cob length decreased linearly with increase in plant population. These results indicate that there is a positive relationship between plant spacing and cob length of maize, probably due to variable plant competition.

Moreover, for the combination of variety and plant spacings it was observed that V_1S_3 showed significantly the longest cob length (16.250 cm), which was statistically similar to V_1S_2(15.860 cm). Among the other treatments V_2S_1 showed significantly the shortest cob length (13.500 cm). Likewise V_2S_3 showed significantly moderate cob length (14.500 cm) which was statistically similar to V_1S_2 (13.923 cm). (Figure 4.2.6).

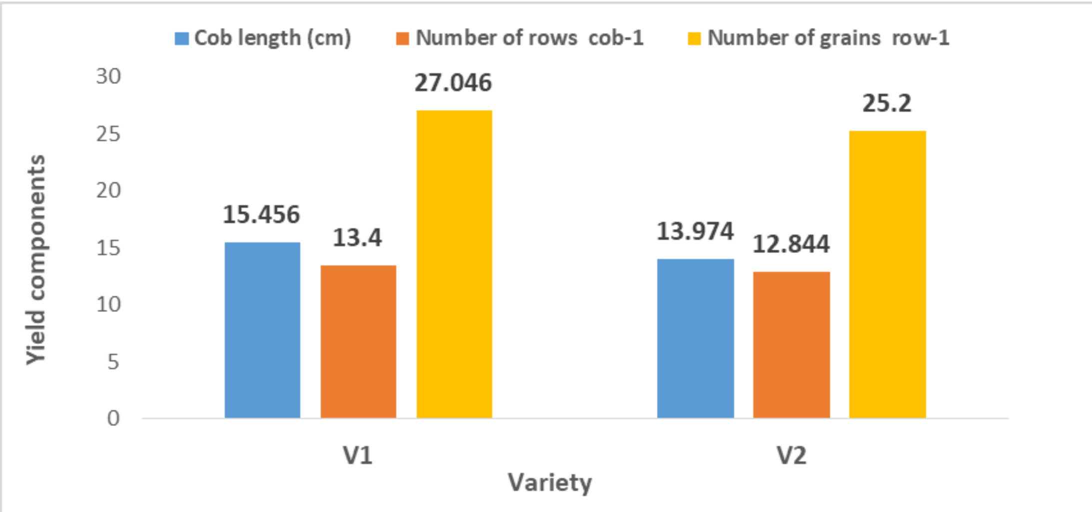
4.2.3.2. Number of rows cob^{-1}

It was found that number of rows cob^{-1} was affected by the treatments of varieties, spacing and their combinations (Figure 4.2.4, 4.2.5 and 4.2.6).
V_1 was produced significantly the maximum number of rows cob^{-1} (13.400) while V_2 was produced significantly the lowest number of rows cob (12.844).

Among the spacings, S_3 showed significantly the highest number of rows cob^{-1}(13.350), which was statistically alike with S_2 (13.067).while S_1 produced significantly the lowest number of rows per cob (12.950).

However, for the combination of variety and spacing it was found that V_1S_3 was achieved significantly the highest grain rows cob^{-1} (13.767) which was statistically similar to V_1S_2 (13.250).Among the other treatments V_2S_1 showed significantly the lowest number of grains rows cob^{-1}(12.733) which was statistically similar to V_1S_1, V_2S_3 and V_2S_1(13.167,12.967 and 12.867 respectively). Hashemi *et al.*(2005) reported a linear decline in number of kernel rows/ear with increasing plant density. The high barrenness (%) at high densities was due to the absence of the usual sink for the assimilate supply and limiting optimum conversion of light energy to grain in maize grown at high plant densities which inhibited the plants to produce viable ears.

Ritchie and Alagarswamy (2003) reported that barrenness occurred more frequently when plant densities exceed 10 plants/m2



Here, V_1 = PSC-121, V_2 = KS-510

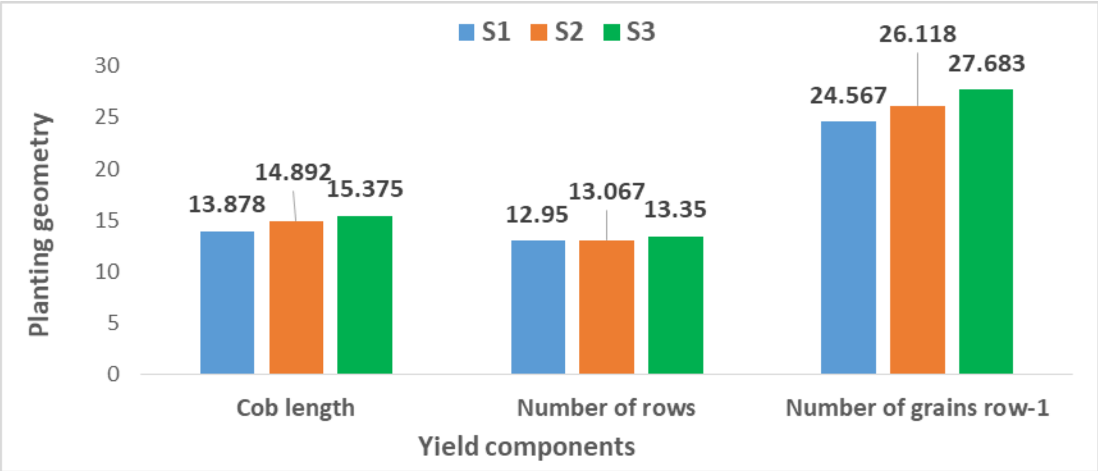
Figure 4.2.4. Effect of variety on cob length; number of rows per cob; number of grains per rows and total number of grains per cob

4.2.3.3. Number of grains row^{-1}

It was found that number of grains per row was affected by the varieties, spacing and their combinations (Figure 4.2.4, 4.2.5 and 4.2.6).V_1 was produced significantly the maximum number of grains per row (27.06) while V_2 was produced significantly the minimum number of grains per row (25.200).

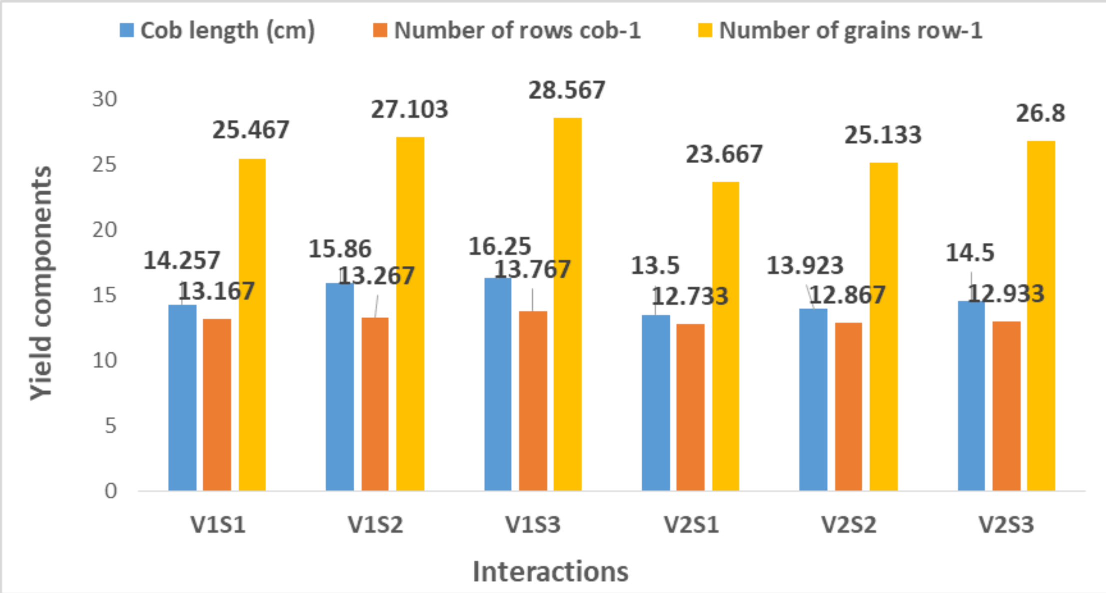
Among the spacings S_3 showed significantly the highest number of grains per row (27.683), which was statistically alike with S_2 (26.118).while S_1 produced significantly the lowest number of grains per row (24.567).

However, for the combination of variety and spacing it was found that V_1S_3 was achieved significantly the highest grains per row (28.567) which was statistically similar to V_1S_2 and V_2S_3 (27.103 and 26.800 respectively). Among the other treatments V_2S_1 showed significantly the lowest number of grains per row (23.667) Likewise V_1S_1 showed significantly moderate grains per row (25.467) which was statistically similar to V_2S_2 (25.133). Similar results have been reported by Seyed Sharifi *et al*. (2007) and Zhang *et al*. (2006), who reported that the number of grains/row of corn had significantly affected by maize hybrids.



Here, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm × 25 cm

Figure 4.2.5. Effect of planting geometry on cob length (cm); number of rows per cob; number of grains per row



Here, V_1 = PSC-121, V_2 = KS-510, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm × 25 cm

Figure-4.2.6. Interaction effect of variety and planting geometry on cob length, number of rows cob,$^{-1}$ number of grains row^{-1}

4.2.3.4. Number of grains cob^{-1}

Number of grains cob^{-1} was significantly influenced by varieties, spacing and their combinations (Figure 4.2.7, 4.2.8 and 4.2.9). The maximum number of grains cob^{-1} (370.75) was significantly reported from the treatments having V_1 while the minimum number of grains cob^{-1} (354.18) was significantly reported from the variety V_2. (350.08). (Figure 4.2.7).

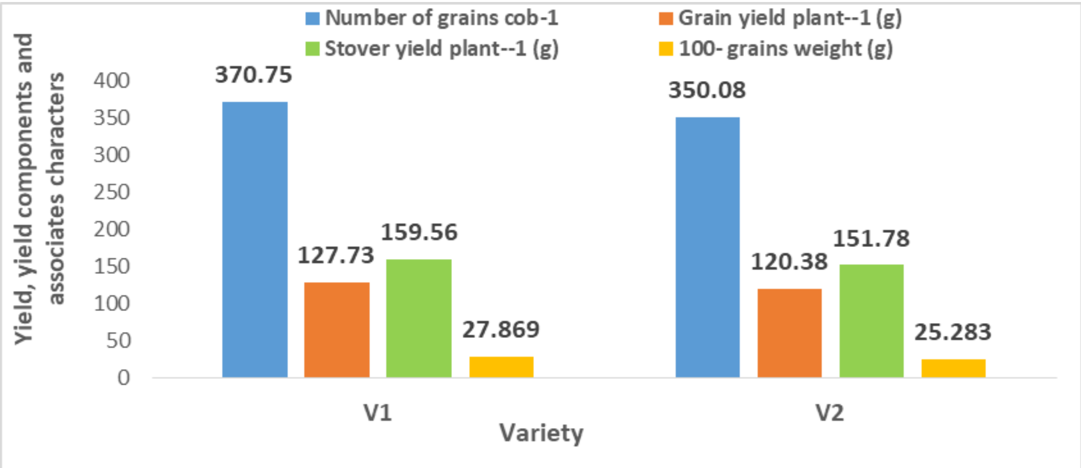
However, in white maize spacing treatments showed the significant effects on number of grains per cob. Number of grains cob^{-1}was increased with the increasing spacing levels. Among the various spacing treatments, S_3 produced significantly highest number of grains cob^{-1}(376.31), which was statistically similar to S_2 (361.37) and the lowest number of grains cob^{-1} was produced significantly from S_1 (294.47) treatment. Moreover, the combination of variety and spacing revealed that V_1S_3 showed significantly the highest number of grains cob^{-1} (386.33) than the other combinations, which were statistically similar to V_1S_2 (370.36), V_2S_3 (366.29) and V_1S_1 (355.57). V_2S_1 showed significantly the minimum number of grains cob^{-1} (331.57).This variation might be due to the fact that widely spaced plants encountered less intra plant competition than closely spaced plants and thus exhibited better growth that contributed to more number of kernels per ear.In agreement with this result, Eskandarnejada *et al.* (2013) reported that inter-row spacing of 30 cm produced more number of kernels per ear than that 20 cm plant spacing. Moreover, Mukhtar *et al.* (2012) reported that wider spacing (17.50 cm) produced higher number of kernels per ear (717.00) while narrower spacing (10 cm) gave lower number of grains ((540.30).. Plant spacing of 30 cm produced more number of kernels per ear (416.30) than that of 20 cm plant spacing (410.20) (Mahmood *et al.,* 2001). Similar results have also been reported by Gambin *et al*.,(2006), Malaviarachchi *et al.* (2007) and Arif *et al*. (2012) who reported that number of kernels per ear decreased with increase in plant density of maize. The lowest number of kernels/ear at high plant density may be due to high competition for the resources such as light, moisture and fertilizer**.** The results are as the same with obtained by Seyed Sharifi and Taghizadeh (2009) and Sangoi (2000).

4.2.3.5. 100-grain weight

The variety, plant spacings and their combinations influenced of 100-grain weight in white maize (Figure 4.2.7, 4.2.8 and 4.2.9). The highest 100-grain weight was significantly found in V_1 (27.869 g) variety and the lowest was significantly found in V_2 (25.283 g) variety (Figure 4.2.7). These results are in conformity with the findings of Rogers and Lomman (1988), Konuskan (2000) and Gozubenli *et al.* (2001) who stated that there were varietal differences in 1000-grain weight, which increased with increasing plant spacing.

Plant spacings treatments showed the significant effects on 100- grain weight. The highest 100-grain weight was significantly found in S_3 (28.043 g) spacing which was statistically similar to S_2 (26.647) spacing and the lowest 100-grain weight was significantly recorded in S_1 (25.038 g) spacing (Figure 4.2.8).

For their combinations, the highest 100-grain weight was significantly counted from V_1S_3 (29.313 g), which was statistically similar to V_1S_2 (27.960 g), while the minimum 100-grain weight was significantly observed from V_2S_1 treatment (23.410 g) (Figure 4.2.9). Likewise, V_2S_2 showed significantly moderate 100-grain weight (26.773 g) which was statistically similar to V_1S_1 (26.333 g) but higher than that of V_2S_2 (25.333 g) (Figure 4.2.9). Results showed that the lowest plant population density resulted in the heaviest grains. Akcin *et al.* (1993) also reported that 1000-grain weight increased with decreasing plant population density in maize. Low grain weight in high Plant population density (PPD) might be due to availability of less photo synthates for grain development because of high interspecific competition which could have resulted in low rate of photosynthesis and high rate of respiration as a result of enhanced mutual shading. Reduction in 1000-grain weight due to high plant population density has also been reported by Mannino *et al.*, 1990, Dong and Nian (1995), Cox (1996) and Tyagi *et al.* (1998). With increased inter and intra-row spacing, thousand kernel weight decreased. This decrease might be because of assimilates partitioning between higher numbers of kernels used in connection with the decreased inter plant competition that lead to increased plant capacity, for utilizing the environmental inputs in building great amount of metabolites to be used in developing new tissues and increasing its yield components. In addition, wider spaced plants, that improved the supply of assimilates to be stored in the kernel hence, the weight of thousand kernel increased. The present result was in line with that of Mahmood *et al.* (2001) who reported that plant spacing of 30 cm produced significantly higher 1000 kernels weight than 10 cm plant spacing. According to Zamir *et al.* (2011), the highest 1000 kernels weight (253 g) was produced at 30 cm intra-row spacing followed by 25 cm intra-row spacing (249 g) and the lowest 1000 kernels weight (223 g) was produced at intra-row spacing of 15 cm The result was in agreement with Ogunlela *et al.* (2005), Arif *et al.* (2010) and Mukhtar *et al.* (2012) who reported that 1000 kernels weight decreased with increase in plant density.



Here, V_1= PSC-121, V_2 = KS-510

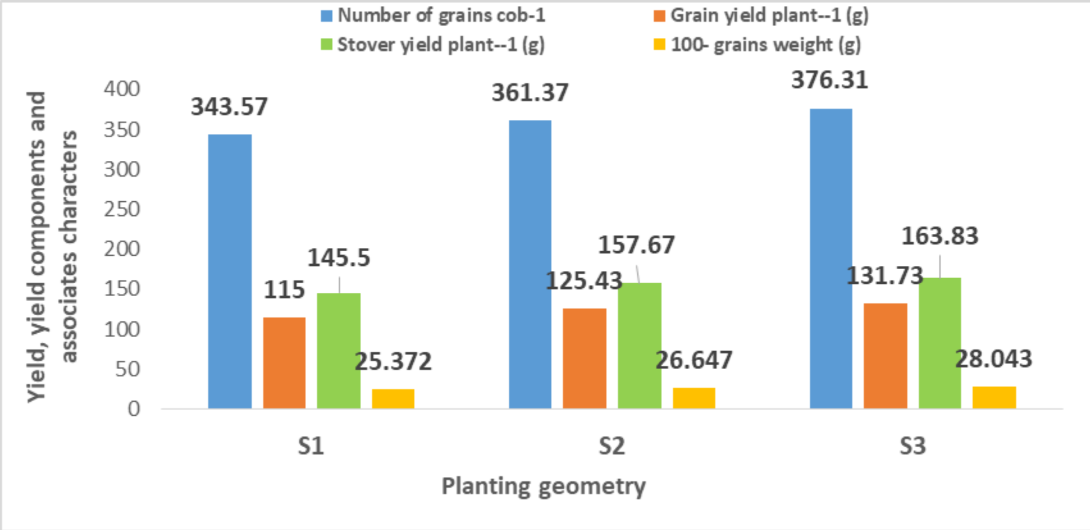
Figure 1.2.7. Effect of variety on grain yield per plant, Stover yield plant^{-1}, 100-grain weight of grains

4.2.3.6. Grain yield plant^{-1}

The variety, plant spacings and their combination significantly influenced the grain yield plant^{-1} (g) in white maize (Figure 4.2.7, 4.2.8 and 4.2.9). Maximum grain yield plant^{-1} (127.73 g) was significantly achieved with the variety V_1 and the minimum grain yield plant^{-1} (120.38 g) was significantly achieved with the variety V_2.

For plant spacings treatments the highest grain yield plant^{-1} (131.73 g) was significantly obtained from S_3 spacing which was statistically similar to S_2 (125.45 g) spacing and significantly the minimum per plant grain yielder was S_1 (115.00 g).

For their combinations, maximum grain yield plant^{-1} (132.40 g) was significantly counted from $V_1S_{3,}$ which was statistically similar to V_1S_2 (128.53 g) and V_2S_3 (128.80 g) while the minimum grain yield plant^{-1} was significantly observed for V_2S_1 (110.00 g) treatment combinations. Likewise, V_2S_2 showed significantly more grain yield plant^{-1} (122.33 g) than that of V_1S_1 (120.00 g). Increase in grain yield per plant at wider spacing is not surprising because lower plant density exerts lesser interplant competition for space as well as growth factors. The result of this study was in agreement with Ahmad *et al.* (2006) who reported that increasing plant population reduced yield of individual plants but increased yield per unit area of maize. Similarly, Gozubenli *et al.* (2004) reported that grain yield per plant increased with the increase of inter and intra-row spacing. This result was also in line with Eskandarnejada *et al.* (2013) who obtained decreased grain yield per plant under narrower inter and intra- row spacing on maize.Our findings were the same with Bangarwa *et al* (1988), Farnham (2001) and Mobasser *et al.* (2007). Widdicombe and Thelen (2002) reported that plant density had a significant effect on grain yield and the highest plant density level evaluated resulting in the highest grain yield. Variation in grain weight per ear differed significantly between the two hybrids with higher being in PSC 121 (Akbar *et al.*, 2016)



Here, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm × 25 cm

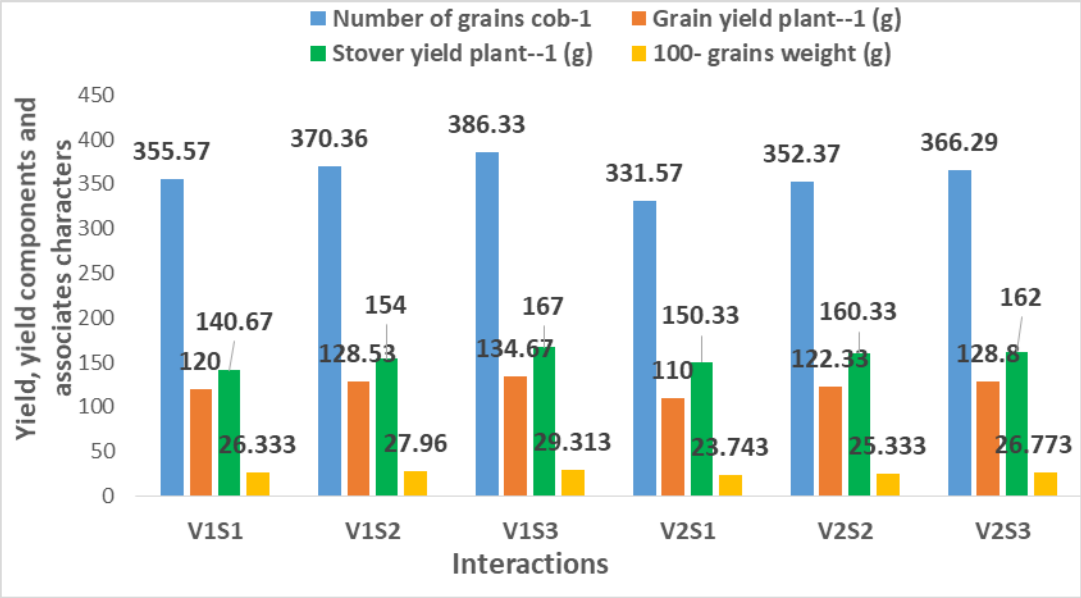
Figure 1.2.8. Effect of planting geometry on grain yield per plant, Stover yield plant^{-1} and 100-grains weight

4.2.3.7. Stover yield plant^{-1}

The variety, plant spacings and their combinations remarkably influenced the stover yield plant^{-1} (g) in white maize (Figure 4.2.7, 4.2.8 and 4.2.9). Maximum stover yield plant^{-1} (159.78 g) was significantly produced in V_1 variety and the minimum stover yield plant^{-1} (151.56 g) was significantly produced in V_2 variety.

For plant spacings treatments maximum stover yield plant^{-1} (163.83 g) was significantly obtained from S_3 spacing which was statistically similar to S_2 (157.67 g) and the minimum stover yield plant^{-1} was significantly found from S_1 (145.50 g) spacing.

For their combinations, maximum stover yield plant^{-1}(167.67 g) was significantly counted from V_1S_3 which was statistically similar to V_2S_2 (161.33 g) and V_2S_3 (160.00 g) while the minimum stover yield plant^{-1} was observed from V_1S_1 (140.67 g). Likewise, V_1S_2 showed significantly more stover yield plant^{-1} (154.00 g) than that of V_2S_1 (150.33 g). The highest above ground dry biomass yields per plant at the widest inter and intra-row spacing might be due to high stem diameter and high leaf area because there is more availability of growth factors and better penetration of light at wider row spacing. In agreement with this study, Gozubenli *et al.* (2004) reported that above ground dry biomass yield per plant increased with the increase of inter and intra-row spacing. Similarly, Miko and Manga (2008) reported that above ground dry biomass per plant was significantly increased with decreased plant density of maize.



Here, V_1 = PSC- 121, V_2 = KS -510, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm × 25 cm

Figure-1.2.9. Interaction effects of variety and planting geometry on grain yield per plant, stover yield plant^{-1} and 100-grains weight of white maize

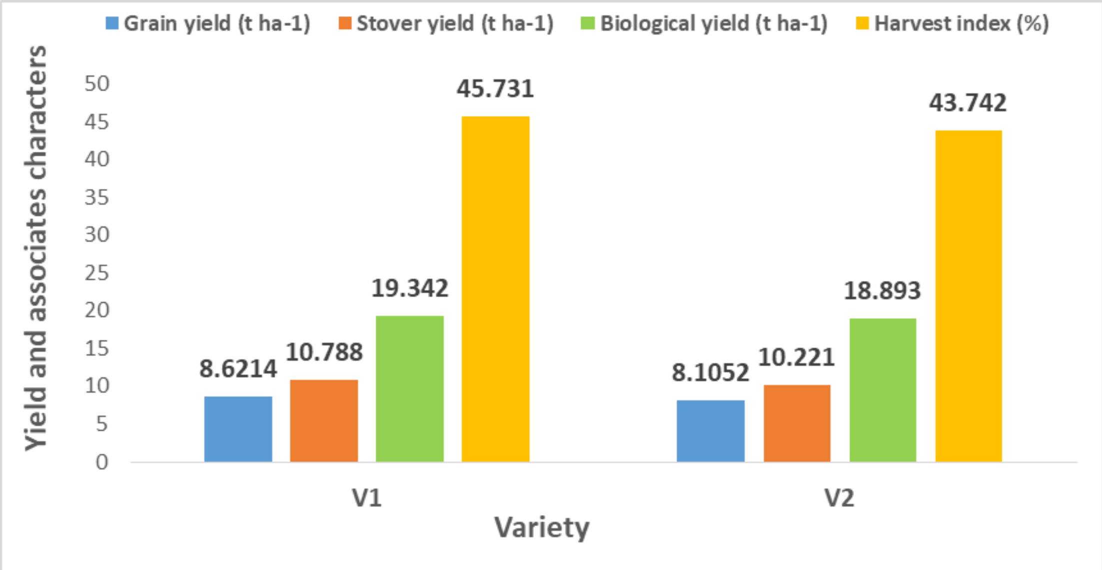
4.2.3.8. Grain yield

Grain yield is a function of integrated effects of genetic makeup of cultivars and growing conditions on the yield components of a crop. Grain yield is the end result of many complex morphological and physiological processes occurring during the growth and development of a crop. The growing conditions are changed by different plant spacings.

The variety, plant spacings and their combinations remarkably influenced the grain yield in white maize (Figure 4.2.7, 4.2.8 and 4.2.9). Maximum grain yield (8.62 t ha^{-1}) was achieved from V_1 variety and the minimum grain yield (8.10 t ha^{-1}) was achieved from V_2 variety. These differences in the grain yield of hybrids are due to the differences in their potential yields. The present results are in good agreement with the findings of Konuskan (2000), Gozubenli *et al.* (2001) and Farnham (2001).

For plant spacings treatments the highest grain yield (9.20 t ha^{-1}) was achieved from S_1 spacing and the minimum grain yield (7.52 t ha^{-1}) was recorded from S_1 spacing. Porter *et al.* (1997) reported inconsistent optimal plant density levels ranging from 86000 to 101270 plants ha^{-1} for corn grain yield across three Minnesota locations.

For their combinations, the highest grain yield was recorded from V_1S_1 (9.60 t ha-^{1}) and the minimum grain yield was observed from V_2S_3(7.36 t ha^{-1}) treatment combination. Eskandarnejada *et al.* (2013) reported that higher grain yield of maize (15.25 t ha^{-1}) was obtained at narrower (55 cm x 20 cm) spacing than at wider (75 cm x 30 cm) spacing which is 11.43 t ha^{-1}. Mukhtar *et al*. (2012) showed that higher grain yield of maize (8.370 t ha^{-1}) was obtained with 12.50 x 70 cm spacing while lower (6.646 t ha^{-1}) at 17.50 cm x 70 cm spacing. According to result at higher plant density, overall grain yield of maize increased due to increasing number of ears per hectare. This might be due to the fact that high population ensured early canopy coverage and maximizes light interception greater crop growth rate and crop biomass resulting increased yield in maize. In agreement with this result, Maqsood *et al.* (2002) reported that there was higher grain yield of maize (6.6 t ha^{-1}) at narrower spacing of 60 cm x 15 cm against the lower grain yield (3.28 t ha-1 ha^{-1}) at wider spacing of 60 cm x 30 cm. Farnham (2001) reported that maize grain yield increased from 10.1 to 11.2 t ha^{-1} as plant density increased from 59,000 to 89,000 plant ha^{-1}. According to Shrestha (2013), grain yield (5.11 t ha^{-1}) obtained under plant density of 66666 plants/ha (60 × 25 cm spacing) was significantly higher than that of 55555 plants/ha (60 × 30 cm spacing) but that was at par with yield of 83333 plants/ha (60 × 20 cm spacing). A similar trend in yield across planting density has been observed by Malaviarachchi *et al.* (2007) who reported that grain yield increased with increasing maize plant density. Yousaf *et al*. (2007) reported that the highest grain yield produced at narrow spacing of 45 cm x 25 cm (88,888 plants ha-1) and the lowest grain yield was recorded for 75 cm x 30 cm spacing (44,4,44 plants ha^{-1}). Similar results have been reported by, Fulton (1990), Naraqanaswamy *et al.*(1994), Baron *et a*l.(2001) and Arif *et al*. (2010) on maize spacing trial. Grain yield was significantly influenced by plant density. The positive relationship between grown yield and plant density was due to the high number of ears harvested and high number of plants per unit area (Dawadi and Sah1, 2012)..



Here, V_1= PSC-121, V_2 = KS-510

Figure 4.2.10. Effect of variety on grain yield; stover yield; biological yield and harvest index

4.2.3.9.10. Stover yield

It was observed that stover yield indicated significant effects at variety, plant spacings and their combinations in white maize (Figure 4.2.10, 4.2.11 and 4.2.12). The highest stover yield (10.788 t ha^{-1}) was significantly observed in V_1 followed by V_2 (10.221 t ha^{-1}) variety which was significantly the lowest stover yielder.

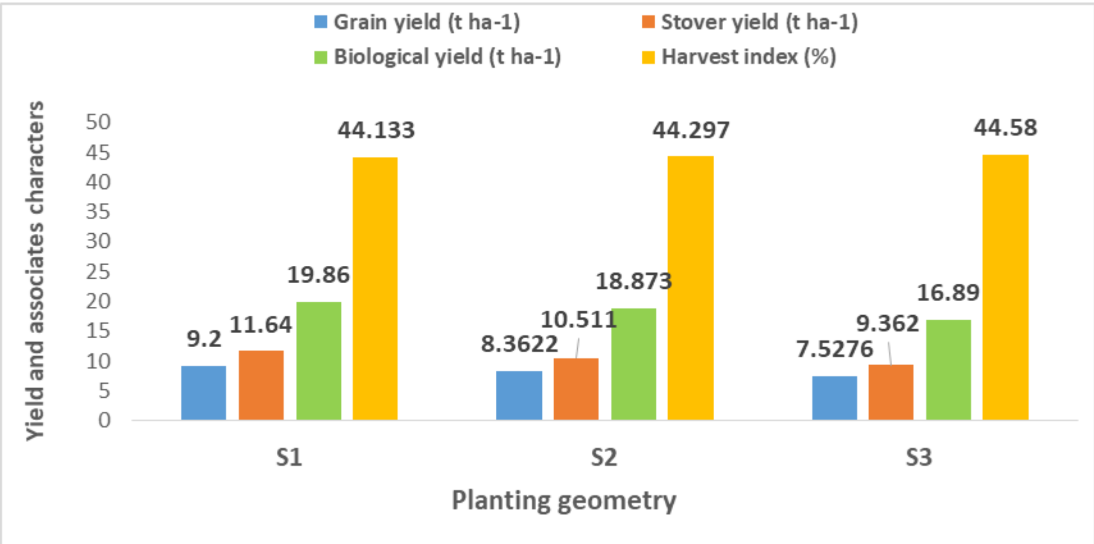
In the plant spacings treatments, S_1 treatment was significantly the highest stover yielder (11.640 t ha^{-1}) followed by S_2 (10.511 t ha^{-1}) which was significantly the medium stover yielder and S_3 (9.362 t ha^{-1}) treatment was significantly the lowest stover yielder.

However, for the combinations of variety and plant spacing it was observed that the maximum stover yield was significantly produced by V_2S_1 (12.027 t ha^{-1}), which was statistically similar to V_1S_1 (11.253 t ha^{-1}). The lowest stover yield was significantly revealed with V_1S_3 (9.143 t ha^{-1}). Likewise, V_2S_2 (10.756 t ha^{-1}) produced significantly medium stover yield than that of V_2S_3 (9.581 t ha^{-1}) and V_1S_2 (10.267 t ha^{-1}).

It is clear from the data that the straw yield was progressively decreased with each decrease in plant population. The variability in straw yield per hectare is the result of variation in the crop stand per unit area. These results are in line with the findings of Knapp and Reid (1981), Anjum (1987) and Tetio-Kagho and Gardner (1988 b).

This might be due to higher plant population recorded at narrow inter and intra-row spacing and hence greater dry matter production.

In agreement with this result Mahmood *et al*. (2001) showed that total biomass yields of maize were significantly higher in the narrow intra-row spacing (20 cm) than in wider intra-row spacing (30 cm) due to more number of taller plants per unit area and better interception of solar radiation. According to Yousaf *et al.* (2007), maize planted at 45 cm row spacing produced 14% and 34 % higher total above ground dry biomass than that of 60 and 75 cm row spaced sown crop, respectively. Plant spacing of 15 cm produced 42% and 22% higher above ground dry biomass than that recorded for 30 cm and 22.5 cm plant spacing, respectively. Similarly, Gobeze *et al*. (2012) reported that the highest biomass was recorded at row spacing of 25 cm with plant density of 10 plants m2 and followed by the same row spacing with plant density of 12.5 plants m2 while the lowest biomass was observed at row spacing of 90 cm with plant density of 5 plants m2.Dawadi and Sah, (2012) also observed the similar result. They stated that the increase of stover yield with the increase of plant densities may be due to increasing numbers of plants and dry matter yield. Scarsbrook and Doss (1973) reported that stover yields of hybrid maize usually increased with each increment of plant population up to 80,000 plants/ha.



Here, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm × 25 cm

Figure 4.2.11. Effect of planting geometry on grain yield; stover yield; biological yield and harvest index

4.2.3.10. Biological yield

Biological yield is a major contributor to total output of any crop and dependent upon crop management, type of variety and various other factors. Biological yield was increased significantly with the different varieties, plant spacings and their combinations (Figure 4.2.10, 4.2.11 and 4.2.12).

Two varieties showed non-significant effect on biological yield. Among the varieties V_1 produced highest biological yield (19.393 t ha^{-1}). V_2 produced the minimum biological yields (18.842 t ha^{-1}) (Figure 4.2.10).

Among various plant spacing treatments, S_1 showed significantly the maximum biological yield (19.860 t ha^{-1}) and S_2 (18.873 t ha^{-1}) produced significantly the moderate biological yield whereas S_3 revealed significantly the lowest biological yield (16.890 t ha^{-1}) (Figure 4.2.11).

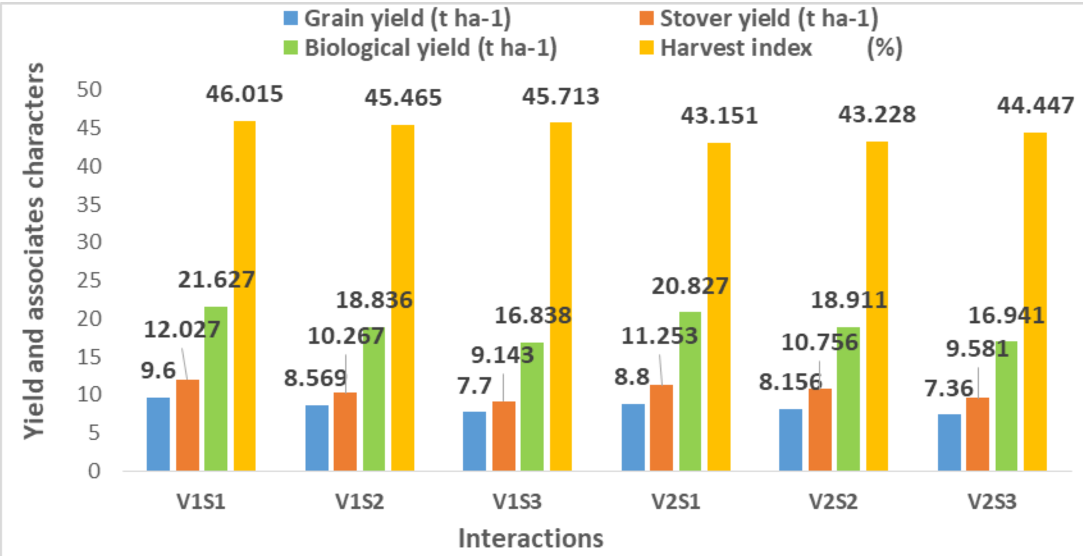
However, for their combinationsV_1S_1 (21.627 t ha^{-1}) showed significantly the highest biological yield, which was statistically identical to V_2S_1 (20.827 t ha^{-1}) .Treatments V_2S_2 produced significantly the moderate biological yield (18.911 t ha^{-1}) which was statistically at par to V_1S_2 (18.836 t ha^{-1}). Treatment V_2S_3 (16.941 t ha^{-1}) showed significantly the lowest biological yield which was statistically identical to V_1S_3 (16.838 t ha^{-1}) (Figure 4.2.12). Alike result was found by Tajul *et al*., (2013) who stated that Biological yield was increased progressively with the progressive increase in planting densities. This might be due to higher number of plants per unit area. The biological yield production was largely a function of photosynthetic surface, which was also favorably influenced. These results are also consistent with the findings of Plensicar & Kustori (2005) who reported that maximum biological yield was found at higher planting density.

4.2.3.11. Harvest index

Harvest index is the partitioning of dry matter by plant among biological and economic yield. Two varieties showed significant effect on harvest index (Figure 4.2.10, 4.2.11 and 4.2.12). Among the treatments, V_1 showed significantly the highest harvest index (45.175 %), whereas V_2 showed significantly the lowest (43.742 %) harvest index (Figure 4.2.10).

The plant spacing treatments showed non-significant effect on harvest index. S_3 showed numerically the highest harvest index (44.410 %), which was statistically similar to S_2 (44.287 %), and S_1 showed numerically the lowest harvest index (44.133 %) (Figure 4.2.11).

The combinations of variety and plant spacing treatments, it was observed that V_1S_1 (46.015 %) showed significantly the maximum harvest index, which was statistically similar to V_1S_3 (45.713%) and V_1S_2 (45.465 %). Likewise. V_2S_3 (44.447 %) had more harvest indexer than that of V_2 S_2 (43.228 %) and V_2S_1 (43.151 %) harvest index (Figure 4.2.12). The reasons for such results could be better utilization of available nutrients by maize plants in highest plant population as compared to lowest plant population. In lowest plant population, weeds also compete with crop for nutrients. Similarly grain become a dominant sink at their maturity stage and the entire photo assimilate deposited in the grains as compared to other parts of the plant. Highest plant population produced more grain and thus resulted in maximum harvest index. Ahmad & Khan (2002) reported that increase in plant density significantly increased harvest index. In agreement with this result Eskandarnejada *et al.* (2013) showed that intermediate inter-row spacing gave significantly higher harvest index of maize than both lower and higher inter-row spacing. Similarly, Yousaf *et al*. (2007) reported that harvest index initially increased with increasing plant and row spacing but declined when plant density increased further. Tollenaar *et al*. (1997) also reported that maize grain yield declines when plant density is increased beyond an optimum, primarily because of the decline in harvest index (HI) and increased stem lodging.



Here, V_1 = PSC - 121, V_2 = KS - 510, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm × 25 cm

Figure-4.2.12. Interaction effects of variety and planting geometry on grain yield; stover yield; biological yield and harvest index

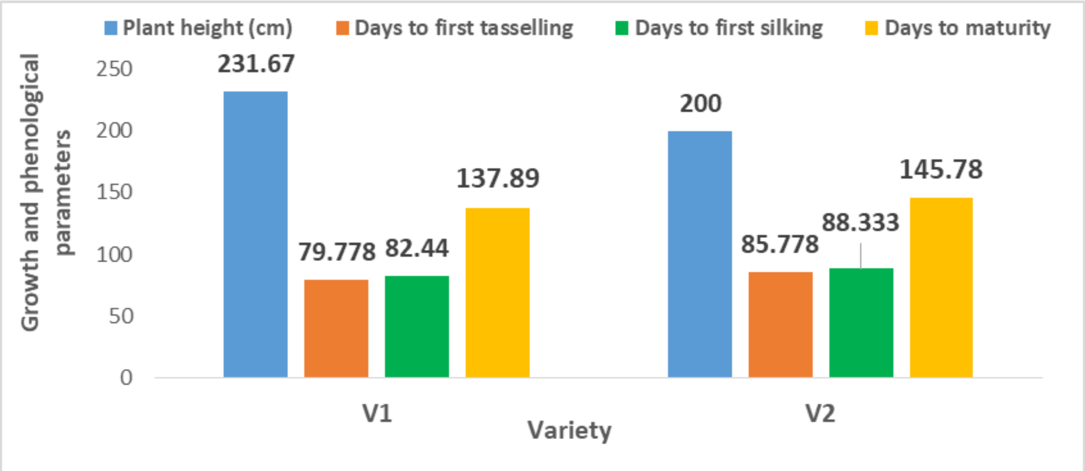
4.3. Experiment 3: Growth and yield assessment of different varieties of Indian white maize under varying planting geometry at Dhamrai Upazila, Dhaka (rabi 2015-16)

4.3.1. Plant height

Various treatments such varieties, plant spacing and their combination were used to observe their effects on plant height of white maize and the results was represent in figure 4.3.1, 4.3.2 and 4.3.3 respectively. It was revealed in the experiment that plant height was significantly influenced by varieties, plant spacing and their combinations. Between variety V_1 and V_2, V_1 was recorded to give taller plant (231.67 cm) as compared to that of V_2 having plant height of 200.00 cm. There was a statistically significant difference between the varieties.

For plant spacing treatments, the highest plant height was found at S_3 plant spacing (222.50 cm) followed by S_2 (217.00 cm). S_2 and S_3 were statistically identical. However, the shortest plants were recorded from S_1 (208.00) having a statistically significant relation with others two treatments.

For their various combinations, V_1S_3 showed significantly the tallest plant (237.33 cm) which was statistically similar with that of V_1S_2 (233.33), whereas V_2S_1 revealed significantly the smallest (191.67 cm) and it was statistically similar with V_2S_2 (200.67 cm). Likewise, V_1S_1 (224.33 cm) was recorded to have the significantly longer plants over V_2S_3 (207.67 cm).



Here, V_1 = PSC- 121, V_2 = KS - 510

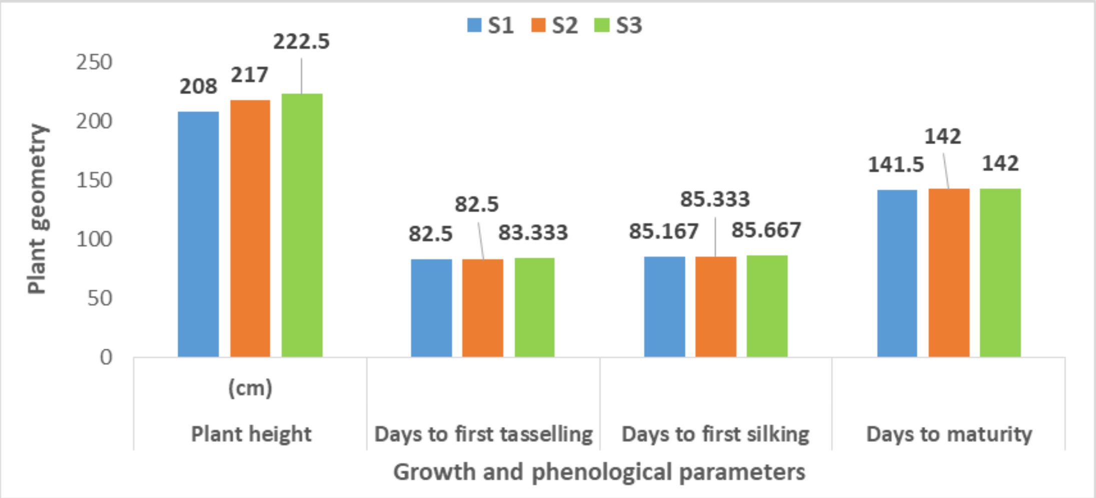
Figure 4.3.1. Effect of variety on plant height, days to first tasseling, days to first silking and days to maturity

4.3.2. Days to first tasseling

Two varieties were used to observe their effects on days to first tasseling of white maize (Figure 4.3.1). It was found that days to tasseling had significantly been influenced by varietal treatments. Between the treatments, V_2 required more days for tasseling (94.889 days) followed by V_1 (79.778 days).

A range of plant spacing was also used to observe days to first tasseling of white maize (Figure 4.3.2). It was found that S_3 showed the highest required days to first tasseling (83.333 days) followed by S_2 (82.50 days) and S_1 (82.50 days) consecutively. The treatments were statistically identical referring no effect of spacing on days to first tasseling. It is mentionable that S_1 and S_2 were numerically same regarding days to first tasseling.

The results regarding the combined effect of variety and spacing was placed in the Figure 4.3.3. For the combination of variety and plant spacing it was found that V_2S_3 treatment took maximum days to tasseling (86.66 days) and it was statistically significant over all other treatment combinations. Whereas, the minimum days to tasseling was recorded from V_1S_1 (79.33 days) and it was statistically similar with that of V_1S_2 (79.66 days) and V_1S_3 (80.667 days). Likewise, V_2S_2 (85.33 days) and V_2S_3 (85.33 days) were in the midst of maximum and minimum value and statistically similar to each other.



Here, S_1 = 50 cm x 25 cm; S_2 = 60 cm x 25 cm; S_3 = 70 cm x 25 cm

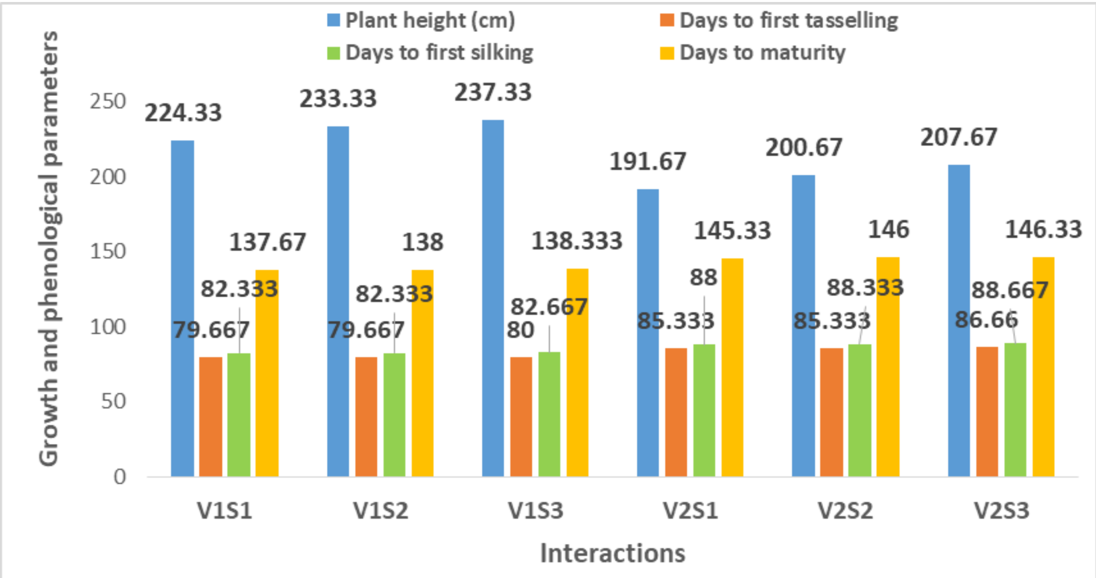
Figure 4.3.2. Effect of plant spacing on plant height, days to first tasseling, days to first silking and days to maturity

4.3.3 Days to first silking

Results regarding the effect of variety, spacing and combination are shown in the Figure 4.3.1, 4.3.2 and 4.3.3. It was found that days to first silking was significantly influenced by varieties. Between the treatments, V_2 variety needed more days to silking (88.333 days) followed by V_1 (82.44 days).

Three plant spacing were used to observe days to first silking of white maize. It was found that S_3 required the maximum (85.667 days) days to first silking followed by S_2 (85.33 days) and S_1 (85.16 days) consecutively. All of the three spacing treatments were statistically identical referring an insignificant effect of spacing on days to first silking.

On the other hand, for the combination of variety and plant spacing it was found that V_2S_3 treatment took more days to silking (88.667 days), which was statistically similar to V_2S_2 (88.333 days) and V_2S_1 (88.00 days). However, V_1S_1 revealed (82.333 days) the minimum days to silking and it was statistically similar with V_1S_2 (82.333 days) and V_1S_3 (82.667 days).



Here, V_1 = PSC -121; V_2 = KS -510; S_1 = 50 cm x 25 cm; S_2 = 60 cm x 25 cm; S_3 = 70 cm x 25 cm

Figure 4.3.3. Interaction effect of variety and plant spacing on plant height, days to first tasseling, days to first silking and days to maturity of white maize

4.3.4. Days to maturity

A statistically significant variation was reported in plant maturity in relation to the varieties (Figure 4.3.1). V_2 took more days to be matured (145.78 days) whereas V_1 took minimum days to be matured (137.89 days).

Effect of plant spacing was found insignificant regarding days to maturity as all of the treatments were statistically identical (Figure 4.3.2). In the experiment it was found that S_2 took the highest number of days for getting maturity (142.00 days) followed by S_2 (142.00 days). Both S_3 and S_2 required numerically equal number of days to get maturity. The lowest number of days required for attaining maturity was recorded from S_1 (141.50 days).

On the other hand, for the combination of variety and plant spacing it was found that, V_2S_2 and V_2S_3 treatments simultaneously took the highest days to be matured (146.33 days) and were statistically significant over all other treatment combinations. However, V_1S_1 was recorded to give the minimum days to maturity (137.67) and it was statistically similar with V_1S_2 (138.00) and V_1S_3 (138.33) (Figure 4.3.3).

4.3.5. Cob length

Significant difference was found between the varieties on cob length (Figure 4.3.4). Maximum cob length of about 17.011 cm was obtained from V_1 (PSC-121) and the minimum (15.906 cm) was recorded from V_1 (KS-510).

Spacing had a significant effect on cob length (cm) (Figure 4.5.5). Among the various plant spacing treatments, S_3 produced the longest cob (17.367 cm), whereas S_1 produced the shortest one (15.50 cm). S_2 was in the midst of S_3 and S_1 giving cob length of about 16.508 cm.

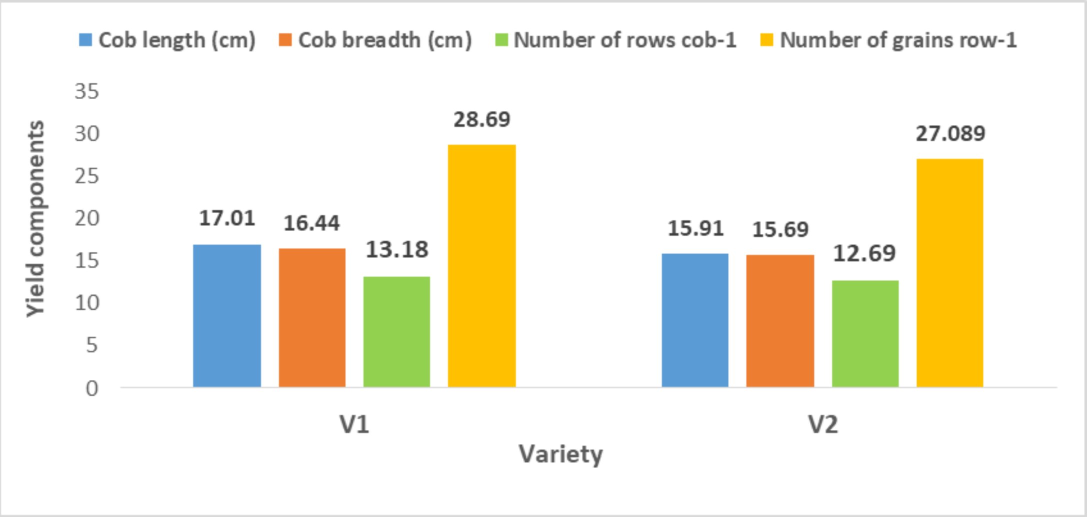
The findings of variety and spacing interaction are placed in the Figure 4.3.6. For the combination of variety and plant spacing it was observed that V_1S_3 treatments showed the highest cob length (17.867 cm) and it was statistically significant over all other treatment combinations. V_1S_3 was followed by V_1S_2 (17.06 cm) and was statistically significant with V_2S_3 (16.867 cm). The shortest cob was obtained from V_2S_1 (14.90 cm) which maintained a statistically significant relationship with all other interactions. Likewise, V_2S_2 was recorded to have fourth highest cob length (15.95 cm) which was statistically similar with V_1S_1 (16.10 cm).

4.3.6. Cob breadth

Different varieties, plant spacing and their combinations were applied to know their effects on cob breadth (cm) of white maize (Figure 4.3.4, 4.3.5 and 4.3.6). A significant effect of variety on cob breadth was reported in the experiment. Between the tested varieties, V_1 (PSC-121) showed the higher cob breadth (16.444 cm) followed by V_2 (KS) having cob breadth of about 15.689 cm.

Among the plant spacing used in the experiment, S_3 was reported to provide the maximum cob breadth (16.45 cm) followed by S_2 (16.13 cm). S_3 and S_2 were statistically identical to each other. However, the minimum cob breadth of about 15.167 cm was recorded from S_1 and it was statistically significant over S_3 and S_2.

However, among their combination treatments V_1S_3 revealed the maximum cob breadth (16.833 cm) which was statistically similar with V_1S_2. On the other hand, the minimum cob breadth of 15.233 cm was recorded from V_2S_1 and it was statistically significant over all other treatment combinations. Likewise, V_2S_2 (15.767 cm) showed the immediate shortest cob breadth and was statistically similar with V_2S_3 (16.067 cm).



Here, V_1 = PSC -121, V_2 = KS -510

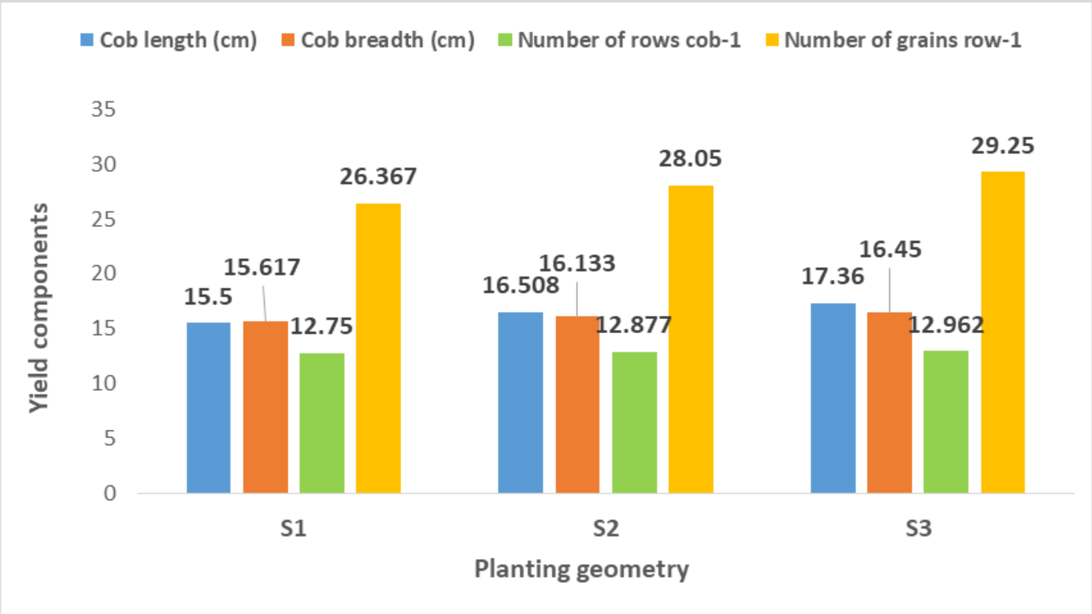
Figure 4.3.4. Effect of variety on cob length (cm); cob breadth (cm), number of rows per cob and number of grains per rows

4.3.7. Number of rows cob^{-1}

Experimental findings regarding the effect of variety, spacing and their interactions are showed in the Figure 4.3.4, 4.3.5 and 4.3.6. From the experiment it was revealed that variety had a significant effect on number of rows cob^{-1}. Comparatively higher number of rows cob^{-1} (13.181) was reported from V_1 (PSC-121) than that of V_2 (KS) (12.544).

In case of effect of spacing on number of rows cob^{-1}, the highest number of rows cob^{-1} (12.962) was obtained from S_3 followed by S_2 (12.87) and S_1 (12.75) consecutively. Irrespective of numerical variation among the treatments there was no statistically significant difference indicating an insignificant effect of spacing on number of rows cob^{-1}.

However, for the combination of variety and spacing it was found that V_1S_3 showed the highest grain rows cob^{-1} (13.27) and it was statistically identical with V_1S_2 giving 13.20 grain rows cob^{-1}. Both V_1S_2 and V_1S_3 were statistically similar with V_1S_1 (13.067). On the other hand, the lowest number of rows cob^{-1} (12.433) was obtained from V_2S_1 and was statistically similar with V_2S_2 (12.553). Likewise, V_2S_3 (12.647) was in the midst of highest and lowest results.



Here, S_1 = 50 cm x 25 cm; S_2 = 60 cm x 25 cm; S_3 =70 cm x 25 cm

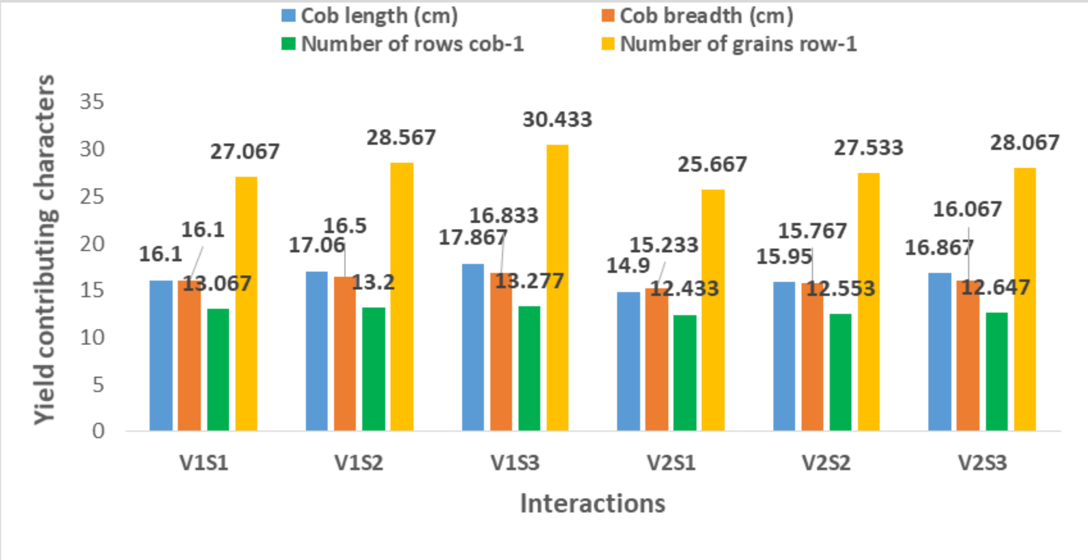
Figure 4.3.5. Effect of spacing on cob length; cob breadth number of rows per cob and number of grains per rows

4.3.8. Number of grains row^{-1}

From the experiment it was revealed that variety had a significant effect on number of grains row^{-1} (Figure 4.3.4). Comparatively higher number of rows cob^{-1} (28.689) was reported from V_1 (PSC-121) than that of V_2 (KS) (27.089).

Moreover, spacing treatments in white maize showed the significant effects on number of grains row^{-1} (Figure 4.3.5). Number of grains row^{-1} was increased with an increase in spacing levels. Among the various spacing treatments, S_3 spacing produced the highest number of grains row^{-1} (29.250) followed by S_2 (28.05). S_3 and S_2 were statistically similar to each other. However the lowest number of grains row^{-1} was obtained from S_1 (26.36) and maintained a statistically significant relation with S_3 and S_2.

However, the combination of variety and spacing revealed that V_1S_3 showed the highest number of grains rows^{-1}(30.433) (Figure 4.3.6), which was statistically similar to V_1S_2 (28.567). Among the treatments V_2S_1 showed the very minimum number of grains rows^{-1}(25.667) and it was statistically similar with that of V_2S_2 (27.533) and V_1S_1 (27.067). Likewise, V_2S_3 was recorded to give the third highest number of grains rows^{-1} (28.067).



Here, V_1= PSC -121; V_2 = KS-510, S_1= 50 cm x 25 cm; S_2 = 60 cm x 25 cm; S_3 =70 cm x 25 cm

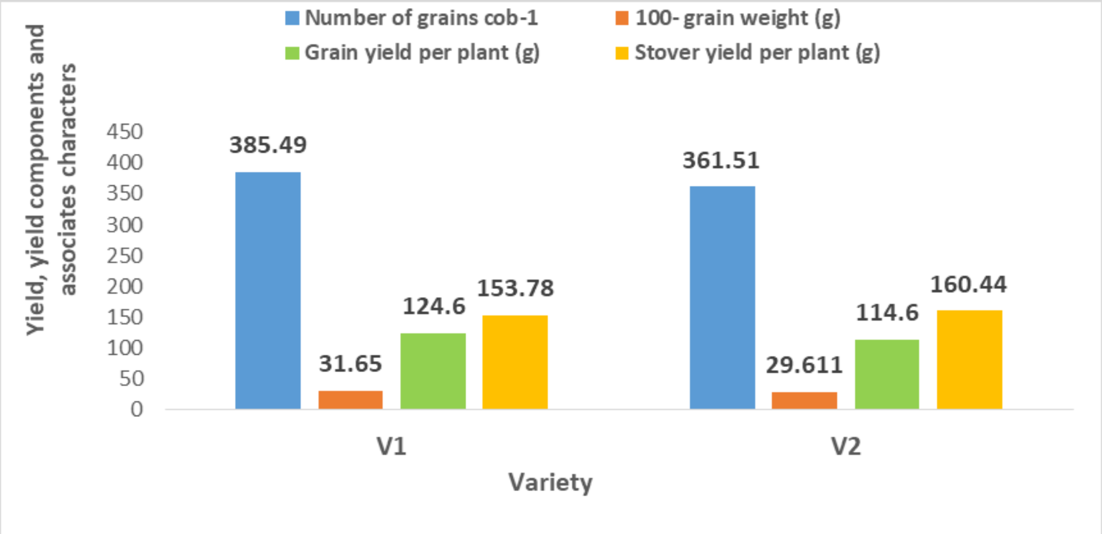
Figure 4.3.6. Interaction effect of variety and spacing on cob length; cob breadth, number of rows per cob and number of grains per row of white maize

4.3.9. Total number of grains cob^{-1}

Total number of grains cob^{-1} was significantly influenced by varieties, spacing and their combinations (Figure 4.3.7, 4.3.8 and 4.3.9). Between the varieties, the maximum number of grains cob^{-1} (385.49) was reported from V_1 (PSC-121) as compared to that of V_2 (KS) (361.51).

However, in white maize spacing treatments showed the significant effect on number of grains cob^{-1}. Among the various spacing treatments, S_3 produced the highest number of grains cob^{-1}(392.83) followed by S_2 which produced the second highest number of grains cob^{-1}. However, the lowest number of grains cob^{-1} was reported from S_1 (352.20).

Moreover, the combination of variety and spacing revealed that V_1S_3 showed the highest number of grains cob^{-1}(406.27) which was statistically significant over all other treatment combinations. V_1S_3 was followed by V_1S_2 (385.47) which was statistically similar with V_2S_3 (379.49) and V_2S_2 (365.47). Among the treatments V_2S_1 (339.67) was reported to provide the very minimum number of grains cob^{-1} and was statistically significant over all other treatment combinations. Likewise, V_1S_1 (364.73) was recorded to give the immediate minimum result and was statistically similar with V_2S_2 and V_2S_3.



Here, V_1 = PSC -121; V_2 = KS -510

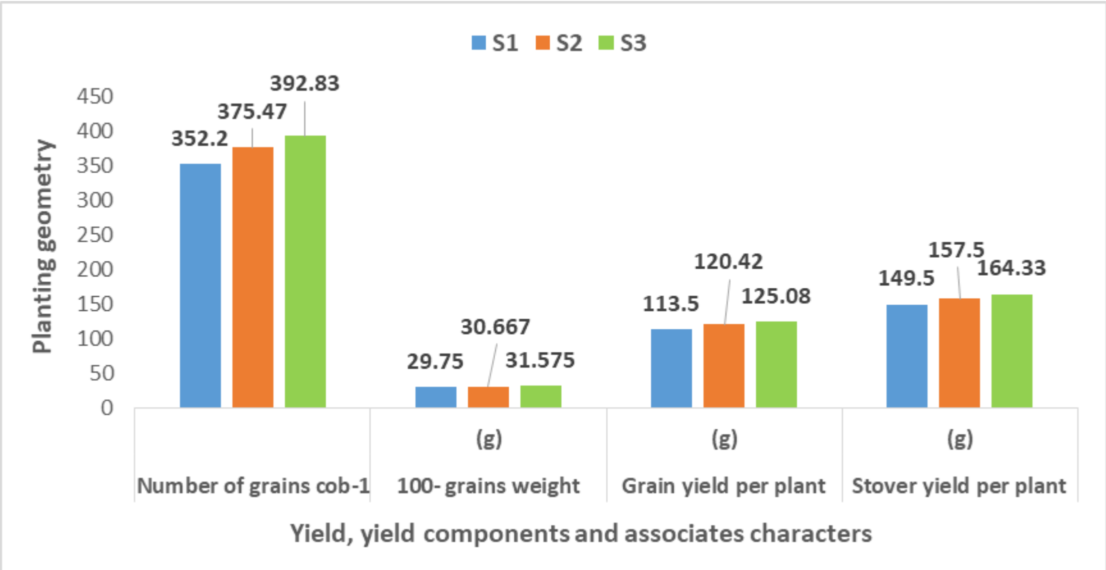
Figure 4.3.7. Effect of variety on number of grains cob^{-1}, 100-grain weight; grain yield per plant and stover yield per plant of white maize

4.3.10. 100-grain weight

The variety, plant spacing and their combinations influenced significantly the weight of 100-grain in white maize (Figure 4.3.7, 4.3.8 and 4.3.9). Between the varieties used in the experiment, the maximum 100- grain weight (31.650 g) was produced by V_1 as compared to that of V_2 (29.611 g).

Plant spacing treatments showed the significant effects on 100- grain weight. The maximum 100 grain weight of about 31.575 g was found from S_3 followed by S_2 (30.667 g). S_2 was statistically similar with that of S_3. On the other hand, the lowest 100 grain weight was obtained from S_1 (29.75 g) and it was also statistically similar with S_2.

For their combination, the highest 100- grain weight (32.450 g) was produced with V_1S_3 and it was statistically similar with V_1S_2 (31.667 g). The minimum weight of 100-grain (28.667 g) was produced by the V_2S_1 maintaining a statistically similar relation with V_2S_2 (29.667 g). Likewise, V_1S_1 (30.833 g) and V_2S_3 (30.50 g) were statistically similar with V_1S_2 (31.667 g).



Here, S_1 = 50 cm x 25 cm; S_2 = 60 cm x 25 cm; S_3 = 70 cm x 25 cm

Figure 4.3.8. Effect of spacing on number of grains cob^{-1},100-grain weight; grain yield per plant and stover yield per plant of white maize

4.3.11. Grain yield plant^{-1}

The variety, plant spacings and their combination significantly influenced the grain yield plant^{-1} (g) in white maize (Figure 4.3.7, 4.3.8 and 4.3.9). Maximum grain yield plant^{-1} (124.6 g) was significantly achieved with the variety V_1 and the minimum grain yield plant^{-1} (114.6 g) was significantly achieved with the variety V_2.

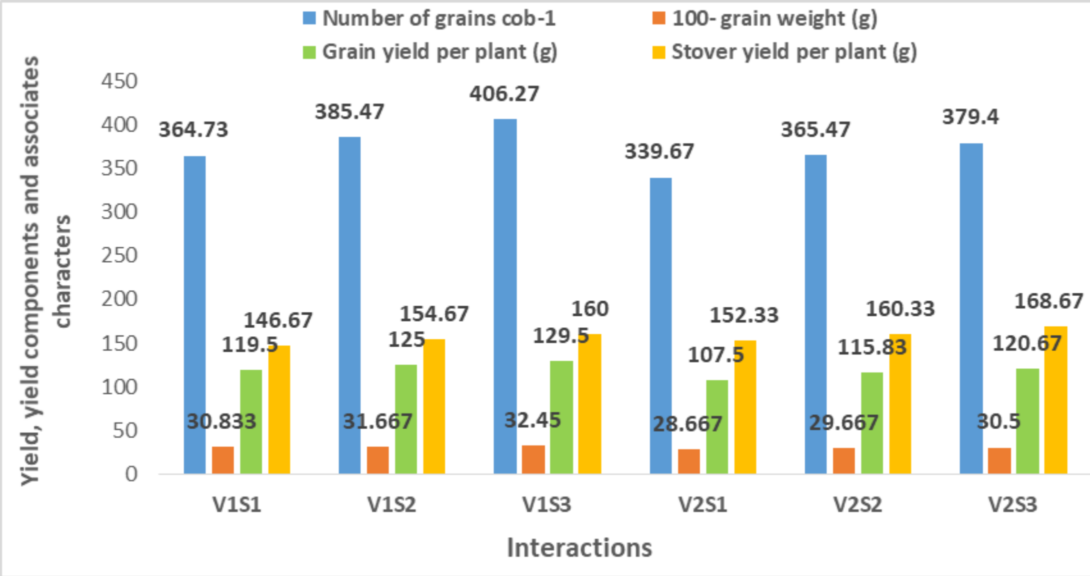
For plant spacings treatments maximum grain yield plant^{-1} (125.08 g) was significantly obtained with the treatment S_3 which was statistically similar to S_2 (120.42 g) and significantly the minimum per plant grain yielder was S_1 (113.50 g). For their combinations, maximum grain yield plant^{-1} (129.50 g) was significantly counted from treatment V_1S_3, which was statistically similar to V_1S_2 (125.00 g) while the minimum grain yield plant^{-1}was significantly observed for V_2S_1 treatment (107.50 g).

4.3.12. Stover yield plant^{-1}

The variety, plant spacings and their combination remarkably influenced the stover yield plant^{-1} (g) in white maize (Figure 4.3.7, 4.3.8 and 4.3.9). Maximum stover yield plant^{-1} (160.44 g) was significantly produced with the variety V_2 and the minimum stover yield plant^{-1} (153.78 g) was significantly produced with the variety V_1.

For plant spacings treatments maximum stover yield plant^{-1} (164.33 g) was significantly obtained with the treatment S_3 which was statistically similar to S_2 (157.50 g) and the minimum stover yield plant^{-1} was significantly found with the treatment S_1 (149.50 g).

For their combination, maximum stover yield plant^{-1}(168.67 g) was significantly counted from treatment V_2S_3 which was statistically similar to V_2S_2 (160.33 g) and V_1S_3 (160.00 g) while the minimum stover yield plant^{-1} was observed from V_1S_1 treatment (140.67 g).



Here, V_1 = PSC - 121; V_2 = KS- 510; S_1 = 50 cm x 25cm; S_2 = 60 cm x 25cm; S_3 = 70 cm x 25 cm

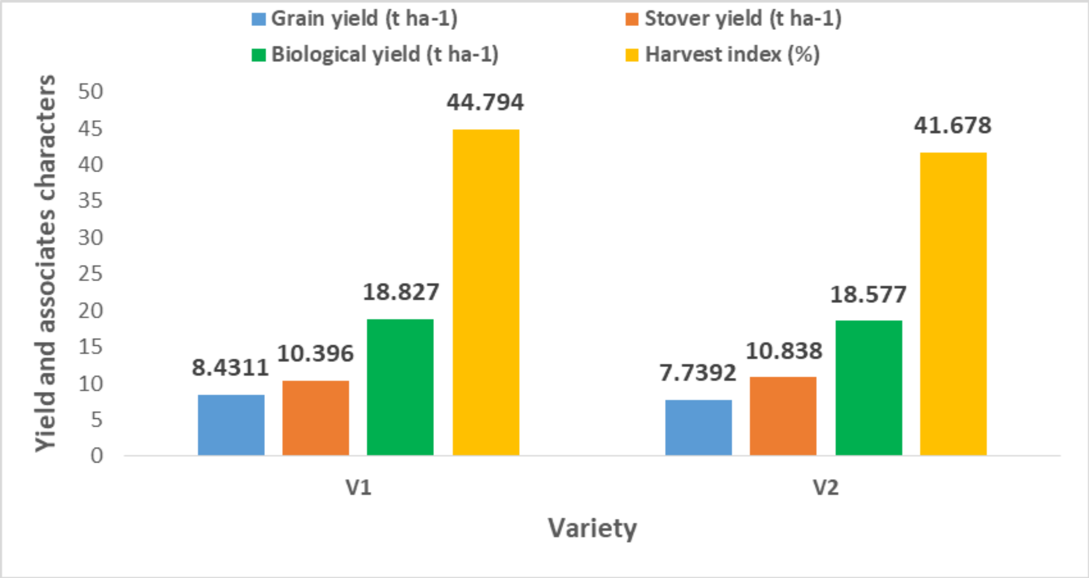
Figure 4.3.9. Interactions effect of variety and spacing on number of grains cob^{-1}, 100-grain weight; grain yield per plant and stover yield per plant

4.3.13. Grain yield

The variety, spacing and their combination remarkably influenced the grain yield in white maize (Figure 4.3.10, 4.3.11 and 4.3.12 respectively). Maximum grain yield (8.431t ha^{-1}) was achieved with the treatment V_1 and the minimum grain yield (7.739 t ha^{-1}) was achieved with the treatment V_2. It might be happened due to satisfactory soil moisture throughout the growing period.

For plant spacing treatments, maximum grain yield (9.08 t ha^{-1}) was achieved with the treatment S_1 whereas the lowest grain yield (7.15 t ha^{-1}) was recorded from S_3. S_2 was in the middle of S_1 and S_3 giving a grain yield of 8.02 t ha^{-1}. All of the three treatments were recorded to have a statistically significant relation among themselves.

For their combination, maximum grain yield (9.1467 t ha^{-1}) counted from treatment V_1S_1 and it was statistically significant over all other treatment combinations. V_1S_1 was followed by V_2S_1 (8.60 t ha^{-1}) which was statistically similar with V_1S_2 (8.33 t ha^{-1}). From others treatments applications the minimum grain yield was observed for V_1S_2 treatment (8.0000 t ha^{-1}). The lowest grain yield (6.895 t ha^{-1}) was recorded from V_2S_3. Likewise, the immediate lowest grain yield was reported from V_1S_2 (7.222 t ha^{-1} which was statistically identical with V_1S_3 (7.40 t ha^{-1}).



Here, V_1 = PSC -121; V_2 = KS -510

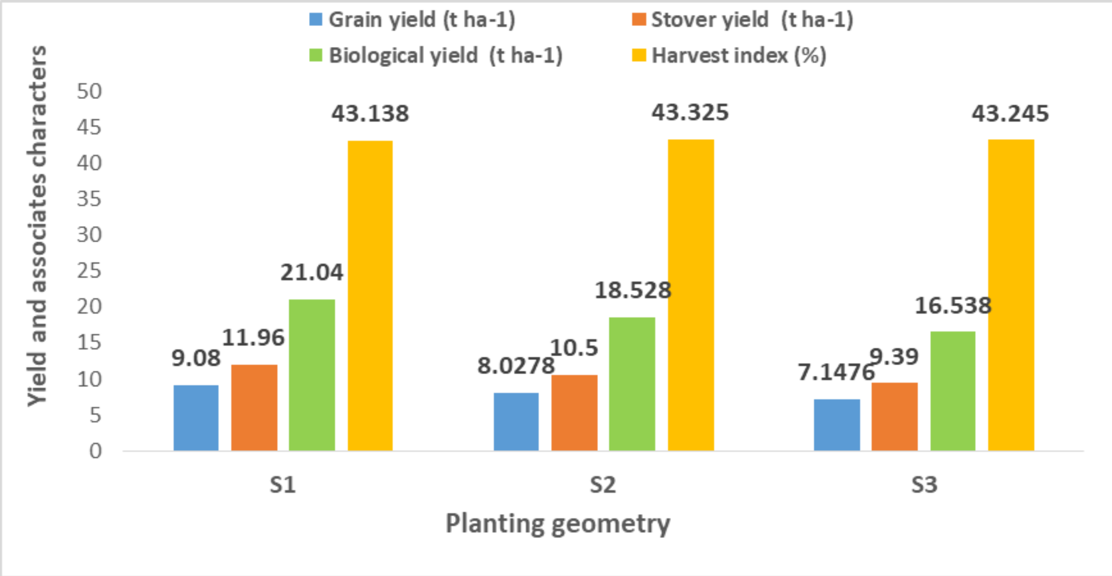
Figure 4.3.10. Effect of variety on grain yield; stover yield; biological yield and harvest index of white maize

4.3.114. Stover yield

In the experiment it was observed that stover yield was significantly influenced by variety, plant spacing and their combinations in white maize (Figure 4.3.10, 4.3.11 and 4.3.12). Between the varieties, higher stover yield of about 10.838 t ha^{-1} was observed in V_2 followed by V_1 (10.396 t ha-1).

In case of the effect of plant spacing on stover yield, a significant difference among the treatments was observed. S_1 was reported to give the highest stover yielder (11.96 t ha^{-1}). S_1 was followed by S_2 which produced a stover yield of about 10.50 t ha^{-1}. On the other hand, the lowest stover yield (9.390 t ha^{-1}) was recorded from S_3. It might be due to sufficient water enhanced more vegetative growth resulting more stover yield.

However, for the combination of variety and plant spacing it was observed that the maximum mean maize for the production of stover yield (12.187 t ha^{-1}) from V_2S_1 which was statistically identical to V_1S_1 (11.733 t ha^{-1}). The second highest stover yield (10.689 t ha^{-1}) was recorded from V_2S_2 and it was statistically similar with that of V_1S_2 (10.311 t ha^{-1}). The lowest stover yield of 9.143 t ha^{-1} was recorded from V_1S_3 and was statistically similar with V_2S_3 (9.638 t ha^{-1}).



Here, S_1 = 50 cm x 25cm; S_2 = 60 cm x 25 cm; S_3 = 70 cm x 25 cm

Figure 4.3.11. Effect of spacing on grain yield; stover yield; biological yield and harvest index of white maize

4.3.15. Biological yield

Biological yield was influenced significantly by plant spacing and their combinations (Figure 4.3.11 and 4.3.12 respectively) whereas the effect was insignificant in case of varietal effect (Figure 4.3.10). In the experiment it was observed that in case of biological yield, V_1 showed the comparatively higher biological yield of about 18.827 t ha^{-1} over V_2 (18.577 t ha^{-1}).

Plant spacing treatments had a significant effect on biological yield. Among various plant spacing, S_1 showed the highest biological yield (21.04 t ha^{-1}) followed by S_2 that showed the biological yield of about 18.528 t ha^{-1}. On the other hand , the lowest biological yield (16.53 t ha^{-1}) was observed from S_3. The treatments were statistically significant from each other.

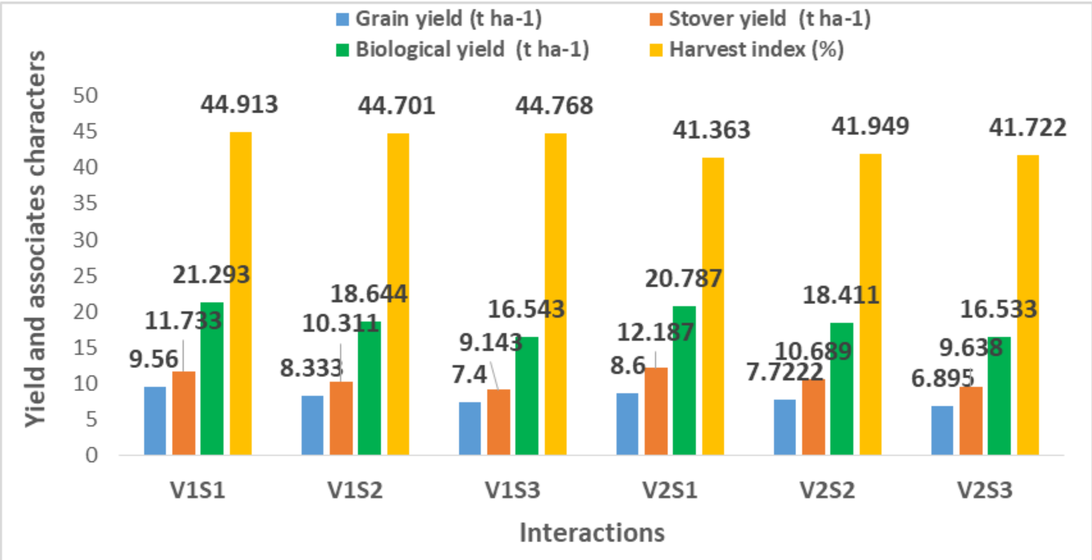
However, for their combinations V_1S_1 showed the maximum biological yield (21.293 t ha^{-1}) and it was statistically identical with V_2S_1 (20.787 t ha^{-1}). V_2S_1 was followed by V_1S_2 (18.644 t ha^{-1}) and it was also statistically identical with V_2S_2 (18.411 t ha^{-1}). On the other hand, the lowest biological yield (16.533 t ha^{-1}) was obtained from V_2S_3 having a statistically identical relation with V_1S_3 (16.543 t ha^{-1}).

4.3.16. Harvest index

Varietal treatments had a significant on harvest index (Figure 4.3.10). Between varietal treatments, V_1 had showed the higher harvest index (44.794%) as compared to that of V_2 (41.678%).

The various plant spacing treatments were statistically identical to each other irrespective of numerical variation in respect of harvest index (Figure 4.3.11). Among the treatments, the consecutive highest to lowest harvest index (%) was recorded from S_2 (43.325%), S_3 (43.245%) and S_1 (43.138%)

Moreover, for the combination of variety and plant spacing it was observed that V_1S_1 showed the highest harvest index (44.913 %) having a statistically identical relation to V_1S_2 (44.701 %) and V_1S_3 (44.768 %) (Figure 4.3.9). The lowest harvest index was recorded from V_2S_1 (41.363%) and it was statistically identical with V_2S_2 (41.949 %) and V_2S_3 (41.722 %) (Figure 4.3.12).



Here, V_1 = PSC -121; V_2 = KS-510; S_1 = 50 cm x 25cm; S_2 = 60 cm x 25cm; S_3 =70 cm x 25 cm

Figure 4.3.12. Interactions effect of variety and spacing on grain yield; stover yield; biological yield and harvest index

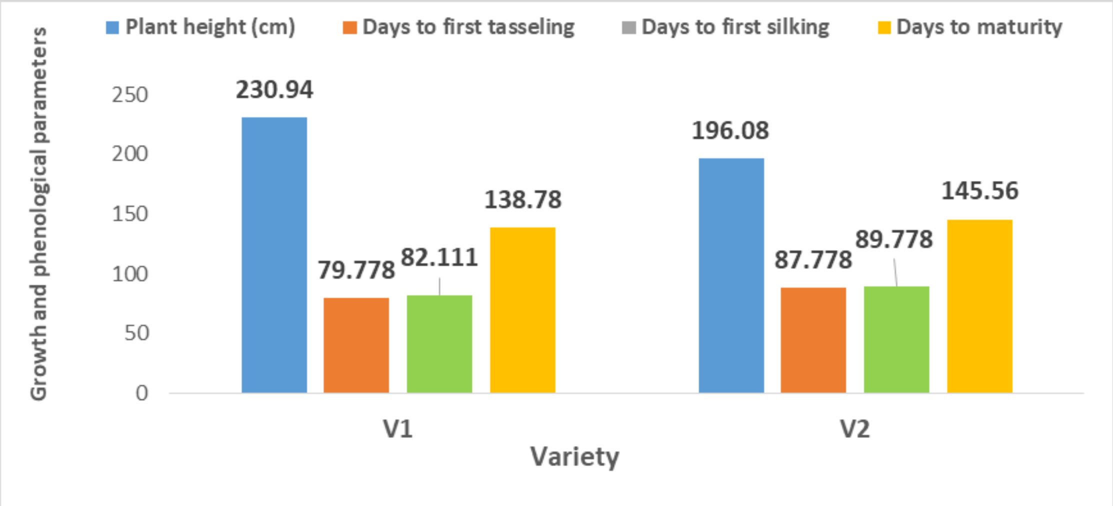
4.1. Experiment 4: Growth and yield assessment of two Indian white maize varieties under varying planting geometry at Rangpur district (rabi 2015-16)

4.4.1. Plant height

Various treatments such variety, plant spacing and their combination were used to observe their effects on plant height of white maize and the result was represented in figure 4.4.1, 4.4.2 and 4.4.3.It was revealed from the mentioned figure that, plant height was significantly influenced by the varieties. V_1 (230.94 cm) showed the longest plants followed by V_2 (196.88 cm), which was also the shortest.

Plant height was significantly influenced by the plant spacing. Among the two spacing treatments, S_3 revealed the tallest plant (221.46 cm) followed by S_2 (212.96 cm), whereas S_1 produced the shortest plant (206.25 cm)

Their combination was significant effect on plant height. Among the observed treatments, V_1S_3 showed the tallest plant (236.92 cm) which was statistically similar to V_1S_2 **(**230.92 cm) However, V_2S_1 (187.50 cm) revealed the smallest plants which was statistically similar to V_2S_2 (194.50 cm). Likewise, V_1S_1 had longer plant (225.00 cm) than that of V_2S_3 (205.75 cm).



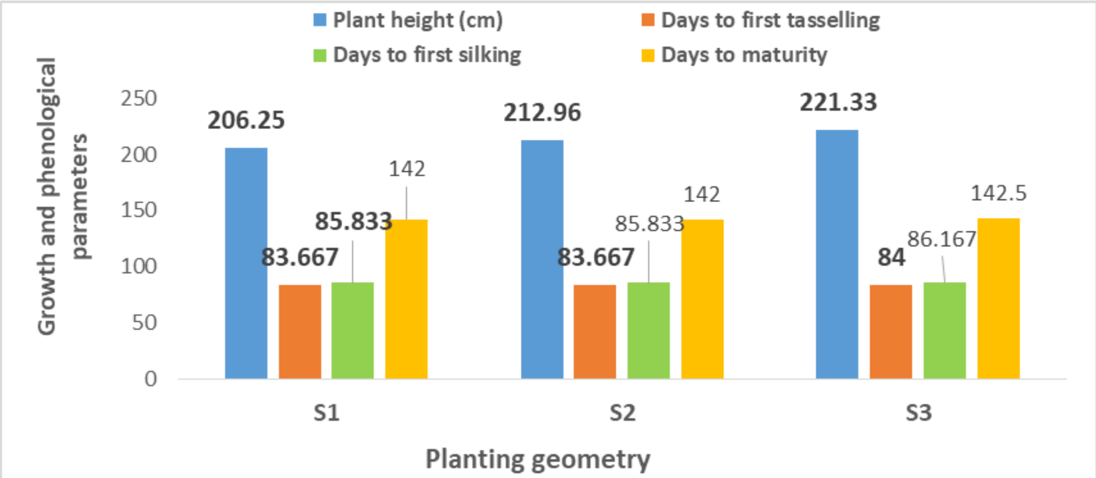
Here, V_1 = PSC -121, V_2 = KS - 510

Figure 4.4.1 Effect of variety on plant height, days to first tasseling, days to first silking and days to maturity of white maize

4.4.4. Days to tasseling

Days to tasseling significantly influenced by the varieties, and their combinations but did not influence by the plant spacing treatments and the result was represented in figure 4.4.1, 4.4.2 and 4.4.3. For individual treatments V_2 (87.667 days) took significantly the maximum days to tasseling. On the other hand, V_1 (79.667 days) showed significantly the lowest days to tasseling.

For various plant spacing treatments, S_3 showed the highest days to tasseling. (84.000 days), whereas S_1 (83.667 days) and S_2 (83.667 days) took the minimum days to tasseling.



Here, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm x 25 cm

Figure 4.4.2 Effect of variety on plant height, days to first tasseling, Days to first silking and days to maturity of white maize

4.4.5. Days to silkling

Days to silking also significantly influenced by the varieties, and their combinations but did not influence by the plant spacing treatments and the result was represented in figure 4.4.1, 4.4.2 and 4.4.3. For individual treatments V_2 (89.778 days) took significantly the maximum days to silking. On the other hand, V_1 (82.111 days) showed the lowest days to silking.

For various plant spacing treatments, S_3 showed the highest days to silking. (86.167 days), which was statistically alike to whereas S_1 (85.885 days) and S_2 (85.883 days) took the minimum days to silking.

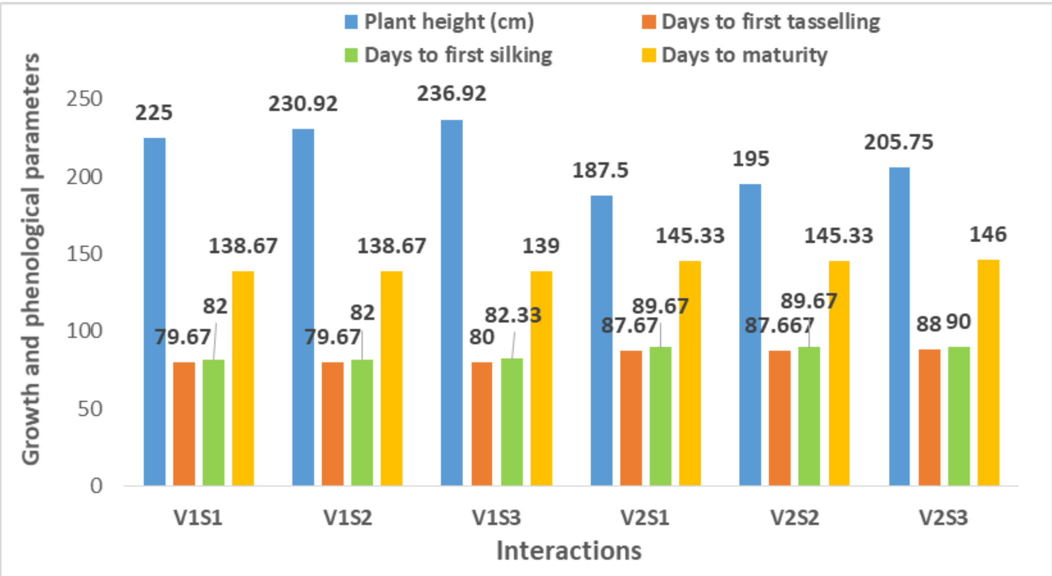
Among the combination treatments, V_2S_3 (90.000 days) showed the significantly highest days to silking which was statistically similar with V_2S_2 (89.667 days) and V_2S_1 (89.667 days). Whereas V_1S_1 performed the lowest (82.00 days) which was statistically similar to V_1S_2 (82.00 days) and V_1S_3 (82.223 days).

4.4.5. Days to maturity

Days to maturity was significantly influenced by the varieties, and their combinations plant spacing treatments but did not influence and the result has been represented in figure 4.1.1, 4.4 2 and 4.4.3. For individual treatments, V_2 took significantly the maximum days to be matured (145.56 days. On the other hand, V_1 showed significantly the lowest days (138.788 days) to be matured.

For various plant spacing treatments, S_3 showed the highest days to be matured (146.00 days), whereas S_1 and S_3 took the minimum days (145.33 days each) to be matured.

Among the combination treatments, V_2S_2 (146.00 days) showed the significantly highest days to be matured. Whereas V_1S_1 (134.33 days) perform the lowest which was statistically similar to V_1S_3 (138.67 days).



Here, V_1 = PSC -121, V_2 = KS -510, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm x 25 cm

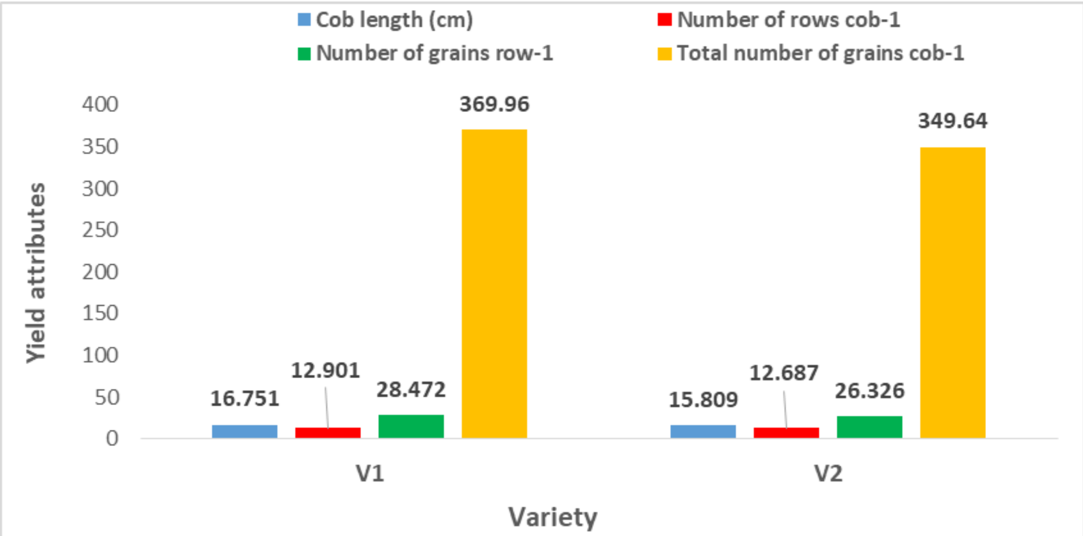
Figure 4.4.3. Interaction effect of variety and plant spacing on plant height, days to first tasseling, day to first silking and days to maturity

4.4.6. Cob length

Statistically significant differences was found among the varieties, plant spacing and their combinations on the production of cob length of white maize (Figure 4.4.4, 4.4.5 and 4.4.6). Maximum cob length (16.751 cm) was achieved with V_1 and the minimum was achieved V_2 (15.809 cm).

Among plant spacing treatments, S_3 produced significantly the tallest cobs (16.680 cm) which was statistically similar to S_2 (16.377 cm) and the shortest cobs was found from S_1 (15.783 cm)

Moreover, for the combinations of variety and plant spacing, it was observed that V_1S_3 (17.133 cm) treatments showed the highest cob length, which was statistically similar to V_1S_2 (16.887 cm), V_1S_1 (16.233 cm), V_2S_3 (16.227 cm) and V_2S_2 (15.867 cm) while V_2S_1 (15.333 cm) showed the shortest cob length.



Here, V_1 = PSC-121, V_2 = KS -510

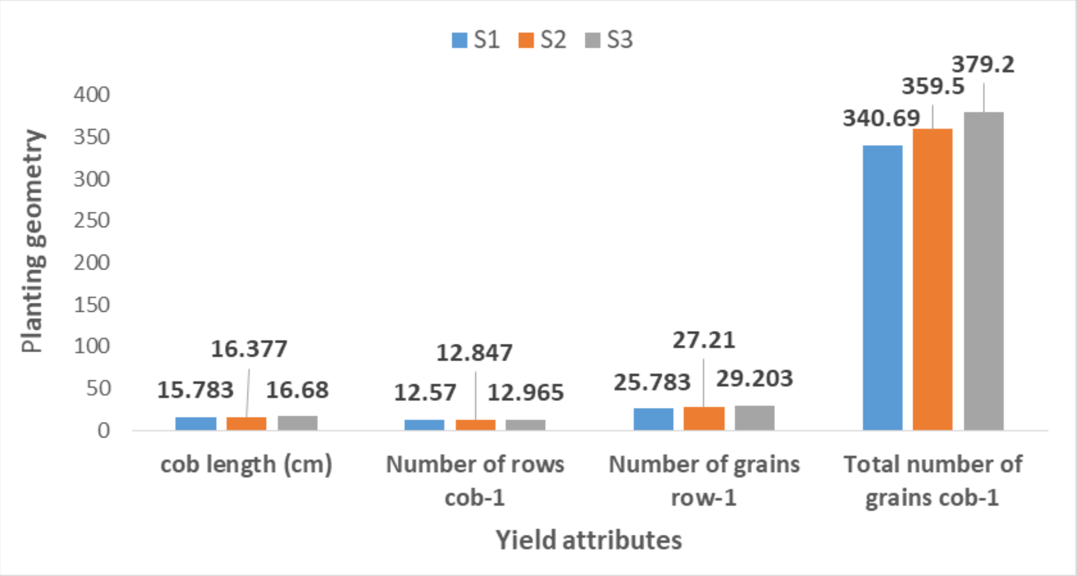
Figure 4.4.4. Effect of variety on cob length; number of rows per cob; number of grains per rows and number of grains per cob of white maize

4.4.7. Number of rows cob^{-1}

Number of rows cob^{-1} was significantly influenced by varieties, plant spacing and their combinations (Figure 4.4.4, 4.4.5 and 4.4.6). The maximum number of rows cob^{-1} was reported from the treatments having V_1 variety (12.901) and V_2 (12.687) was significantly the lowest performer (Figure 4.4.4)

However, in white maize plant spacing treatments showed the significant effects on number of rows cob^{-1}. Among the various treatments, S_3 (12.965) produced highest number of rows cob^{-1} which was statistically similar to S_2 (12.847) and S_1 (12.570) produced the lowest number of rows cob^{-1} (Figure 4.4.5).

Moreover, their combinations revealed that V_1S_3 showed the highest number of rows cob^{-1} (13.073) which was statistically similar to others excepting V_1S_1 (12.680) while V_2S_1 (12.460) showed significantly the minimum number of rows cob^{-1} (Figure 4.4.6).



Here, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm x 25 cm

Figure 4.4.5. Effect of spacing on cob length (cm); number of rows per cob; number of grains per rows and total number of grains per cob of white maize

4.4.8. Number of grains row^{-1}

Number of grains row^{-1} was significantly influenced by varieties, plant spacing and their combinations (Figure 4.4.4, 4.4.5 and 4.4.6). The maximum number of grains row^{-1} (28.472) was reported from the treatments having V_1 variety and V_2 was the lowest performer (26.226) (Figure 4.4.4).

However, in white maize plant spacing treatments showed significant differences on number of grains row^{-1}. Among the treatments, S_3 (29.203) produced highest number of grains row^{-1} which was statistically similar to S_2 (27.21) whereas S_3 produced significantly the lowest (25.782) number of grains row^{-1}(Figure 4.4.5).

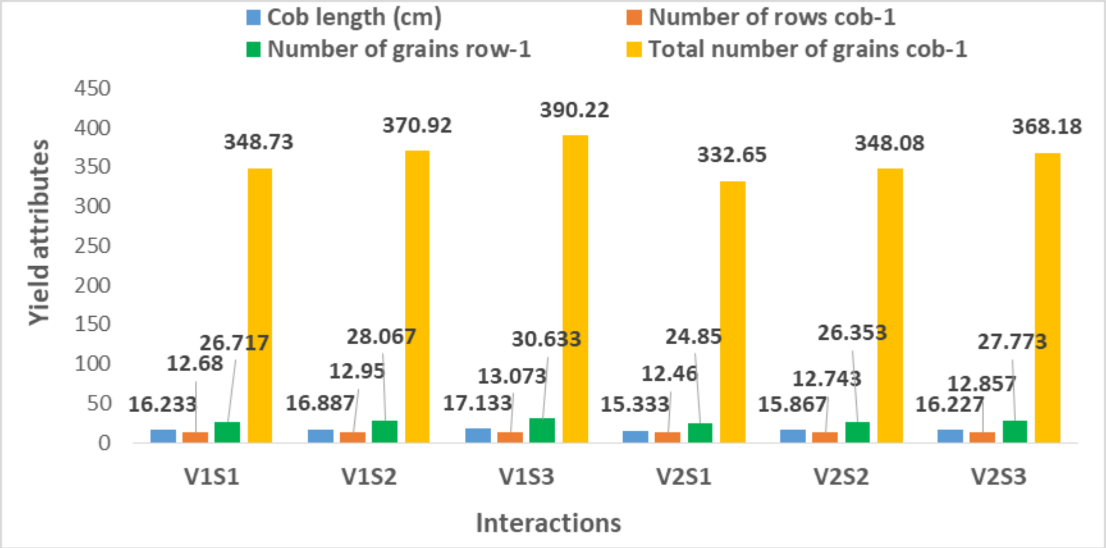
Moreover, their combination revealed that, V_1S_3 showed the highest number of grains row^{-1} (30.633 which was statistically similar with V_1S_2 (28.067) and V_2S_3 (27.733). Again, the treatment, V_2S_1 showed the lowest number of grains row^{-1}(24.850) which was statistically similar to V_2S_1 (27.517) and V_1S_1 (26.717) (Figure 4.4.6).

4.4.9. Total number of grains cob^{-1}

Total number of grains cob^{-1} was significantly influenced by varieties, plant spacing and their combinations (Figure 4.4.4, 4.4.5 and 4.4.6). The maximum number of grains cob^{-1} was reported from the treatments having V_1 (369.96) and V_2 (349.64) was significantly the lowest performer (Figure 4.4.4).

However, plant spacing treatments showed the significant effects on number of grains cob^{-1}. Among the various treatments, S_3 produced highest number of grains cob^{-1} (379.20) and followed by S_2 (359.50) and S_1 produced the lowest number of grains cob^{-1} (340.69) (Figure 4.4.5).

Moreover, their combination revealed that V_1S_3 showed significantly the highest number of grains cob^{-1} (419.75) which was statistically similar to V_1S_2 (370.92). Among the other treatments V_2S_1 showed the lowest number of grains cob^{-1} (322.65), which was statistically similar to V_2S_2 (348.08) and V_1S_1 (348.78) (Figure 4.4.6).



Here, V_1 = PSC -121, V_2 = KS -510. S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm x 25 cm

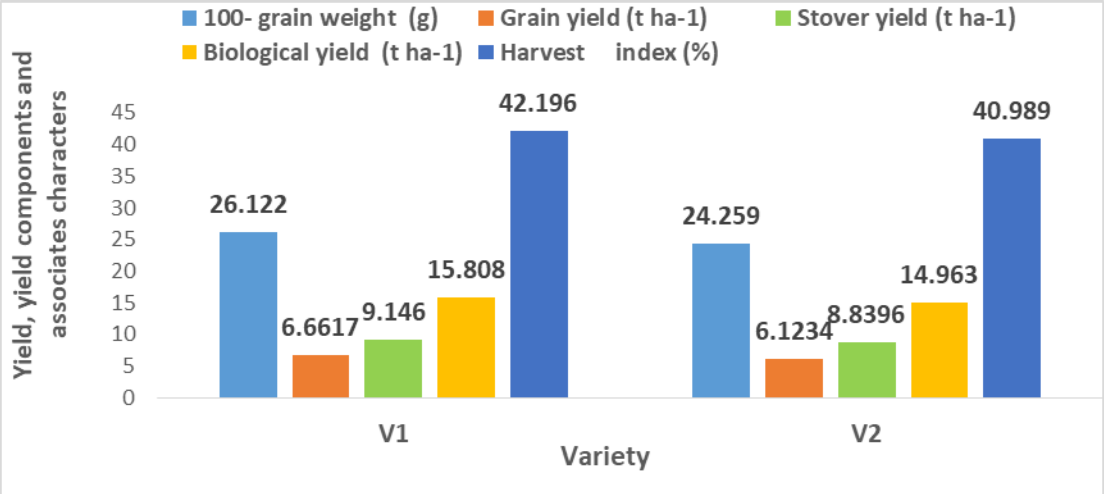
Figure 4.4.6. Interaction effect of variety and plant spacing on cob length, number of rows cob,$^{-1}$ number of grains row,$^{-1}$ and total number of grains cob^{-1}of white maize

4.4.10. 100-grain weight (g)

The varieties, plant spacing and their combination also influenced the weight of 100-grain in white maize (Figure 4.4.7, 4.4.8 and 4.4.9). The highest 100- grain weight was significantly produced with V_1 (26.200 g) and the lowest with V_2 (24.259 g) (Figure 4.4.7).

Plant spacing treatments showed the statistically significant effects on 100- grain weight,. Among them, the maximum 100- grain- weight (27.055 g) was significantly found from S_3 and followed by the S_2 (25.197 g) while the minimum weight of 100-grain (23.437 g) was produced by the S_1 treatment (Figure 4.4.8).

Treatment combinations revealed that V_1S_3 showed significantly the highest 100-grain weight (28.000 g) than the other combinations, which was statistically similar to V_1S_2 (26.160 g), and V_2S_3 (26.110 g) whereas V_2S_1 showed significantly the minimum weight (22.667 g) which was statistically similar to V_2S_2 (24.00 g) (Figure 4.4.9).



Here, V_1 = PSC -121; V_2 = KS -510

Figure 4.4.7. Effect of variety on 100-grains weight; grain yield; stover yield; biological yield and harvest index of white maize

4.4.11. Grain yield

The varieties, plant spacing and their combination remarkably significantly influenced the grain yield in white maize (Figure 4.4.7, 4.4.8 and 4.4.9). Maximum grain yield (6.6617 t ha^{-1}) was significantly achieved with the treatment V_1. The minimum grain yield (6.1234 t ha^{-1}) was significantly obtained from the treatment V_2.

For plant spacing treatments, the highest grain yield (7.0746 t ha^{-1}) was significantly found from the treatment S_1 and followed by S_2 (6.2885 t ha^{-1}) while the minimum grain yielder (5.8145 t ha^{-1}) was S_3.

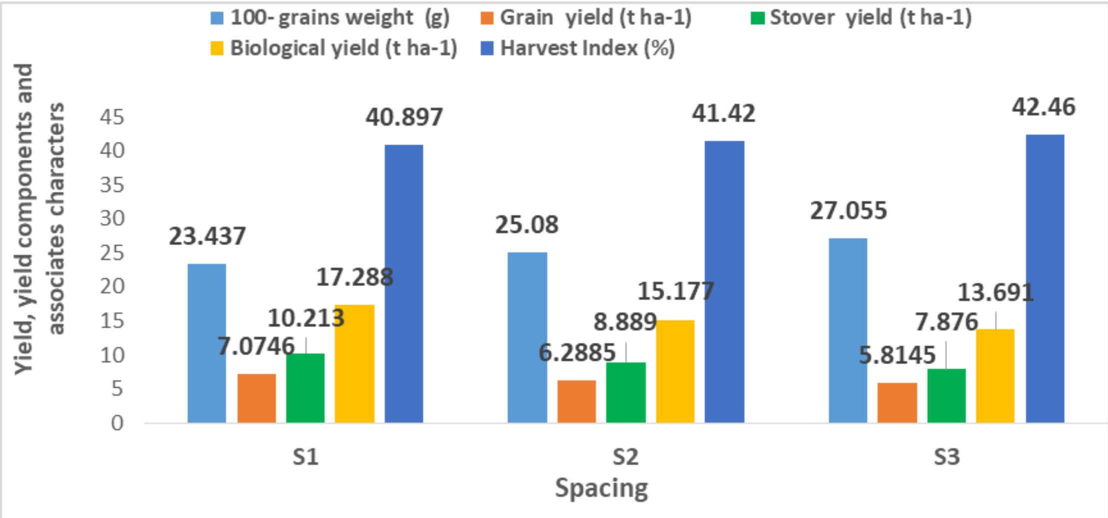
For their combination, maximum grain yield (7.3793 t ha^{-1}) counted from treatment V_1S_1 followed by V_2S_1 (6.7699 t ha^{-1}) and V_1S_2 (6.5418 t ha^{-1}) whereas the minimum grain yield was observed from V_2S_2 treatment (5.5650 t ha^{-1}).

4.4.12. Stover yield

It was observed that stover yield statistically significant effects at varieties, plant spacing and their combinations (Figure 4.4.7, 4.4.8 and 4.4.9). The highest stover yield was observed in V_1 (9.1460 t ha^{-1}) followed by V_2 (8.8396 t ha^{-1}) which was lowest producer.

In the plant spacing treatments, S_1 (10.213 t ha^{-1}) treatment was the highest stover yielder, followed by S_2 (8.889 t ha^{-1}) while S_3 treatment was the lowest yielder (7.876 t ha^{-1}).

However, for the combination of varieties and plant spacing it was observed that the maximum stover yield was produced by V_1S_1 (10.400 t ha^{-1}), which was statistically similar to V_2 S_1 (10.027 t ha^{-1}) followed by V_1S_2 (9.000 t ha^{-1}) and V_2S_2 (8.778 t ha^{-1}) while V_2S_3 was the lowest yielder (8.3556 t ha^{-1}) which was statistically similar to V_1 S_3 (8.038 t ha^{-1}).



Here, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm; S_3 = 70 cm x 25 cm

Figure 4.4.8. Effect of plant spacing on 100-grains weight; grain yield; stover yield; biological yield and harvest index of white maize

4.4.13. Biological yield

Biological yield also increased significantly with the different varieties, plant spacing both separately and in combinations (Figure 4.4.7, 4.4.8 and 4.4.9). Data revealed that, varieties V_1 produced significantly the highest biological yield (15.808 t ha^{-1}) and V_2 produced the minimum biological yields (14.963 t ha^{-1}) (Figure 4.4.7).

In the plant spacing treatments, S_1 (17.288 t ha^{-1}) treatment was significantly the highest biological yielder, followed by S_2 (15.177 t ha^{-1}) while S_3 treatment was the lowest yielder (13.691 t ha^{-1}) (Figure 4.4.8).

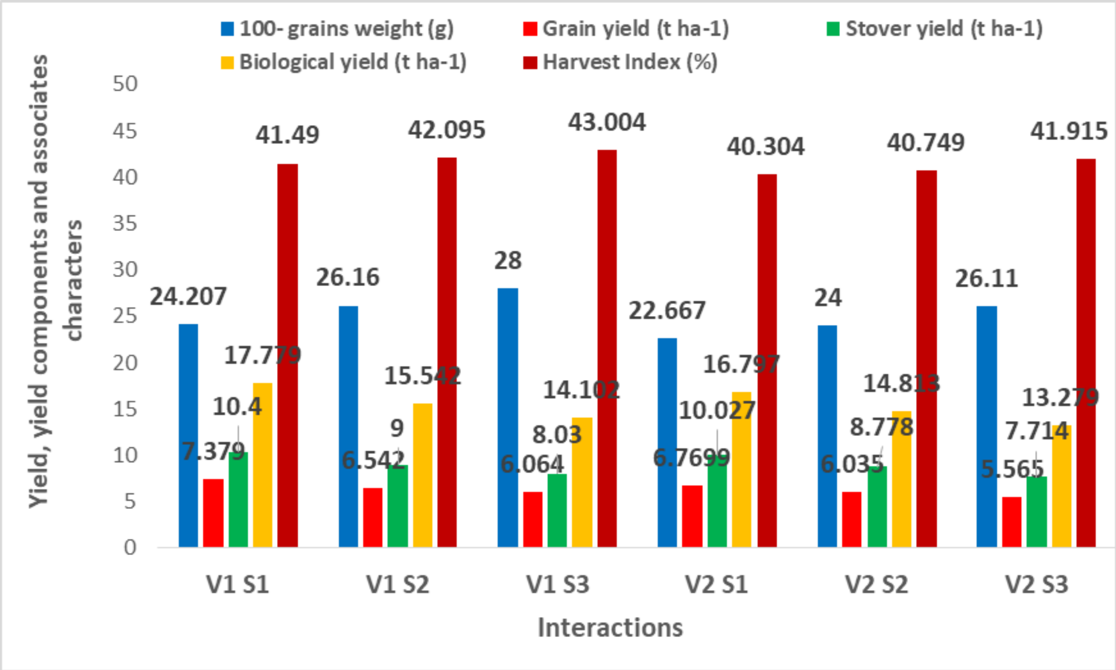
From their combinations, V_1S_1 showed the maximum biological yield (17.779 t ha^{-1}), which was statistically identical to V_1S_1 (16.797 t ha^{-1}) in this study. Treatment, V_2S_3 produced the minimum (13.279 t ha^{-1}) biological yield (Figure 4.4.9).

4.4.14. Harvest Index

White maize varieties showed statistically significant effect on harvest index. V_1 (42.196 %) showed the highest HI, whereas V_2 (40.989 %) was the lowest (Figure 4.4.7).

The plant spacing treatments also showed significant differences on harvest index. Among them, S_3 (43.512 %) showed the highest harvest index which was statistically similar to S_2 (42.460 %) while S_1 (40.897 %) had the lowest (Figure 4.4.8).

Moreover, harvest index varied significantly due to combination of varieties and plant spacing treatments. It was observed that, V_1S_1 treatment showed the highest harvest index (43.004 %), which was statistically similar to others V_1 S_2 (42.095 %), V_2 S_2 (41.915 %) and V_1 S_1 (41.490 %) excepting V_2S_2 (40.749 %) whereas V_2S_1 (40.3040 %) had the lowest harvest indexer (Figure 4.4.9).



Here, V_1 = PSC -121, V_2 = KS -510, S_1 = 50 cm × 25 cm; S_2 = 60 cm × 25 cm;

S_3 = 70 cm x 25 cm

Figure 4.4.9. Interaction effect of variety and spacing on 100-grains weight; grain yield; stover yield; biological yield and harvest index of white maize

4.5. Experiment 5: Performance of white maize (var. PSC-121) under varying planting geometry at SAU, Dhaka (rabi 2016-17)

4.5.1. Plant height

Plant height is an important component which helps to determine the growth attained during the growth period. Various plant spacing treatments were used to observe their effects on plant height of white maize and the result was represented in figure 4.5.1. It was revealed from the mentioned figure that plant height was significantly influenced by plant spacing. Among the treatments, the tallest plant was significantly found at S_4 (242.93 cm) which was statistically similar to S_2 and S_3 (239.00 cm and 236.40 cm) and among other the plant spacing treatments S_1 revealed the smallest (232.20 cm).) due to crowding effect of the plant and higher intra specific competition for resources. This trend explains that as the number of plants increased in a given area the competition among the plants for nutrients uptake and sunlight interception also increased (Sangakkara *el al.*, 2004). Similar result was also reported by Bahadur *et al.* (1999) where they noticed that higher plant height were recorded in higher spacing and lower plant height was found in lower plant spacing in maize.

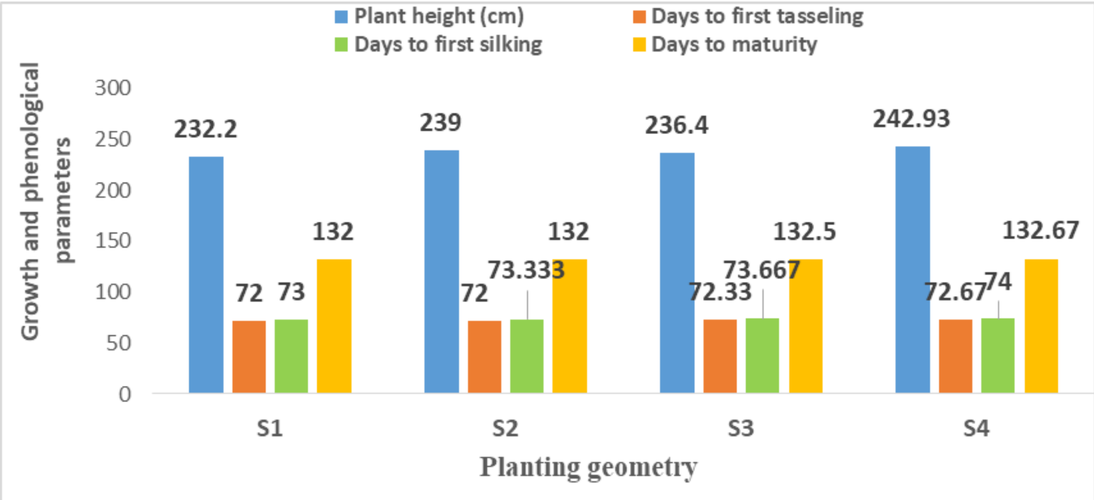
4.5.2. Days to first tasseling

Various plant spacing treatments were used to observe their effects on days to first tasseling of white maize and the result was represented in figure 4.5.1. It was revealed from the mentioned figure that days to first tasseling was non- significantly influenced by the plant spacing. It was found that days to tasseling was non-significantly influenced by plant spacing treatments. Among the treatments, S_4 spacing took numerically more number of days to tasseling (74.000 days). S_2 and S_3 (73.667days, and 73.667 days) took medium number of days to tasseling and among other the plant spacing treatments S_1 took the less number of days to tasseling (73.667 days) of white maize. . The present result is in line with that of Gozubenli (2004) who reported that the effect of inter and intra-row spacing did not significantly affect on tasseling and maturity period of maize. Similarly, Park *et al*., (1989) reported that plant density did not affect days to tasseling and maturity. According to Zenebe (2004), the effect of plant population was not significant on days to 50% flowering and days to 90% maturity of sorghum.

4.5.3. Days to first silking

Various plant spacing treatments were used to observe their effects on days to first silking of white maize and the result was represented in figure 4.5.1. It was revealed from the mentioned figure that days to first silking was non-significantly influenced by plant spacing.

It was found that days to silking was non-significantly influenced by plant spacing treatments. Among the plant spacing treatments, S_4 spacing took numerically more number of days to silking (74.000days) and S_2 and S_3 (73.667days and 73.667 days) took medium number of days to silking whereas S_1 took the less number of days to silking (73.667 days) of white maize.



Here, S_1 = 50 cm x 20 cm; S_2 = 50 cm x 25 cm; S_3 = 60 cm x 20 cm; S_4 = 60 cm x 25 cm

Figure 4.5.1: Effect of plant spacing on plant height, days to first tasseling, days to first silking and days to maturity of white maize

4.5.4. Days to maturity

There was non-significant variation reported in plant maturity with plant spacing. Numerically, S_4 took more days to be matured (132.33 days) followed by S_2 and S_3 (132.00 days and 132.00 days respectively) took medium days to be matured while S_1 took the less number of days to be matured (132.00 days) of white maize.

4.5.5. Cob length

Significant difference on the production of cob length in white maize was found among the plant spacing treatments (Figure 4.5.2). Cob length was increased with the plant spacing increases. Among the treatments, S_4 was significantly produced the highest cob length (18.367 cm) which was statistically similar to S_2 and S_3 (17.767 cm and 17.293 cm) treatments while S_1 (16.433 cm) showed the lowest cob length. The present result was supported by the findings of Biswas K, Quayyum M. A., (1991) and Johnson D.E, Wilman D., (1997). They found that higher plant densities produced smaller cob compared with the traditional plant density of maize.

4.5.6. Cob breadth

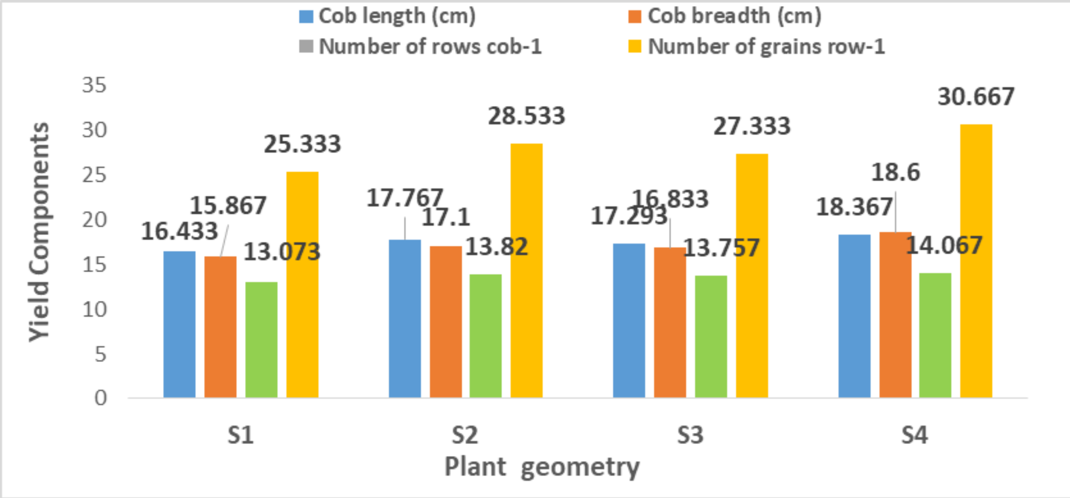
Significant difference was found for the plant spacing treatments in terms of cob breadth (Figure 4.5.2).Data revealed that, S_4 was significantly showed the highest cob breadth (18.600cm) which were statistically similar to S_2 and S_3 (17.100cm and 16.833cm) treatments whereas S_1 (15.867cm) showed the lowest cob breadth.

4.5.7. Number of rows cob^{-1}

Number of rows cob^{-1} showed statistically significant differences due to different plant spacing treatments (Figure 4.5.2). It was revealed from the mentioned figure that, S_4 was significantly produced the maximum rows cob^{-1} (14.067) which was statistically similar to S_2 and S_3 (13.820 and 13.757) while S_1 was significantly produced the minimum rows per cob (13.073). The result was supported by Shams et al (2002).The number of grain rows per cob decreased as the plant population increased. Usually under high population stress, the late developing distal spikelets fail to set kernels and when the slow growing silks finally emerge, little or no pollen is available for fertilization. Also, high stand density reduces ear shoots growth, which results in fewer spikelets primordial was transformed into functional florets by the time of flowering. The limited carbon and nitrogen supply to the cob finally stimulates young kernel abortion immediately after fertilization (Sangoi L., 2001).

4.5.8. Number of grains row^{-1}

The number of grains per row is an important yield parameter. Number of grains per row was significantly influenced by plant spacing (Figure 4.5.2).). Number of grains per row increased with increasing spacing. Among the plant spacing treatments, the maximum grains rows^{-1} (32.133) was found from S_4 treatment which was statistically similar to S_2 (28.533) and closely followed by S_3 (27.333) while S_1 was significantly produced the minimum grains rows^{-1} (25.133). These result was supported by the findings of Abuzar *et al.* (2011) and Andrade *et al*. (1993) where they observed that an increase in plant density decrease the number of grains per row in maize.

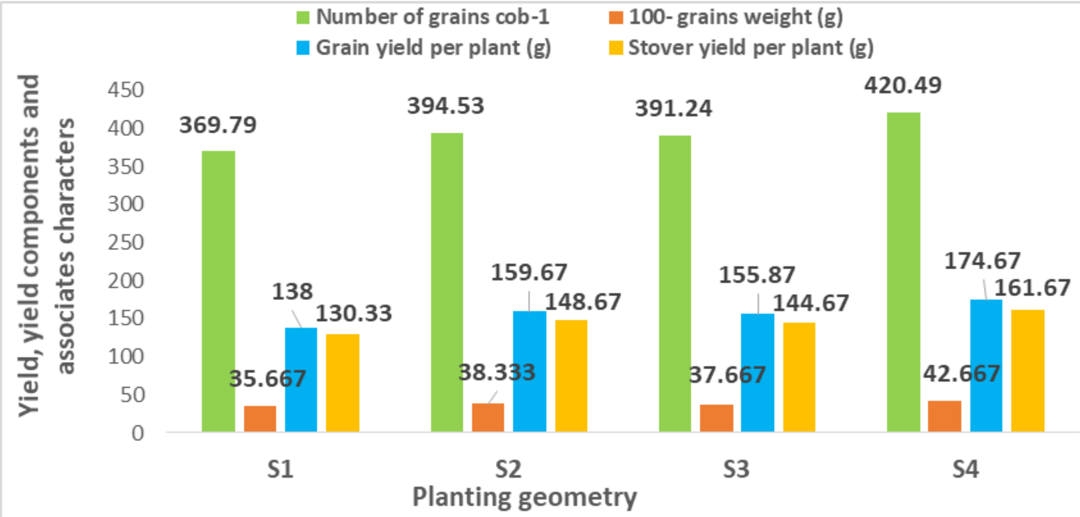


Here, S_1 = 50 cm x 20 cm; S_2 = 50 cm x 25 cm; S_3 = 60 cm x 20 cm; S_4 = 60 cm x 25 cm

Figure 4.5.2: Effect of plant spacing on cob length; number of rows per cob; number of grains per rows and number of grains per cob of white maize

4.5.9. Total grains cob^{-1}

Number of grains per cob is important yield attributes which determine the yield potential of crop. Number of grains per cob was significantly influenced due to different plant spacing treatments (Figure 4.5.2).). Data revealed that, the highest number of grains per cob (420.49) was found from S_4 treatment which was statistically alike with S_2 (394.53) and S_3 (391.24) whereas the lowest grains cob^{-1} was recorded from S_1 (369.79). The decreased kernels number per ear in the spacing of 50 cm x 20 cm might be nutrient competition due to less space per plot in the experiment. This variation might be due to the fact that widely spaced plants encountered less intra plant competition than closely spaced plants and thus exhibited better growth that contributed to more number of kernels per ear. In agreement with this result, Eskandarnejada *et al.* (2013) reported that inter-row spacing of 30 cm produced more number of kernels per ear than that 20 cm plant spacing. Moreover, Mukhtar *et al*. (2012) reported that wider spacing (17.50 cm) produced higher number of kernels per ear (717.00) while narrower spacing (10 cm) gave lower number of grains ((540.30). According to Zamir *et al*. (2011), the highest 1000 kernels weight (253 g) was produced at 30 cm intra-row spacing followed by 25 cm intra-row spacing (249 g) and the lowest number of ears per plant (223 g) was produced at intra-row spacing of 15 cm. Plant spacing of 30 cm produced more number of kernels per ear (416.30) than that of 20 cm plant spacing (410.20) (Mahmood *et al.*, 2001). Similar results have also been reported by Gambin *et al.*, (2006), Malaviarachchi *et al*. (2007) and Arif *et al*. (2012) who reported that number of kernels per ear decreased with increase in plant density of maize. Tetio-kagho and Gardner (1988) and Andrade, *et al*. (1993) had also reported that kernel number per plant declines sharply when the plant density increases which support our research finding.



Here, S_1 = 50 cm x 20 cm; S_2 = 50 cm x 25 cm; S_3 = 60 cm x 20 cm; S_4 = 60 cm x 25 cm

Figure 4.5.3: Effect of spacing on 100-grain weight; grain yield per plant; stover yield per plant; biological yield and harvest index of white maize

4.5.10. 100-grain weight

100-grains weight is also important yield attributes which determine the yield potential of crop. 100-grain weight showed significant differences due to different plant spacing (Figure 4.5.2).). Data revealed that, the highest 100-grain weight was found from S_4 (420.49 g) followed by S_2 (394.53 g) which was statistically at par with S_3 (394.53 g). The lowest 100-grain weight was obtained from S_1 (369.79 g) treatment. With increased inter and intra-row spacing, thousand kernel weight decreased. This decrease might be because of assimilates partitioning between higher numbers of kernels used in connection with the decreased inter plant competition that lead to increased plant capacity, for utilizing the environmental inputs in building great amount of metabolites to be used in developing new tissues and increasing its yield components. In addition, wider spaced plants, that improved the supply of assimilates to be stored in the kernel hence, the weight of thousand kernel increased. The present result was in line with that of Mahmood *et al.* (2001) who reported that plant spacing of 30 cm produced significantly higher 1000 kernels weight than 10 cm plant spacing. The result was in agreement with Ogunlela *et al.* (2005), Arif *et al.* (2010) and Mukhtar *et al*. (2012) who reported that 1000 kernels weight decreased with increase in plant density. The result was supported by Biswas K. and Quayyum M. A (1991), where they found that decreased 100-grain weight with decreasing spacing.

4.5.11. Grain weight plant $^{-1}$

The plant spacing significantly influenced the grain weight plant $^{-1}$ of white maize (Figure 4.7.3). The highest grain weight plant $^{-1}$ (174.67 g) was recorded from S_4. Treatments S_2 (159.67 g) and S_3 (155.87 g) produced medium grain weight plant $^{-1}$ which were statistically similar to each other. The lowest grain weight plant $^{-1}$ (138.00 g) was observed from S_1. In general, at all intra-row spacing, grain yield per plant increased with increase in inter-row spacing. Increase in grain yield per plant at wider spacing is not surprising because lower plant density exerts lesser interplant competition for space as well as growth factors. Furthermore, greater yield per plant in present investigation at wider spacing resulted from higher 100 kernel weight and higher number of kernels per ear at wider spacing combinations. The result of this study was in agreement with Ahmad *et al*. (2006) who reported that increasing plant population reduced yield of individual plants but increased yield per unit area of maize. Similarly, Gozubenli *et al.* (2004) reported that grain yield per plant increased with the increase of inter and intra-row spacing. This result was also in line with Eskandarnejada *et al.* (2013) who obtained decreased grain yield per plant under narrower inter and intra- row spacing on maize. The results are also in agreement with findings of .Abuzar *et al.* (2011) where they observed the minimum grain yield per plant at the highest population densities. Luque *et al* (2006) also found that grain yield per plant is decreased due to decreasing light and other environmental resources. A similar trend in yield differences across planting density had been reported by Zhang *et al*., 2006. Xue, *et al*..(2002) also reported that grain yield increased with increase plant density. Moriri *et al..(*2010) also found that high plant density causes stress to plants and reduces plant growth in maize resulting lower yield per plant.

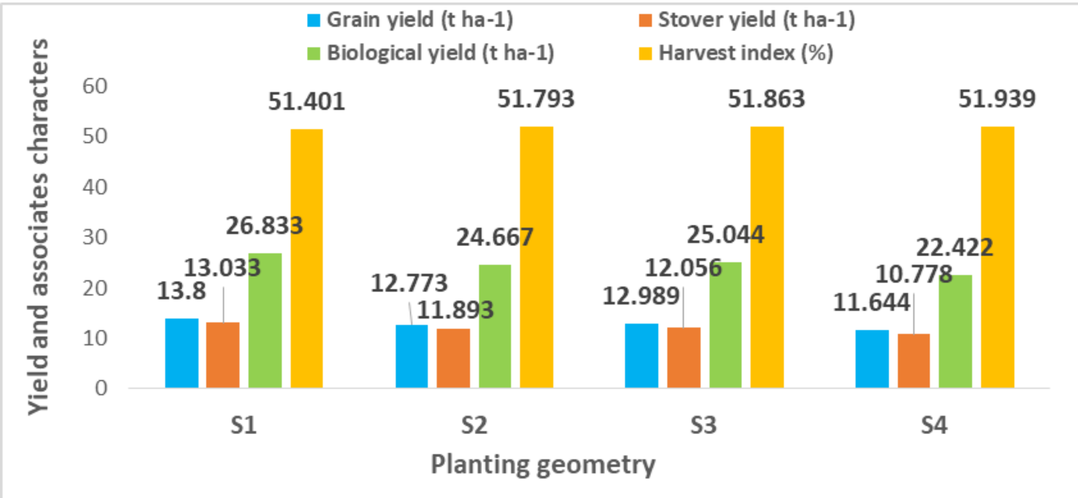
4.5.12. Stover yield per plant

Stover weight plant $^{-1}$ was affected significantly by the plant spacing treatments (Figure 4.5.3). S_4 produced maximum stover weight plant $^{-1}$ (161.67 g). The medium stover weight plant $^{-1}$ was obtained from S_2 (148.67g) and S_3 (144.67 g) respectively which were statistically similar to each other while the minimum stover weight plant $^{-1}$ was achieved with S_1 (130.33 g).

4.5.13. Grain yield per hectare

Grain yield is the main target of crop production. Grain yield per hactare varied significantly due to plant spacing of white maize. Data on grain yield was presented in figure 4.5.3. It was observed that, the highest grain yield per hectare (13.800 t ha^{-1}) was achieved with the treatment S_1 which was statistically similar to S_3 and S_4 (12.989 t ha^{-1} and 12.773 t ha^{-1} respectively) whereas the lowest grain yield per hectare (11.644 t ha^{-1}) was produced with the treatment S_4. Similar type of findings were reported by Barthakur., *et al.* (1975) in his experiment where it was observed that narrow inter-row spacing (50 cm) resulted higher yield than wider inter- row spacing (75 cm). Verma and Singh (1976) had reported that grain yield of spring maize was significantly improved with the increase in plant population from 65000 plants plants ha-^{1} to 85000 plants ha-^{1} on sandy loam soils of Agra, India. Eskandarnejada *et al*. (2013) also reported that higher grain yield of maize (15.25 t ha-1) was obtained at narrower (55 cm x 20 cm) spacing than at wider (75 cm x 30 cm) spacing which is 11.43 t ha-1. Mukhtar *et al.* (2012) showed that higher grain yield of maize (8.370 t ha-1) was obtained with 12.50 x 70 cm spacing while lower (6.646 t ha-1) at 17.50 cm x 70 cm spacing. According to their result at higher plant density, overall grain yield of maize increased due to increasing number of ears per hectare. Similarly, Farnham (2001) reported that maize grain yield increased from 10.1 to 11.2 t ha-1 as plant density increased from 59,000 to 89,000 plant ha$^{-1.}$ A similar trend in yield across planting density has been observed by Malaviarachchi *et al*. (2007) who reported that grain yield increased with increasing maize plant density. Yousaf *et al.* (2007) reported that the highest grain yield produced at narrow spacing of 45 cm x 25 cm (88,888 plants ha-1) and the lowest grain yield was recorded for 75 cm x 30 cm spacing (44,4,44 plants ha-1). Similar results have been reported by, Fulton (1990), Naraqanaswamy *et al.* (1994), Baron *et al.* (2001) and Arif *et al.* (2010) on maize spacing trial.

Similar effect of spacing on grain yield was also reported by (Biswas and Quayyum, 1991, Wei and Leiu 1984). The closest spacing put the crop under high intra and inter-specific competition cause low rate of nutrient absorbing and capturing at vegetative and grain filling stages, resulting in relatively low magnitude of all the yield attributes coupled with shortening of crop life and forced maturity during vegetative phase and maturity adversely affected plant height, the number of cob per plant and the number of grains per cob, which ultimately reduced the grain yield per plant. On the other hand, the higher yield obtained from S_1 and S_2 condition were mainly favored for all supportive factors, probably supported the physiological processes and thereby attributed to higher number of plant per hectare lead to higher number of cob per hectare as well as higher number of total grains per hectare and higher 100 grain weight. Bahadur *et al.*, (1999) also found similar results in their experiments.



Here, S_1 = 50 cm x 20 cm; S_2 = 50 cm x 25 cm; S_3 = 60 cm x 20 cm; S_4 = 60 cm x 25 cm

Figure 4.5.4: Effect of spacing on grain yield; stover yield; biological yield and harvest index of white maize

4. 5. 14. Stover yield

Different plant spacing showed statistically significant differences in terms of stover yield of white maize (Figure 4.5.4). Data revealed that the highest stover yield (13.800 t ha^{-1}) was observed from S_1 which was statistically similar with S_3 and S_4 (12.989 t ha^{-1} and 12.773 t ha^{-1}) whereas the lowest stover yield (11.644 t ha^{-1}) was obtained from S_4. Park et al., (1989) reported that increasing plant density linearly increased stover yield.

4.5.15. Biological yield

Biological yield is the total biomass produced by the plant during its life cycle. Biological yield influenced significant by the different plant spacing treatments

(Figure 4.5.4). The highest biological yield (26.833 t ha^{-1}) was significantly found from S_1 and followed by S_3 (25.044 t ha^{-1}) and S_2 (24.667 t ha^{-1}) which were statistically similar to each other. Again the lowest biological yield (22.422 t ha^{-1}) was recorded from S_4 . Miko and Manga (2008) showed that higher sorghum dry biomass yield was obtained at narrow inter row spacing. When the intra-row spacing become narrower from 30 cm to 20 cm, the biomass yield per ha increased significantly while intra-row spacing of 20 cm and 25 cm were at par with each other. This might be due to higher plant population recorded at narrow inter and intra-row spacing and hence greater dry matter production. In agreement with this result Mahmood *et al.* (2001) showed that total biomass yields of maize were significantly higher in the narrow intra-row spacing (20 cm) than in wider intra-row spacing (30 cm) due to more number of taller plants per unit area and better interception of solar radiation. According to Yousaf *et al*. (2007), maize planted at 45 cm row spacing produced 14% and 34 % higher total above ground dry biomass than that of 60 and 75 cm row spaced sown crop, respectively. Plant spacing of 15 cm produced 42% and 22% higher above ground dry biomass than that recorded for 30 cm and 22.5 cm plant spacing, respectively. Similarly, Gobeze *et al.* (2012) reported that the highest biomass was recorded at row spacing of 25 cm with plant density of 10 plants m2 and followed by the same row spacing with plant density of 12.5 plants m2 while the lowest biomass was observed at row spacing of 90 cm with plant density of 5 plants m2.

4.5.16. Harvest index

Harvest index is an important parameter indicating the efficiency in partitioning of dry matter to economic part of the crop. The harvest index did not influence significantly by the plant spacing treatments (Figure 4.5.4). Although having non-significant effects the highest harvest index (51.939%) was found from S_4 followed by S_3 (51.863%) and S_2 (51.793%) and the lowest harvest index was recorded (51.401%) from S_1. In agreement with this result Eskandarnejada *et al.* (2013) showed that intermediate inter-row spacing gave significantly higher harvest index of maize than both lower and higher inter-row spacing. Similarly, Yousaf *et al*. (2007) reported that harvest index initially increased with increasing plant and row spacing but declined when plant density increased further. The reasons for such results could be better utilization of available nutrients by maize plants in highest plant population as compared to lowest plant population. In lowest plant population, weeds also compete with crop for nutrients. Similarly grain become a dominant sink at their maturity stage and the entire photo assimilate deposited in the grains as compared to other parts of the plant. Highest plant population produced more grain and thus resulted in maximum harvest index. Ahmad & Khan (2002) reported that increase in plant density significantly increased harvest index. Mobasser *et al.,* (2007) reported that harvest index in rice declines when plant density increases above the critical plant density. The yield/plant may be reduced due to the effects of interplant competition between plants for using of light, water, nutrients and other yield-limiting environmental factors. Similar results was reported by Li *et al*., (2007) in maize hybrids of their experiment.

4.6. Experiment 6: Performance of white maize (var.PSC-121) under varying planting geometry at Dhamrai Upazilla, Dhaka (rabi 2016-17)

4.6.1. Plant height

Plant height showed statistically significant differences due to different plant spacing (Figure 4.6.1). Data revealed that, the tallest plant was observed from S_1 (275.67cm) which was statistically similar to S_2 and S_3 (265.67cm and 262.33 cm) whereas the shortest plant was found from S_4 (255.00 cm).

4.6.2. Days to first tasseling

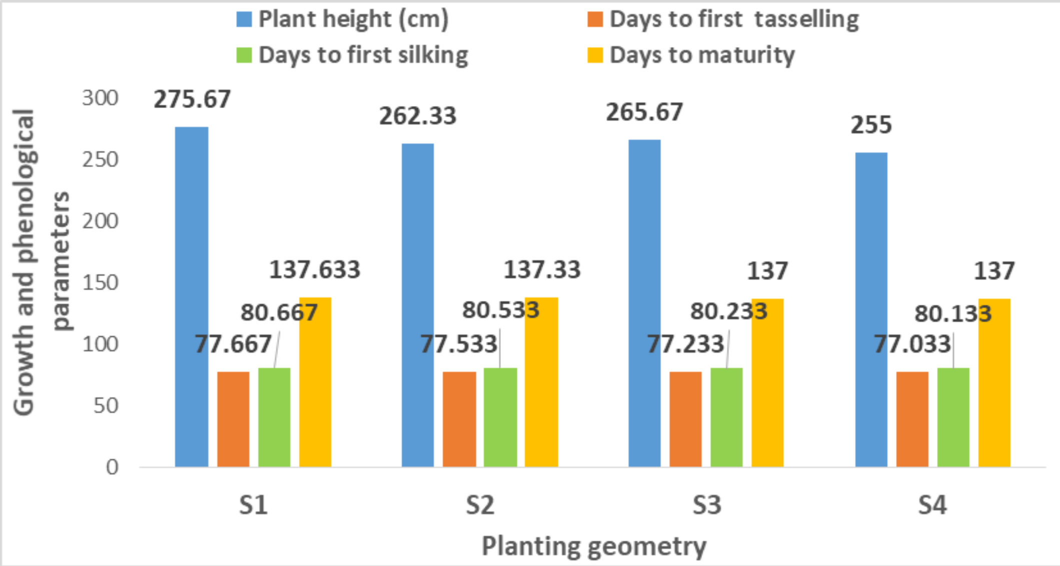
Different plant spacing showed statistically non-significant effect on days to first tasseling (Figure 4.6.1). Although having non-significant effect, S_4 spacing took more days to tasseling S_1 (77.667 days) followed by S_2, S_3 and S_4 (77.333 days, 77.333 days and 77.333 days).

4.6.3. Days to first silking

Different plant spacing showed statistically non-significant difference on days to first silking(Figure 4.6.1). Spacing S_4 took more days to silking S_1 (80.667 days) followed by S_2, S_3 and S_4 (80.333 days, 80.333 days and 80.333days).

4.6.4. Days to maturity

Plant spacing showed non-significant effect on days to maturity of white maize (Figure 4.6.1). Data revealed that, S_1 took more days to be matured (135.67 days) followed by S_2, S_3 and S_4 (137.00 days, 137.00 days and 137.00 days).



Here, S_1 = 60 cm x 25 cm, S_2 = 60 cm x 20 cm, S_3 = 50 cm x 25 cm, S_4 = 50 cm x 20 cm

Figure 4.6.1 Effect of plant spacing on plant height, days to tasseling, days to silking and days to maturity of white maize

4.6.5. Cob length

Statistically significant differences was found among the plant spacing treatments on the production of cob length of white maize (Figure 4.6.2). Cob length was increased with increasing plant spacing. Among the plant spacing treatments, S_1 produced the highest cob length (16.033 cm) which were statistically similar to S_3 (15.433 cm) and closely followed by S_2 (15.167 cm). Again the lowest ear length (14.033 cm) was recorded from S_4.

4.6.6. Number of rows cob^{-1}

Number of rows cob^{-1} showed statistically significant differences due to different plant spacing (Figure 4.6.2). The highest number of rows cob^{-1} (13.867) was observed from S_1 which was statistically similar to S_3 (13.333) and S_2 (13.267), while the lowest number of rows cob^{-1} (12.900) was found from $S_{1.}$

4.6.7. Number of grains row^{-1}

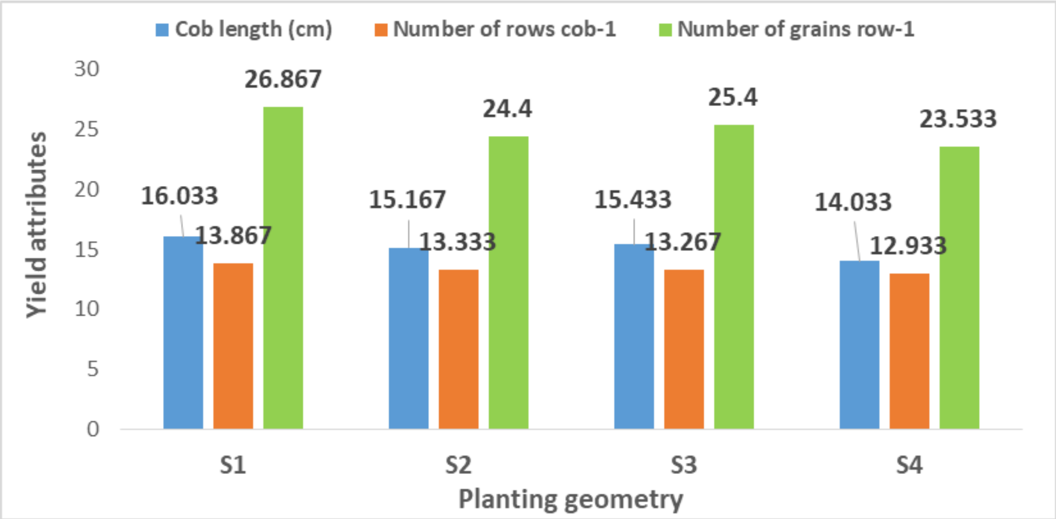
Number of grains rows^{-1} was significantly affected by the plant spacing (Figure 4.6.2). Number of grains rows^{-1} was increased with the increasing spacing levels. It was revealed from the mentioned Figure that, the maximum grains rows^{-1} was observed from S_1 (26.867) which was statistically similar to S_2 and S_3 (24.400 and 25.400) while the minimum grains rows^{-1} was found from S_4 (23.533).

4.6.8. Total grains cob^{-1}

Total grains cob^{-1} showed statistically significant differences due to different plant spacing (Figure 4.6.2). Among the treatments S_1 showed the highest total grains cob^{-1} (386.64) which was statistically as par with the treatments of S_3 and S_2 and (372.04 and 349.65) whereas the lowest grains cob^{-1} (335.81) was produced by S_4.

4.6.9. 100-grain weight

Plant spacing treatments showed statistically the significant effects on 100-grain weight (Figure 4.6.3), where the maximum 100-grain weight (33.667 g) were found S_4 which were statistically similar to S_2 and S_3 (32.667 g and 32.000 g) treatments while the minimum 100-grain weight were found from the S_4 (31.66 g).



Here, S_1= 60 cm x 25 cm, S_2 = 60 cm x 20 cm, S_3 = 50 cm x 25 cm, S_4 = 50 cm x 20 cm

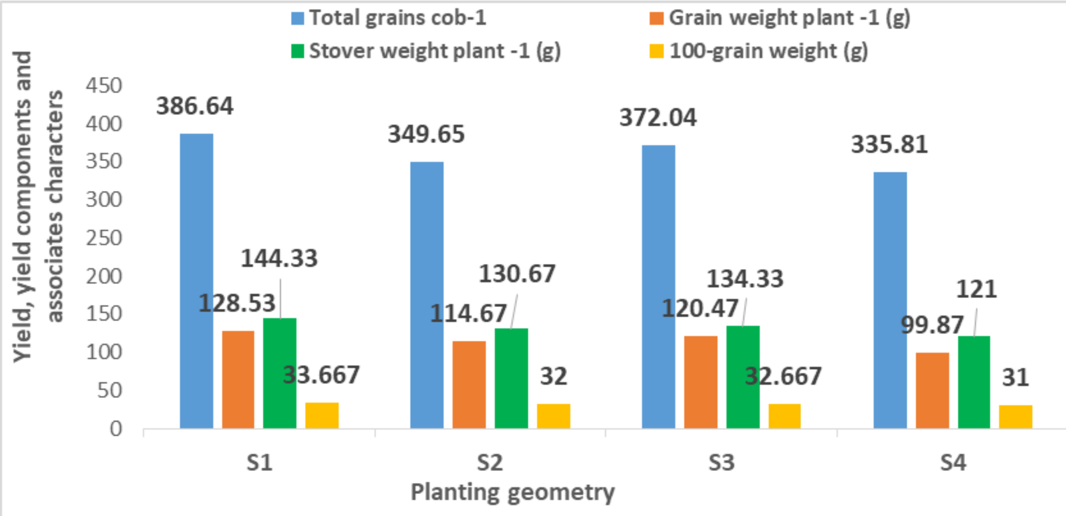
Figure 4.6.2: Effect of spacing on cob length, number of rows cob,$^{-1}$ number of grains row,$^{-1}$ and total grains cob^{-1} of white maize

4.6.10. Grain weight plant $^{-1}$

Plant spacing treatments showed statistically significant effects on grain weight plant^{-1}(Figure 4.6.3) where the maximum grain weight plant^{-1} (128.53 g) was observed from the treatment S_1 which was statistically similar to S_2 (120.47 g) and closely followed by S_3 (114.67 g). Again the minimum grain weight plant $^{-1}$ (99.93 g) was found from the treatment S_4.

4.6.11. Grain yield

Statistically significant variation was observed for different plant spacing treatments in terms of grain yield (Figure 4.6.4). Maximum grain yield was achieved with the treatment S_4 (9.9067 t ha^{-1}) and S_4 (9.6800 t ha^{-1}) which was statistically similar to S_2 (9.4500 t ha^{-1}) and S_5 (9.5573 t ha^{-1}) the minimum grain yield (8.7467 t ha^{-1}) were achieved from the treatment S_1



Here, S_1= 60 cm x 25 cm, S_2 = 60 cm x 20 cm, S_3 = 50 cm x 25 cm, S_4 = 50 cm x 20 cm

Figure-4.6.3: Effect of spacing on 100-grain weight; grain weight plant $^{-1}$ and stover weight plant^{-1}of white maize

4.6.12. Stover weight plant^{-1}

Stover weight per plant significantly influenced by the different plant spacing treatments in white maize (Figure 4.6.3). The highest stover yield per plant (144.33 g) was recorded from S_4, which was statistically similar to S_3 (134.33 g) followed by S_2 (130.67 g) treatment while the lowest stover yield per plant was found in S_4 (121.00 g)

4.6.13. Stover weight

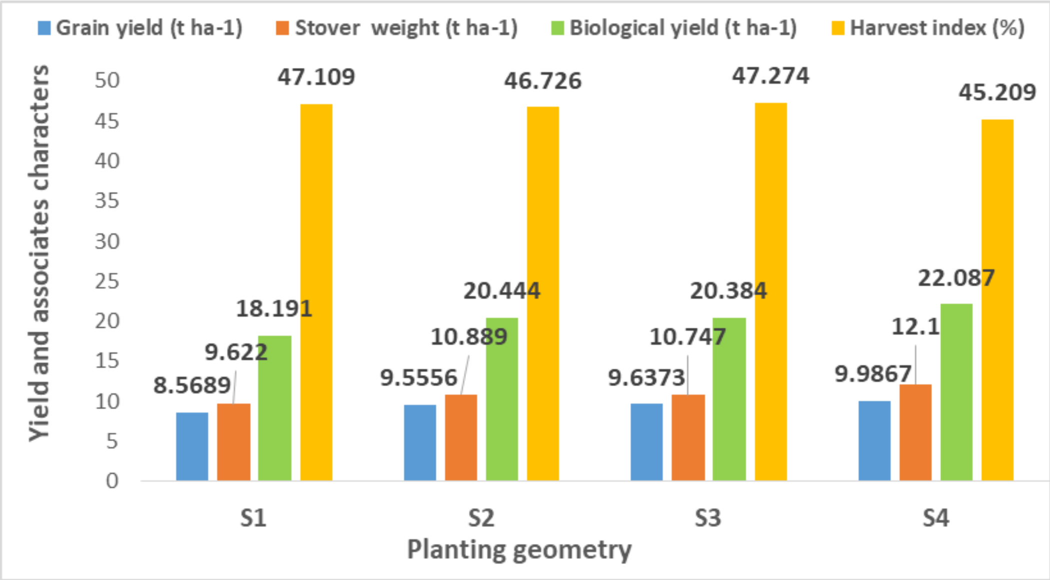
Stover yield showed statistically significant differences due to different plant spacing treatments of white maize (Figure 4.6.4). The highest stover yield (12.100 t ha^{-1}) was observed in S_4 followed by S_2 (10.889 t ha^{-1}) and S_3 (10.747 t ha^{-1}) treatments and lowest value (9.622 t ha^{-1}) was found from S_1.

4.6.14. Biological yield

Biological yield varied significantly due to different plant spacing treatments (Figure 4.6.4). The maximum biological yield (22.087 t ha^{-1}) was obtained from S_4 treatments, followed by S_2 (20.444 t ha^{-1}) and S_3 (20.384 t ha^{-1}) while the lowest biological yield was found from S_1 (18.191 t ha^{-1}).

4.6.15. Harvest index

Plant spacing treatments showed statistically significant effect on harvest index (Figure 4.6.4). Among the treatments, S_1 showed the highest harvest index (47.109 %), which was statistically similar to S_2 and S_3 (47.274 % and 46.726 %) where S_4 showed the lowest harvest index (45.209 %).



Here, S_1 = 60 cm x 25 cm, S_2 = 60 cm x 20 cm, S_3 = 50 cm x 25 cm, S_4 = 50 cm x 20 cm

Figure 6.4.4: Effect of plant spacing on grain yield, stover weight, biological yield and harvest index of white maize

4.7. Experiment 7: Performance of white maize (var. PSC-121) under varying planting geometry at Rangpur district (rabi 2016-17)

4.7.1. Plant height

Plant height is an important component which helps to determine the growth attained during the growth period. Plant height showed statistically significant differences due to different plant spacing (Figure 4.7.1). The highest plant height was recorded from S_4 ((301.67 cm) which was statistically similar to S_2 and S_3 (298.33 cm and 294.00 cm) plant spacing treatments while the lowest plant height was found from S_1 (286.00 cm). due to crowding effect of the plant and higher intra specific competition for resources. This trend explains that as the number of plants increased in a given area the competition among the plants for nutrients uptake and sunlight interception also increased (Sangakkara *el al.*, 2004). Similar result was also reported by Bahadur *et al*. (1999) where they noticed that higher plant height were recorded in higher spacing and lower plant height was found in lower plant spacing in maize.

4.7.2. Days to first tasseling

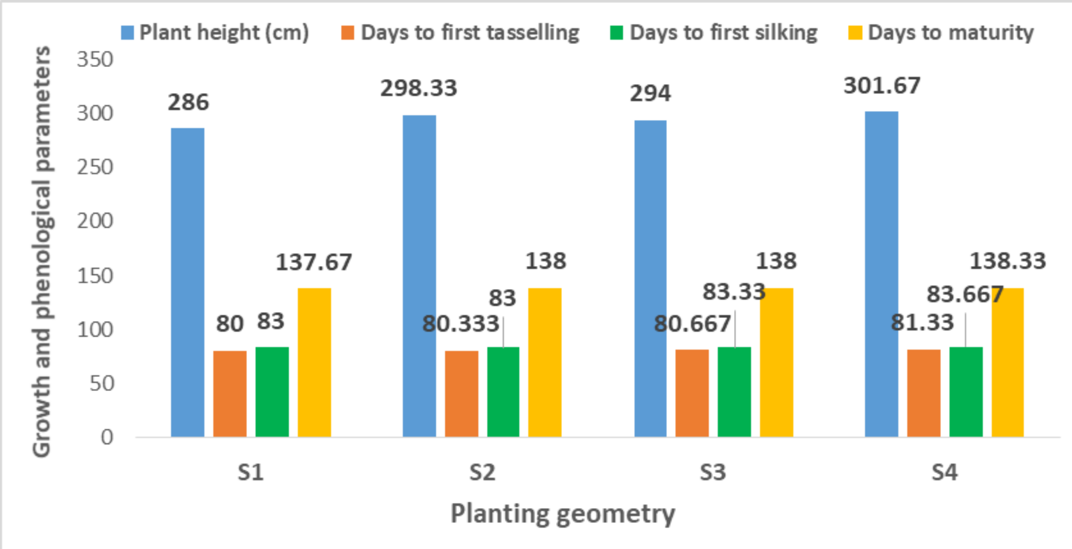
Different plant spacing showed statistically non-significant difference on days to first silking (Figure 4.7.1). Although having non-significant effect, S_4 spacing took more days to tasseling (81.333 days) followed by S_2 S_3 and S_1 (81.000 days, 81.000 days and 81.000 days).

4.7.3. Days to first silking

Days to first silking did not influence significantly by the plant spacing treatments (Figure 4.7.1). Spacing S_4 took more days to first silking (83.33 days) followed by $S_{2,}$ S_3 and S_1 (83.00 days, 83.00 days and 83.00 days).

4.7.4. Days to maturity

Days to maturity did not influence significantly by the plant spacing (Figure 4.7.1). Spacing S_2, S_3 and S_4 took same days to be matured (138.00 days, 138.00 days and 138.00 days) while S_1 took lowest days to be matured (137.67 days).



Here, S_1 = 50 cm × 20 cm, S_2 = 50 cm × 25 cm, S_3 = 60 cm × 20 cm, S_4 = 60 cm × 25 cm

Figure 4.7.1: Effect of plant spacing on plant height, days to first tasselling, days to first silking and days to maturity of white maize

4.7.5. Cob length

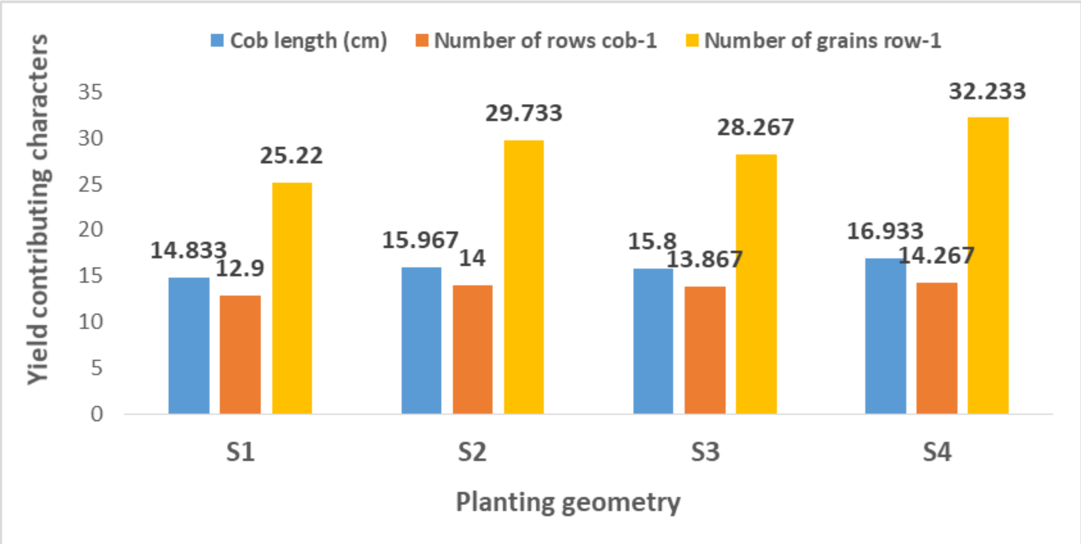
Statistically significant differences were observed on cob length due to various plant spacing treatments of white maize (Figure 4.7.2). Cob length was increased with the plant spacing increases. Among the plant spacing treatments, the highest ear length was found from S_4 (16.933 cm), which was statistically similar to S_2 and S_3 (15.967 cm and 15.800 cm) while the lowest cob length was observed S_1 (14.833 cm). The present result was supported by the findings of Biswas K, Quayyum M. A., (1991) and Johnson D.E, Wilman D., (1997). They found that higher plant densities produced smaller cob compared with the traditional plant density of maize.

4.7.6. Number of rows cob^{-1}

Number of rows cob^{-1} showed statistically significant differences due to different plant spacing (Figure 4.7.2). The highest number of rows cob^{-1} (14.267) was observed from S_4 which was statistically similar to S_2 (14.000) and S_3 (13.867), while the lowest number of rows cob^{-1} was found from S_1 (12.900). The result was supported by Shams *et al* (2002).The number of grain rows per cob decreased as the plant population increased. Usually under high population stress, the late developing distal spikelets fail to set kernels and when the slow growing silks finally emerge, little or no pollen is available for fertilization. Also, high stand density reduces ear shoots growth, which results in fewer spikelets primordial was transformed into functional florets by the time of flowering. The limited carbon and nitrogen supply to the cob finally stimulates young kernel abortion immediately after fertilization (Sangoi L., 2001)

4.7.7. Number of grains row^{-1}

The number of grains per row is an important yield parameter. Different plant spacing showed statistically significant difference on number of grains per row (Figure 4.7.2) Number of grains per row increased with increasing spacing. Among the plant spacing treatments, the maximum number of grains per row was recorded from S_4 (32.233), which was statistically as par with S_2 (29.733) and S_3 (28.267), while the lowest number of grains per row was obtained from S_1 (25.220). These result was supported by the findings of Abuzar *et al.* (2011) and Andrade *et al.* (1993) where they observed that an increase in plant density decrease the number of grains per row in maize.



Here, S_1 = 50 cm× 20 cm, S_2 = 50 cm × 25 cm, S_3 = 60 cm× 20 cm, S_4 = 60 cm × 25 cm

Figure 4.7.2 Effect of plant spacing on cob length, number of rows cob^{-1} and number of grains row^{-1} of white maize

4.7.8. Total grains cob^{-1}

Total grains cob^{-1} varied significantly due to plant spacing under the present trial (Figure 4.7.3). Data revealed that the highest total grains (460.93) cob^{-1} was observed from S_4 which was statistically as par with S_2 (441.07) and followed by S_3 (419.33) while the lowest total grains (36.2) was found from S_1 (374.13). The decreased kernels number per ear in the spacing of 50 cm x 20 cm might be nutrient competition due to less space per plot in the experiment. Tetio-kagho and Gardner (1988) and Andrade, *et al.*(1993) had also reported that kernel number per plant declines sharply when the plant density increases which support our research finding.

4.7.11. 100-grain weight

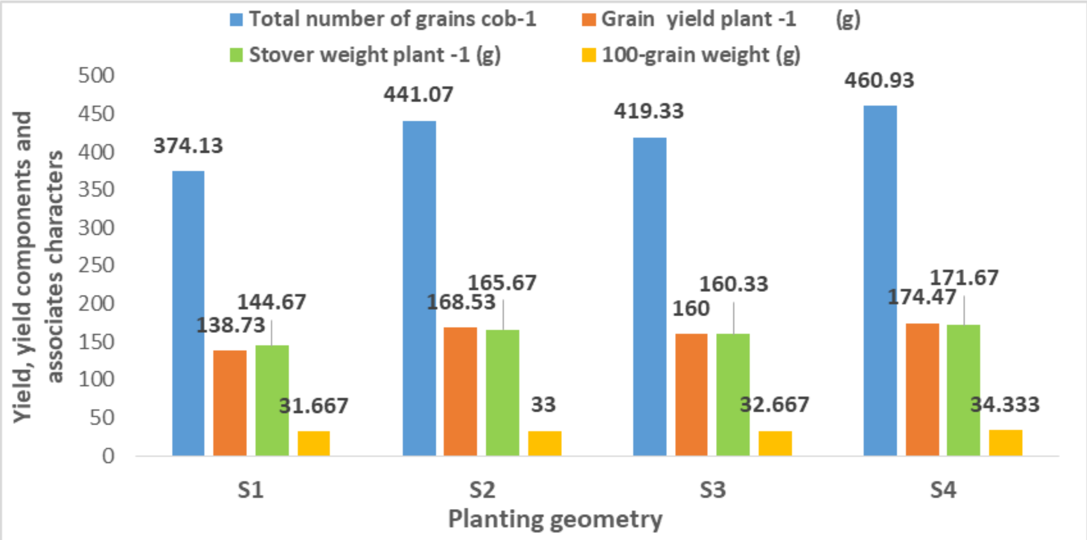
100-seed weight showed statistically significant differences due to different plant spacing (Figure 4.7.3). Data revealed that the highest weight of 100-grain (34.333 g) were found from S_4 treatment, which were statistically similar to S_2 (33.00 g) and S_3 (32.667 g) while the minimum weight of 100-grain (31.667 g) was obtained from the treatment S_1. The result was supported by Biswas and Quayyum (1991), where they found that decreased 100-grain weight with decreasing spacing.

4.7.9. Grain weight plant $^{-1}$

Statistically significant variation was observed for different plant spacing in terms of grain yield per plant (Figure 4.7.3). The highest grain yield per plant (174.87 g) was recorded from S_4 which was statistically similar to S_2 (168.53 g) and followed by S_3 (160.00 g) while the lowest grain yield per plant was obtained from S_1 (138.73 g). The results are also in agreement with findings of .Abuzar *et al.* (2011) where they observed the minimum grain yield per plant at the highest population densities. Luque *et al*. (2006) also found that grain yield per plant is decreased due to decreasing light and other environmental resources. A similar trend in yield differences across planting density had been reported by Zhang et al., 2006. Xue, *et al.* (2002) also reported that grain yield increased with increase plant density. Moriri *et al*. (2010) also found that high plant density causes stress to plants and reduces plant growth in maize resulting lower yield per plant.

4.7.12. Stover yield per plant

Different plant spacing showed statistically significant difference on stover yield per plant (Figure 4.7.3). The highest stover yield plant^{-1} (171.67 g and 165.67 g) were observed in S_4 and S_2 treatments, which were statistically similar to each other. S_3 (160.33 g) was produced medium stover yield plant^{-1} followed by S_1 (144.67 g), which was the lowest stover yielder.



Here, S_1 = 50 cm × 20 cm, S_2 = 50 cm × 25 cm, S_3 = 60 cm × 20 cm, S_4 = 60 cm × 25 cm

Figure 4.7.3 Effect of plant spacing on total number of grains cob,$^{-1}$ grain yield per plant; stover yield per plant and 100- grain weight of white maize

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

Grain yield is the main target of crop production. Different plant spacing showed statistically significant differences on grain yield and data was presented in Figure 4.7.4. It was observed that maximum grain yield (13.873 t ha^{-1}) was achieved with the treatment S_1 which was statistically similar to S_2 and S_3 (13.483 t ha^{-1} and 13.333 t ha^{-1}) and the minimum grain yield (11.631 t ha^{-1}) was found from treatment S_4. Similar type of findings were reported by Barthakur., *et al.* (1975) in his experiment where it was observed that narrow inter-row spacing (50 cm) resulted higher yield than wider inter- row spacing (75 cm). Verma and Singh (1976) had reported that grain yield of spring maize was significantly improved with the increase in plant population from 65000 plants plants ha-^{1} to 85000 plants ha^{-1} on sandy loam soils of Agra, India.

Similar effect of spacing on grain yield was also reported by (Biswas and Quayyum 1991, Wei and Leiu 1984). The closest spacing put the crop under high intra and inter-specific competition cause low rate of nutrient absorbing and capturing at vegetative and grain filling stages, resulting in relatively low magnitude of all the yield attributes coupled with shortening of crop life and forced maturity during vegetative phase and maturity adversely affected plant height, the number of cob per plant and the number of grains per cob, which ultimately reduced the grain yield per plant. On the other hand, the higher yield obtained from S_1 and S_2 condition were mainly favored for all supportive factors, probably supported the physiological processes and thereby attributed to higher number of plant per hectare lead to higher number of cob per hectare as well as higher number of total grains per hectare and higher 100 grain weight. Bahadur *et al.,* (1999) also found similar results in their experiments.

4.7.13. Stover yield

Different plant spacing showed statistically significant difference on straw yield (Figure
4.7.4). The highest stover yield (14.467 t ha^{-1}) was recorded from S_1 treatment and the medium stover yield was found from S_3 (13.361 t ha^{-1}) and S_2 (13.253 t ha^{-1}) treatments which were statistically similar to each other while the lowest stover yield (11.444 t ha^{-1}) was obtained from the treatment S_1. Park *et al.,* (1989) reported that increasing plant density linearly increased stover yield.

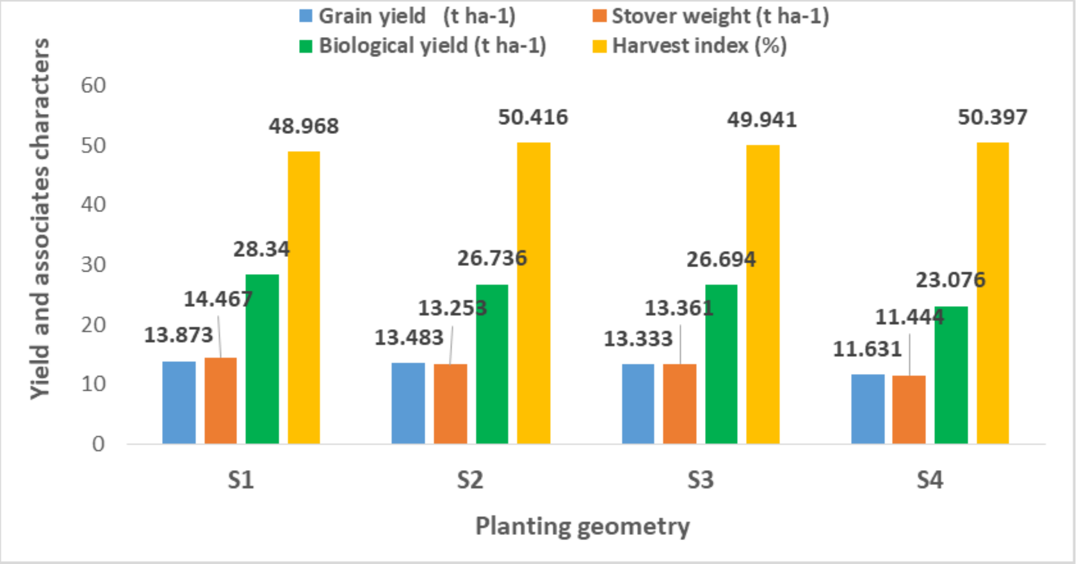
4.7.14. Biological yield

Biological yield showed statistically significant difference due to different plant spacing (Figure 4.7.4). The maximum biological yield (28.340 t ha^{-1}) were observed from S_1 treatment and medium biological yield (26.736 t ha^{-1} and 26.694 t ha^{-1}) were obtained from S_2 and S_3 treatments which were statistically similar to each other whereas S_4 was the lowest biological yielder (23.076 t ha^{-1}).

4.7.15. Harvest index

The physiological efficiency and ability of a crop for converting the total dry matter into economic yield is known as harvest index (HI). Different plant spacing showed statistically non-significant difference on harvest index (Figure 4.7.4). The highest harvest index were recorded from S_2 (50.416 %) followed by S_4 (50.397 %), and S_3

(49.941 %) treatments and the lowest harvest index was found from S_1 (48.968 %) treatments. The reasons for such results could be better utilization of available nutrients by maize plants in highest plant population as compared to lowest plant population. In lowest plant population, weeds also compete with crop for nutrients. Similarly grain become a dominant sink at their maturity stage and the entire photo assimilate deposited in the grains as compared to other parts of the plant. Highest plant population produced more grain and thus resulted in maximum harvest index. Ahmad & Khan (2002) reported that increase in plant density significantly increased harvest index. Mobasser *et al.*, (2007) reported that harvest index in rice declines when plant density increases above the critical plant density. The yield/plant may be reduced due to the effects of interplant competition between plants for using of light, water, nutrients and other yield-limiting environmental factors. Similar results was reported by Li *et al*., (2007) in maize hybrids of their experiment.



Here, S_1 = 50 cm × 20 cm, S_2 = 50 cm × 25 cm, S_3 = 60 cm × 20 cm, S_4 = 60 cm × 25 cm

Figure 4.7.4 Effect of plant spacing on grain yield, stover weight, biological yield and harvest index

6.4.8. Experiment 8: Performance of different white maize varieties as influenced by different levels of irrigation at SAU, Dhaka (rabi 2016-17)

4.8.1. Plant height

4.8.1.1 Impact of irrigation

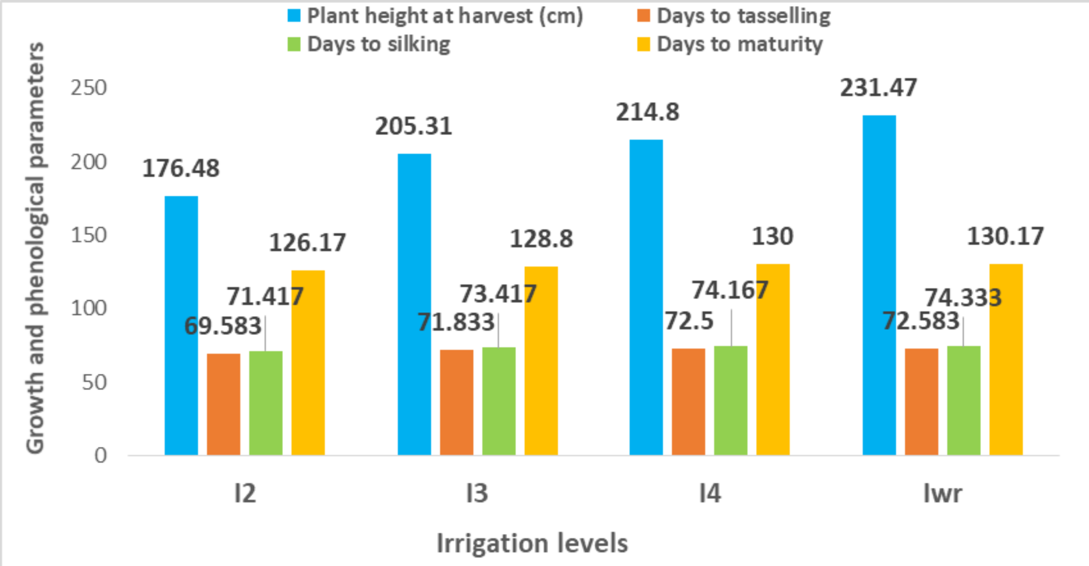
Irrigation levels showed significant effect on plant height (Figure 4.8.1). The plant height increased with the increasing irrigation levels. Among the various irrigation treatments, I_{wr} (irrigation when required) produced tallest plant (231.47 cm) followed by I_4 (214.87 cm) and I_3 (205.31 cm) but the shortest plant was found for I_2 (176.48 cm).

4.8.1.2 Impact of varieties

Plant height was showed statistically significant differences due to different white maize varieties. The highest plant height (223.52 cm) was observed in PSC and the shortest plant height was recorded with Changnuo-1 (196.95 cm). (Figure 4.8.2).

4.8.1.3 Interaction effect of irrigation and varieties

The Interaction effect of irrigation and variety showed significant impact on plant height (Table 4.8.1). The maximum plant height (245.80 cm) was found from $I_{wr}V_1$ which was statistically similar with I_4V_1 (234.60 cm) and the minimum plant height (148.07 cm) was observed from I_2V_2. Likewise $I_{wr}V_3$ had significantly longer plants (231.80 cm) than that of $I_{wr}V_4$ (227.80 cm) and followed by I_4V_3 (221.00 cm) and $I_{wr}V_2$ (220.47 cm). Irrigation plays a vital role in vegetative growth of plant and causing improvement plant height. Findings of present study are similar to the findings of Yazar *et al*. (2012) those who observed highest maize plant height in full irrigation (three times). Similarly, Otegui *et al. (*2005) suggested that, maize crop are highly sensitive to drought stress conditions. The application of less water negatively responded on the plant height (crop sensitivity to drought stress) subsequently reducing the grain yield (English, 2010). It was reported by various researchers that various plant growth attributes were reduced under different water stress conditions (Al-Ashkar *et al*., 2016; Hassan et al., 2016; Rashwan *et al.*, 2016).



Here, I_2 = 25 DAS +75 DAS, I_3 = 25 DAS + 50 DAS + 75 DAS,

I_4 = 25 DAS + 50 DAS + 75 DAS + 100 DAS, I_{wr} = Irrigation when required

Figure 4.8.1 Effect of irrigation levels on plant height, days to tasseling, days to silking and days to maturity

4.8.2. Days to first tasseling

4.8.2.1. Effect of irrigation

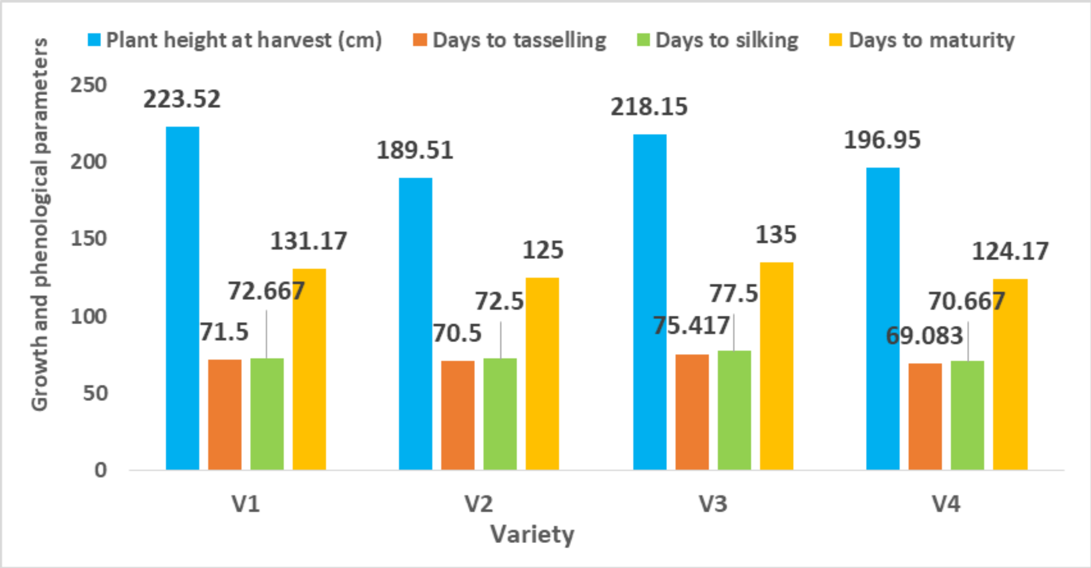
Irrigation levels showed statistically significant effect on days to tasseling (Figure 4.8.1). Among the irrigation levels, I_{wr} (Irrigation when required) took significantly maximum days for tasseling (72.583 days) which was statistically similar with I_4 (72.50 days) while I_2 took minimum days for tasseling (69.583 days)

4.8.2.2. Effect of varieties

Days to tasseling showed statistically significant differences due to different white maize varieties (Figure 4.8.2). V_3 took significantly more days for tasseling (75.417 days) whereas V_4 took significantly less days for tasseling (69.083 days). Likewise V_1 took significantly more days for tasseling (71.500 days) than that of V_2 (70.500 days).

4.8.2.3. Interaction effect of irrigation and varieties

The Interaction effect of irrigation and variety showed significant impact on days to tasseling (Table 4.8.1). The maximum days required for tasseling (76.667 days) was observed from $I_{wr}V_3$ which was statistically similar with I_4V_3 (76.667 days) whereas the minimum days for tasseling (67.667 days) was recorded from I_2V_4 which was statistically similar with I_2V_2 (68.333 days).



Here, V_1 = PSC, V_2 = Changnuo-1, V_3 = Youngnuo-30, V_4 = Changnuo-6

Figure 4.8.2 Effect of variety on plant height, days to tasseling, days to silking and days to maturity

4.8.3. Days to first silking

4.8.3.1. Effect of irrigation

Irrigation levels showed statistically significant impact on days to silking (Figure 4.8.1). Among the various irrigation levels, I_{wr} (Irrigation when required) took significantly maximum days for silking (74.333 days) which was statistically similar with I_4 (74.167 days) while I_2 took minimum days for silking (71.417 days).

4.8.3.2. Effect of varieties

Days to silking showed statistically significant differences due to different white maize varieties (Figure 4.8.2). V_3 took significantly more days for silking (77.500 days) whereas V_4 took significantly less days for silking (70.667 days). Likewise V_1 took significantly medium days for silking (72.667 days) which was statistically similar with V_2 (72.500 days)

4.8.3.3. Interaction effect of irrigation and varieties

Days to silking significantly influenced by the Interaction effect of irrigation and variety (Table 4.8.1). The highest days required for silking (76.667 days) was observed from $I_{wr}V_3$ which was statistically similar with I_4V_3 (78.667 days) and I_4V_3

(77.667 days) while the minimum days for silking (69.000 days) was recorded from I_2V_4.

4.8.4. Days to maturity

4.8.4.1. Effect of irrigation

Days to maturity_showed statistically significant variation due to effect of different irrigation level (Figure 4.8.1). I_{wr} (Irrigation when required) took significantly highest days to be matured (130.17 days) which was statistically similar with I_4 (130.00 days) while I_2 took lowest days to be matured (126.17 days). Likewise, V_1 took significantly more days to be matured (128.80 days) than that of V_2 (126.17 days)

4.8.4.2. Effect of varieties

Different varieties showed statistically significant variations on days to maturity of white maize (Figure 4.8.2). V_3 took significantly maximum days to be matured (77.500 days) whereas V_4 required significantly minimum days to be matured (124.17 days). Likewise, V_1 took significantly more days to be matured (131.17 days) than that of V_2 (125.00 days)

4.8.4.3. Interaction effect of irrigation and varieties

Days to maturity significantly influenced by the Interaction effect of irrigation and variety (Table 4.8.1). The highest days required to be matured (136.33 days) was found from $I_{wr}V_3$ which was statistically similar with I_4V_3 (136.33 days) while the minimum days took to be matured (121.33 days) was recorded from I_2V_4.

Table 4.8.1. Interaction effects of variety and irrigation levels on plant height, days to first tasseling, days to first silking and days to maturity of white maize

Interactions (Irrigation x variety)	Plant height at harvest (cm)	Days to first tasselling	Days to first silking	Days to maturity
I_2 V_1	184.87 f	69.667 f	70.667 f	128.67 c
I_2 V_2	148.07 h	68.333 g	70.667 f	122.33 f
I_2 V_3	204.00 de	72.667 c	75.333 b	132.33 b
I_2 V_4	169.00 g	67.667 g	69.000 g	121.33 g
I_3 V_1	228.80 bc	71.667 de	72.667 cd	131.33 b
I_3 V_2	188.50 ef	70.667 e	72.333 de	125.33 d
I_3 V_3	215.80 cd	75.667 b	77.667 a	134.33 b
I_3 V_4	188.13 ef	69.333 f	71.000 f	124.33 e
I_4 V_1	234.60 ab	72.333 cd	73.667 c	132.33 b
I_4 V_2	201.00 de	71.333 de	73.333 cd	126.00 d
I_4 V_3	221.00 bc	76.667 a	78.333 a	136.33 a
I_4 V_4	202.87 de	69.667 f	71.333 ef	125.33 de
I_{wr} V_1	245.80 a	72.333 cd	73.667 c	132.33 b
I_{wr} V_2	220.47 bc	71.667 de	73.667 c	126.33 d
I_{wr} V_3	231.80 b	76.667 a	78.667 a	136.33 a
I_{wr} V_4	227.80 bc	69.667 f	71.333 ef	125.67 d
LSD (0.05)	**13.68**	**0.97**	**1.09**	**0.87**
CV (%)	**3.92**	**0.87**	**0.89**	**0.40**

Here, V_1 = PSC, V_2 = Changnuo-1, V_3 = Youngnuo-30, V_4 = Changnuo-6,
I_2 = 25 DAS +75 DAS, I_3 = 25 DAS + 50 DAS +75 DAS, I_4 = 25 DAS + 50 DAS +75 DAS +100 DAS,
I_{wr} = Irrigation when required

LSD = Least Significant Difference at 5% level; CV = Coefficient of Variation. Means in column and row followed by the same letters are not significantly different at 5% level of significant

4.8.5 Cob length

4.8.5.1 Effect of irrigation

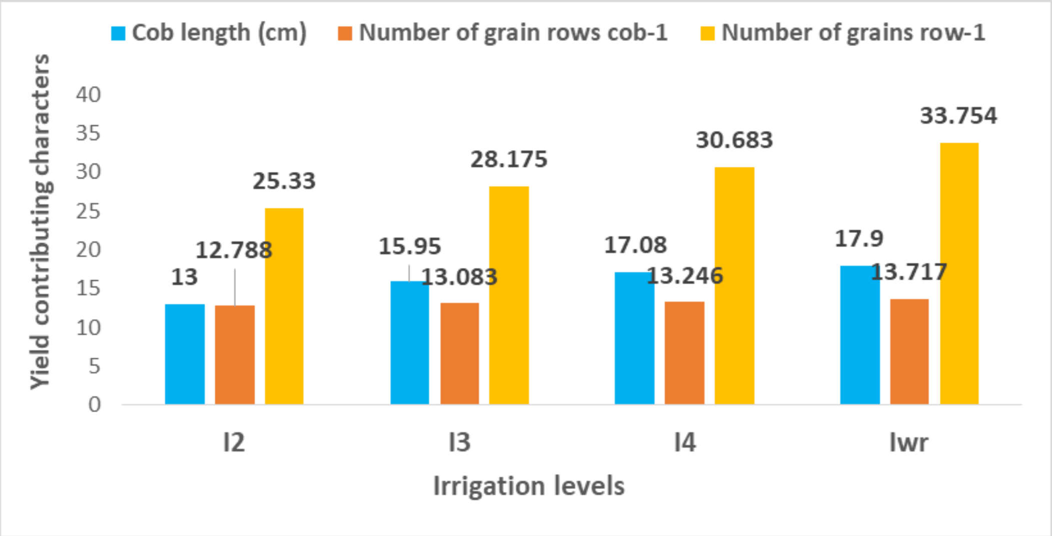
Cob length was significantly influenced by different levels of irrigation (Figure 4.8.4). Cob length was increased with an increase in irrigation levels. Among the various irrigation treatments, irrigation when required (I_{wr}) was produced the longest cobs (17.833 cm) while the smallest cobs was found from I_2 (13.00 cm). Likewise, I_4 showed significantly taller cobs (17.08 cm) than that of I_3 (15.95 cm).

4.8.5.2 Effect of varieties

Different varieties showed significant impact on cob length of white maize (Figure 4.8.4). Maximum cob length (16.929 cm) was achieved with V_1 which was statistically similar with V_2 (16.402 days) and V_3 (16.329 days) while the minimum (15.492 cm) cob length was achieved by V_4 (Changnuo-6).

4.8.5.3 Interaction effect of irrigation and varieties

Cob length was significantly influenced by the combination of irrigation and variety (Table 4.8.2). Data revealed that, the highest cob length (18.433 cm) was significantly recorded from $I_{wr}V_1$ which was statistically as par with $I_{wr}V_2$, and $I_{wr}V_3$ respectively (18.433 cm and 17.700 cm respectively) whereas the lowest cob length (14.04 cm) was significantly found from I_2V_4. Igbadun *et al.* (2008) and Pandey *et al.* (2010) reported that water use efficiency influenced the potential cob length.



Here, I_2 = 25 DAS + 75 DAS, I_3 = 25 DAS + 50 DAS + 75 DAS,

I_4 = 25 DAS + 50 DAS + 75 DAS + 100 DAS, I_{wr} = Irrigation when required

Figure 4.8.3. Effect of irrigation on cob length; number of rows per cob; number of grains per rows of white maize

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

4.8.6.1. Impact of irrigation

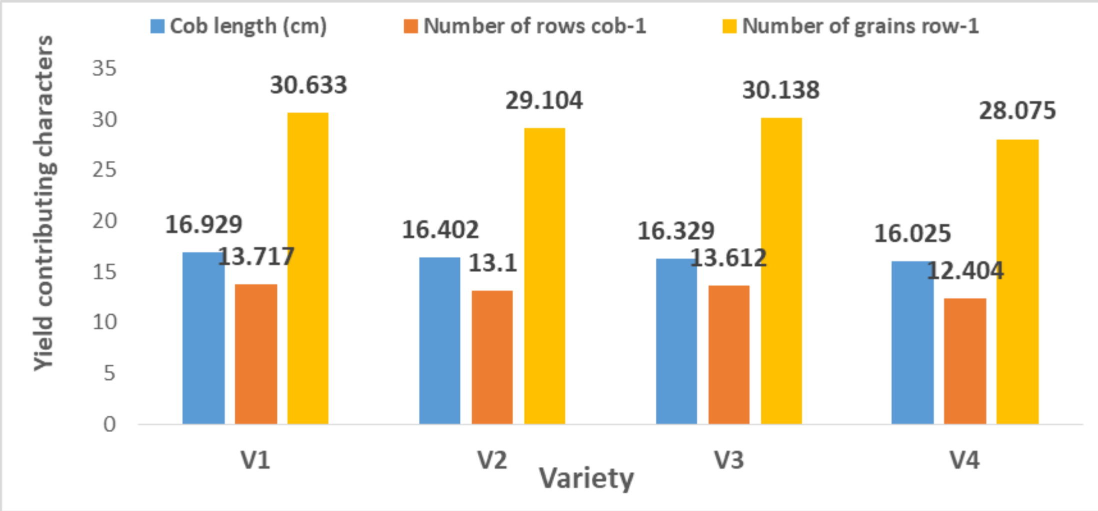
Number of grain rows cob^{-1} was significantly influenced due to different irrigation levels (Figure 4.8.4). Data revealed that, the highest number of grain rows cob^{-1} (13.717) was significantly observed from Iwr which was statistically similar with I_4 (13.246) and I_3 (13.083) respectively while the lowest number of grain rows cob^{-1} was found from I_2 (12.788).

4.8.6.2 Impact of varieties

Different varieties had a positive effect on number of grain rows cob^{-1} of white maize (Figure 4.8.4). Maximum number of grain rows cob^{-1} (13.717) was significantly found from V_1 (PSC-121) which was statistically similar with V_3 (13.612) and followed by V_2 (13.100) while the minimum (12.404) number of grain rows cob^{-1} was significantly observed from V_4 (Changnuo-6).

4.8.6.3 Interaction effect of irrigation and varieties

The Interaction effect of irrigation and variety showed significant effect on number of grain rows cob^{-1} (Table 4.8.2). The highest value of number of grain rows cob^{-1} (14.467) was found from $I_{wr}V_1$ which was statistically as par with $I_{wr}V_3$, $I_{wr}V_4$, I_4V_1, I_4V_3, I_3V_1 and I_2V_3, (14.000,13.733, 13.600, 13.650, 13.533 and 13.333 respectively) and the lowest value was obtained from I_2V_2 (11.9500). Similar results were reported by Kipkorir *et al.* (2002), Gencoglan & Yazar (2009), Farre & Faci (2009) and Bozkurt *et al.* (2011). However, Payero *et al.* (2008) found a positive association between grain rows /cob and the amount of irrigation seasonally. The adding of excessive water was not significant to improve the production of grain yield.



Here, V_1 = PSC, V_2 = Changnuo-1, V_3 = Youngnuo-30, V_4 = Changnuo-6

Figure 4.8.4. Effect of variety on cob length; number of rows per cob; number of grains per rows of white maize

4.8.7. Number of grains row^{-1}

4.8.7.1 Impact of irrigation

Irrigation treatments in white maize showed statistically significant effect on number of grains row^{-1} (Figure 4.8.4). Number of grains row^{-1} was increased with the increasing irrigation levels. Among the various irrigation treatments, irrigation when required (Iwr) was significantly produced the highest number of grains rows^{-1} (33.754) only under I_5 level of irrigation, which was statistically different from other levels of irrigation while the lowest number of grains row^{-1} was recorded from I_2 (25.338). Likewise, I_4 was significantly produced more number of grains row^{-1} (30.683) than that of I_3 (28.175).

4.8.7.2 Impact of varieties

Different varieties showed significant effect on the number of grains row^{-1}(Figure 4.8.4). The maximum number of grains row^{-1} (30.638) was reported from the treatment having V_1, which was statistically similar with V_3 (30.133) and followed by V_2 (29.104) while the lowest performer was V_4 (28.075).

4.8.7.3 Interaction effect of irrigation and varieties

The combination of irrigation and variety showed statistically significant variations on number of grains row^{-1}(Table 4.8.2). Data revealed that, $I_{wr}V_1$ showed the highest number of grains row^{-1} (34.933) than the other combinations which were statistically similar $I_{wr}V_3$, $I_{wr}V_2$ and $I_{wr}V_4$ (33.950, 33.667 and 32.467 respectively). Among the other treatments, I_2V_1 and I_2V_4 was showed significantly the minimum number of grains row^{-1} (23.617 and 23.867 respectively).

The reduction of yield (22.6-26.4%) caused by water stress was correlated with a reduction in number and weight of kernel in maize (Pandey *et al*., 2010).

Table 4.8.2. Interaction effects of irrigation and variety on cob length, number of rows cob,$^{-1}$ number of grains row^{-1} of white maize

Interactions (irrigation x variety)	Cob length (cm)	Number of rows cob^{-1}	Number of grains row^{-1}
I_2 V_1	14.742 gh	13.067 b-d	26.800 f-h
I_2 V_2	14.567 g-i	12.800 c-e	23.617 i
I_2 V_3	15.067 fg	13.333 a-d	27.067 e-g
I_2 V_4	14.100 hi	11.950 e	23.867 hi
I_3 V_1	16.200 c-e	13.600 a-c	29.933 c-e
I_3 V_2	15.800b ef	12.400 de	27.333 e-g
I_3 V_3	16.733 c-e	13.467 a-d	29.933 c-e
I_3 V_4	15.333 ef	12.867 b-e	25.500 g-i
I_4 V_1	17.233 b-d	13.733 a-c	31.333 b-d
I_4 V_2	17.917 ab	13.200 b-d	30.533 cd
I_4 V_3	17.867 bc	13.650 a-c	31.600 b-d
I_4 V_4	16.300 c-e	12.400 de	29.267 d-f
I_{wr} V_1	18.433 a	14.467 a	34.467 a
I_{wr} V_2	18.433 a	12.867 c-e	33.933 a-c
I_{wr} V_3	17.733 a-c	14.000 ab	33.950 ab
I_{wr} V_4	17.442 a-c	13.533 a-d	32.667 ab
LSD(0.05)	**1.16**	**1.08**	**3.03**
CV (%)	**4.26**	**6.10**	**6.10**

Here, V_1 = PSC, V_2 = Changnuo-1, V_3 = Youngnuo-30, V_4 = Changnuo-6,
I_2 = 25 DAS + 75 DAS, I_3 = 25 DAS + 50 DAS+75 DAS, I_4 = 25 DAS + 50 DAS + 75 DAS + 100 DAS,
I_{wr} = Irrigation when required
LSD = Least Significant Difference at 5% level; CV = Coefficient of Variation Means in column and row followed by the same letters are not significantly different at 5% level of significant.

4.8.8 Total number of grains cob^{-1}

4.8.8.1 Impact of irrigation

The total number of grains cob^{-1} was affected by the different irrigation levels (Figure 4.8.4,). The maximum total grains cob^{-1} (443.65) was significantly found from I_{wr} (443.65) and the minimum total grains cob^{-1} (309.98) was recorded from treatment I_2 V_1. Likewise, I_4 was significantly achieved more grains cob^{-1} (413.35) than that of I_3 (367.69).

4.8.8.2 Impact of varieties

The total number of grains cob^{-1} was significantly varied due to different varieties (Figure 4.8.4).The highest grains cob^{-1} was significantly produced with V_1 and V_3 (395.12 and 392.93 respectively) and the lowest grains cob^{-1} was significantly achieved with V_2 and V_4 (374.35 and 372.29 respectively). Both cases they were statistically similar to each other.

4.8.8.3 Interaction effect of irrigation and varieties

The total number of grains cob^{-1} was significantly affected by the Interaction effect of irrigation and variety (Table 4.8.3). The highest total grains cob^{-1} (443.65) was significantly found from IwrV$_1$ which was statistically similar with $I_{wr}V_2$, $I_{wr}V_3$, $I_{wr}V_4$, I_4V_1, I_4V_2 and I_4V_3 respectively (443.39,441.20,444.21,420.32,413.72 and 416.13 respectively)while the minimum total grains cob^{-1} (293.71) was recorded from treatment I_2 V_1.Yazar *et al.* (2012) recorded that the maximum total grain / cob was achieved from full irrigation using drip irrigation method. Ertek & Kara (2013) also reported that deficit irrigation decreased the number of grain per ear, which was in agreement with findings of this study.

4.8.9 100-grain weight

4.8.9.1 Impact of irrigation

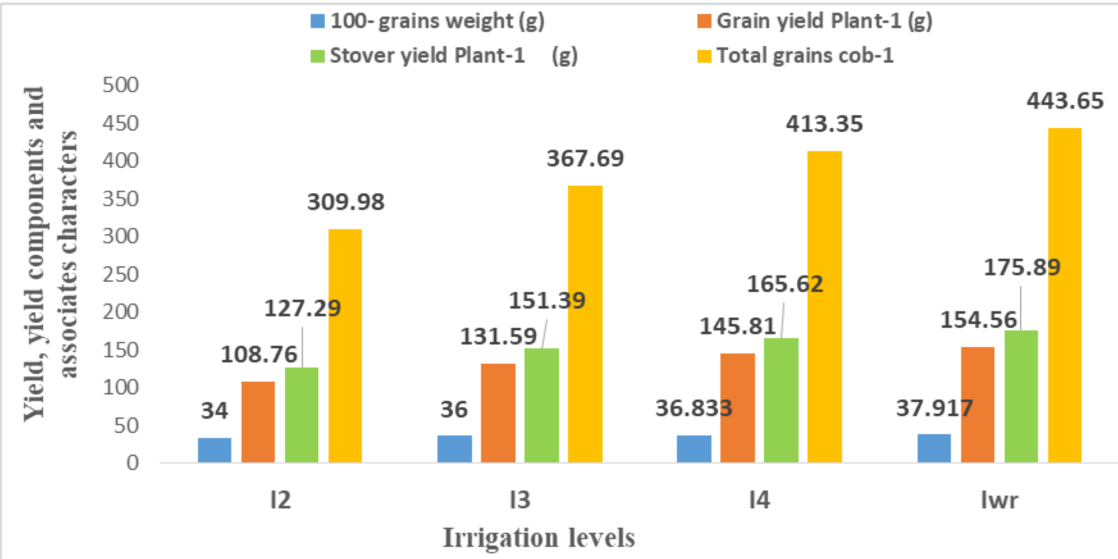
Various irrigation treatments showed the significant effects on 100- grain weight, where the highest 100-grain weight (37.917 g) was significantly found from $I_{wr.}$ and the lowest 100-grain weight (34.000 g) was recorded from I_2 treatment. Likewise, I_4 (36.833 g) was significantly achieved more 100-grain weight than that of I_2 (36.00 g) (Figure 4.8.7).

4.8.9.2 Impact of varieties

The weight of 100-grain also influenced by the varieties of white maize (Figure 4.8.8). The highest 100- grain weight (38.000 g) was produced with V_1 and the lowest 100- grain weight was obtained from V_2 (35.417 g).

4.8.9.3 Interaction effect of irrigation and varieties

The 100- grain weight was significantly affected by the Interaction effect of irrigation and (Table 4.8.3). For their combination, the highest 100- grain weight (40.333 g) was observed from $IwrV_1$ which was drastically different from other treatments combinations and the lowest 100- grain weight was recorded from I_2V_2 (33.667 g) which was statistically similar with I_2V_4 (33.667 g). Above results are in agreement with the findings of Kipkorir *et al.* (2002), Bozkurt *et al*,(2011).



Here, I_2 = 25 DAS +75 DAS, I_3 = 25 DAS + 50 DAS + 75 DAS, I_4 = 25 DAS + 50 DAS + 75 DAS+100 DAS, I_{wr} = Irrigation when required

Figure 4.8.5. Effect of irrigation on 100-grains weight; grain yield plant^{-1} and stover yield plant^{-1} and grains per cob

4.8.10. Grain yield plant^{-1}

4.8.10.1 Impact of irrigation

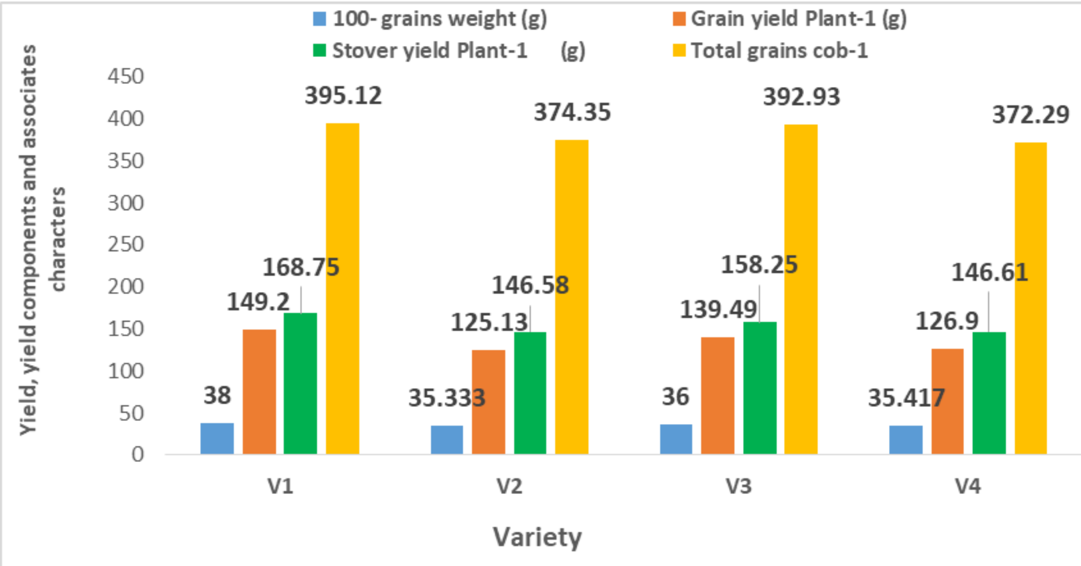
Grain yield plant^{-1} was significantly affected by the different levels of irrigation (Figure 4.8.7). For irrigation treatments, maximum grain yield per plant (154.56 g and 145.81 g respectively) were significantly produced with the treatment I_{wr} and I_4 which were statistically similar to each other. The minimum grain yield per plant (108.76 g) was achieved with the treatment I_2.

4.8.10.2 Impact of varieties

Statistically significant variations were observed for different maize varieties in terms of grain yield per plant (Figure 4.8.8). The highest grain yield per plant (149.20 g) was significantly produced with the treatment V_1 and the lowest grain yield per plant (125.13 g and 126.90 g respectively) were achieved with the treatment V_2 and V_4 respectively.

4.8.10.3 Interaction effect of irrigation and varieties

Interaction effect of irrigation and maize varieties showed significant differences on grain yield plant^{-1}(Table 4.8.3). From their combinations, maximum grain yield plant^{-1} (167.93 g) was significantly counted from treatment $I_{wr}V_1$(167.93 g) which were statistically similar with $I_{wr}V_3$, I_4V_1, I_4V_3, $I_{wr}V_4$, and I_3 V_1 respectively(158.45 g, 157.57 g 150.20 g and 149.00 g, 149.20 g respectively)whereas the minimum grain yield plant^{-1} was found from I_2V_2 (90.91 g**)**



Here, V_1 = PSC, V_2 = Changnuo-1, V_3 = Youngnuo-30, V_4 = Changnuo-6

Figure 4.8.6. Effect of variety on grains per cob, 100-grains weight; grain yield plant^{-1} and stover yield plant^{-1} of white maize

4.8.11. Stover yield plant^{-1}

4.8.11.1 Impact of irrigation

Stover yield plant^{-1} was significantly affected due to different irrigation levels (Figure 4.8.7). For irrigation treatments, maximum stover yield per plant (175.89 g and 165.62 g respectively) was achieved with the treatment I_{wr} and I_4 which were statistically similar to each other. The minimum stover yield per plant (127.29 g) was achieved with the treatment I_2.

4.8.11.2 Impact of varieties

Statistically significant differences were observed for different white maize varieties in terms of stover yield per plant (Figure 4.8.8). Maximum stover yield per plant (168.75 g) was significantly found from the treatment V_1 and the minimum stover yield per plant (146.58 g and 146.61 g respectively) were significantly obtained from the treatment V_2 and V_4 which were statistically similar to each other.

4.8.11.3 Interaction effect of irrigation and varieties

Interaction effect of irrigation and maize varieties showed significant differences on stover yield plant^{-1}(Table 4.8.3). From their combinations, maximum stover yield plant^{-1} (167.93 g) was significantly counted from treatment $I_{wr}V_1$(187.67 g) which was statistically similar with $I_{wr}V_3$, I_4V_1, I_4V_3, and I_3 V_1 respectively(178.00 g, 177.33 g 169.93 g and 169.33 g respectively)whereas the minimum stover yield plant^{-1} was recored from I_2V_2 (110.67 g**)** which was statistically similar with I_2V_4(122.17 g).

Table 4.8.3. Interaction effect of irrigation levels and variety on grains per cob, grain yield per plant; stover yield per plant; biological yield and harvest index of white maize

Interactions (Irrigation x variety)	100- grains weight (g)	Grain yield $plant^{-1}$ (g)	Stover yield $plant^{-1}$ (g)	Total grains cob^{-1}
I_2 V_1	35.000 fg	121.80 e	140.67 e	314.65 e-g
I_2 V_2	33.333 h	90.91 g	110.67 g	303.16 fg
I_2 V_3	34.000 gh	119.84 ef	135.67 ef	328.40 e-g
I_2 V_4	33.667 h	102.50 fg	122.17 fg	293.71 g
I_3 V_1	37.333 cd	149.49 a-c	169.33a-c	399.68 cd
I_3 V_2	35.667ef	124.61 de	144.3 de	346.56 e
I_3 V_3	35.667 ef	129.45 de	149.40 de	385.97 d
I_3 V_4	35.333 e-g	122.81 e	142.50 e	338.54 ef
I_4 V_1	39.000 b	157.57 ab	177.33ab	420.32 a-d
I_4 V_2	36.00 d-f	142.33 b-d	162.33 b-d	413.72 a-d
I_4 V_3	36.333 d-f	150.23 a-c	169.93 a-c	416.13 a-d
I_4 V_4	36.000 d-f	133.11c-e	152.87 c-e	403.24 b-d
I_{wr} V_1	40.66 a	167.93 a	187.67a	445.81 a
I_{wr} V_2	36.333 d-f	142.65 b-d	169.00 bc	443.39 ab
I_{wr} V_3	38.000 bc	158.45 ab	178.00 ab	441.20 a-c
I_{wr} V_4	36.667 de	149.20 a-c	168.90 bc	444.21 ab
LSD (0.05)	**1.27**	**18.94**	**18.11**	**35.89**
CV (%)	**2.20**	**8.33**	**6.94**	**5.55**

Here, V_1 = PSC -121, V_2 = Changnuo -1, V_3 = Youngnuo -30, V_4 = Changnuo -6
I_2 = 25 DAS +75 DAS, I_3 = 25 DAS + 50 DAS + 75 DAS, I_4 = 25 DAS + 50 DAS + 75 DAS+100 DAS, I_{wr} = Irrigation when required
LSD = Least Significant Difference at 5% level; CV = Coefficient of Variation. Means in column and row followed by the same letters are not significantly different at 5% level of significant.

4.8.12. Grain yield

4.8.12.1 Impact of irrigation

Grain yield was significantly affected by the different levels of irrigation (Figure 4.8.7). For irrigation treatments, the highest total grain yield (10.354 t ha^{-1}) was achieved with the treatment I_{wr} which was statistically similar with I_4 (9.72 t ha^{-1}) and the minimum grain yield (7.195 t ha^{-1}) was achieved with the treatment I_2.

4.8.12.2. Impact of varieties

Grain yield was significantly varied due to different white maize varieties (Figure 4.8.8). The highest grain yield (9.9466 t ha-^{1}) was significantly produced with the treatment V_1 and followed by V_3(9.2440 t ha-^{1}) while the lowest grain yield (8.3974 t ha-^{1} and 8.4603 t ha-^{1} respectively) was achieved with the treatment V_2 and V_4 which were statistically identical to each other.

4.8.12.3 Interaction effect of irrigation and varieties

Interaction effect of irrigation and maize varieties showed significant differences on grain yield (Table 4.8.4). From their combinations, maximum grain yield (11.196 t ha-^{1}) was significantly counted from treatment $I_{wr}V_1$ which was statistically similar with $I_{wr}V_{3,}$ I_4V_1 and I_4V_3 respectively (10.563 t ha-^{1}, 10.504 t ha-^{1} and 10.015 t ha-^{1} respectively) whereas the minimum grain yield was recorded from I_2V_2 (6.06 t ha-^{1}**)** which was statistically similar with I_2V_4 (6.833 t ha-^{1}**).** In this research, irrigation is the main factor determining the yield. This result is consistent with the findings of Karam *et al.* (2003), Stone *et al*.(2006), Kara & Biber (2008), Farré & Faci (2009) , Yazar *et al.(*2009) and Abd el-wahed *et al*.(2015) those who reported reduction in grain and dry matter yield, and leaf area index by deficit irrigation conditions. The water stress (deficit water) remarkably influenced productivity and quality in maize (EL Sabagh *et al.*, 2015; Barutcular *et al.*, 2016 a; Barutcular *et al.*, 2016 b; EL Sabagh *et al*., 2017). Similarly, effect of abiotic stress (deficit water) on the growth and grain quality of wheat was reported by Barutcular *et al.* (2016 c) and Barutcular *et al.*(2016 d). However, water availability is usually the most important crop production factor limiting yield and yield traits of maize. (Gencoglan & Yazar, 2009 and Farre & Faci, 2009.

4.8.13. Stover yield

4.8.13.1 Impact of irrigation

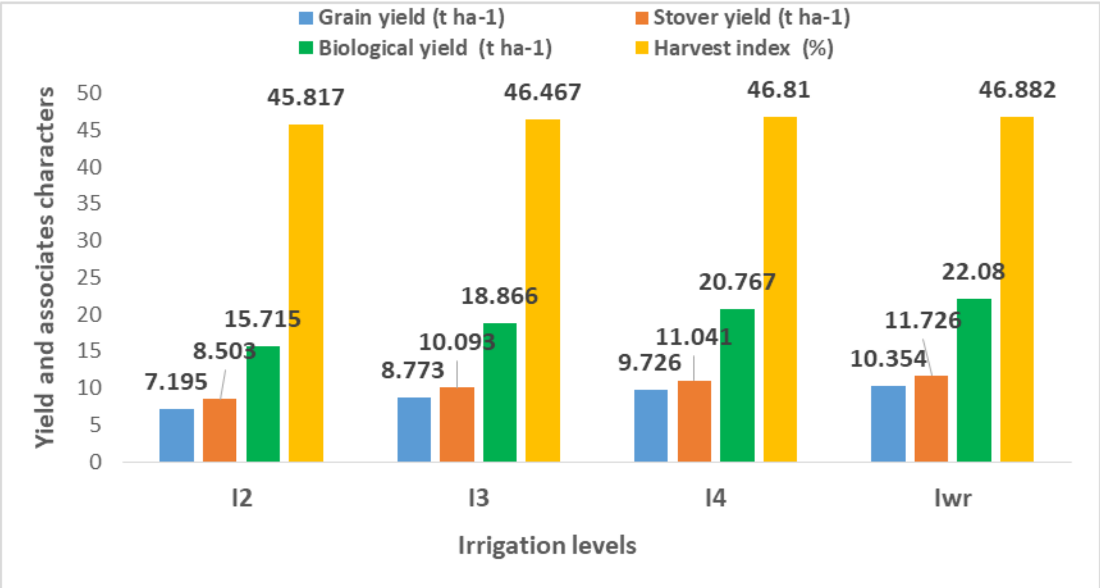
Stover yield was significantly influenced due to different irrigation treatments (Figure 4.8.10). Data revealed that, treatment, I_{wr} was the highest stover yielder (11.726 t ha^{-1}) which was statistically similar with I_4 (11.726 t ha^{-1}) while I_2 was the lowest stover yielder (8.503 t ha^{-1}). It might be due to sufficient water enhanced more vegetative growth resulting more stover yield.

4.8.13.2 Impact of varieties

Statistically significant differences were observed for different white maize varieties in terms of stover yield (Figure 4.8.11). Maximum stover yield (11.267 t ha^{-1}) was significantly recorded from V_1 and closely followed by V_3 (11.267 t ha^{-1}) while the minimum stover yield (9.772 t ha^{-1} and 9.774 t ha^{-1} respectively) was significantly found from the treatments V_2 and V_4, which were statistically similar to each other.

4.8.13.3 Interaction effect of irrigation and varieties

Interaction effect of irrigation levels and white maize varieties showed significant variation on stover yield (Table 4.8.4). From combinations, maximum stover yield was significantly observed from treatment $I_{wr}V_1$(12.511t ha^{-1}) which was statistically similar with $I_{wr}V_3$, I_4V_1, I_4V_3, and I_3V_1 respectively(11.867 t ha^{-1} 11.822 t ha^{-1}, 11.329 t ha^{-1} and 11.289 t ha^{-1} respectively)while the minimum stover yield was found from I_2V_2 (7.37 t ha^{-1} **)** which was statistically similar with I_2V_4(8.144 t ha^{-1}). It might be due to sufficient water enhanced more vegetative growth resulting more stover yield. Studied traits of flax crop significantly influenced by Irrigation intervals (Rashwan *et al*., 2016).



Here, I_2 = 25 DAS + 75 DAS, I_3 = 25 DAS + 50 DAS + 75 DAS, I_4 = 25 DAS + 50 DAS + 75 DAS + 100 DAS, I_{wr} = Irrigation when required

Figure 4.8.7. Effect of irrigation levels on grain yield; stover yield; biological yield and harvest index

4.8.14. Biological yield

4.8.14.1. Impact of irrigation

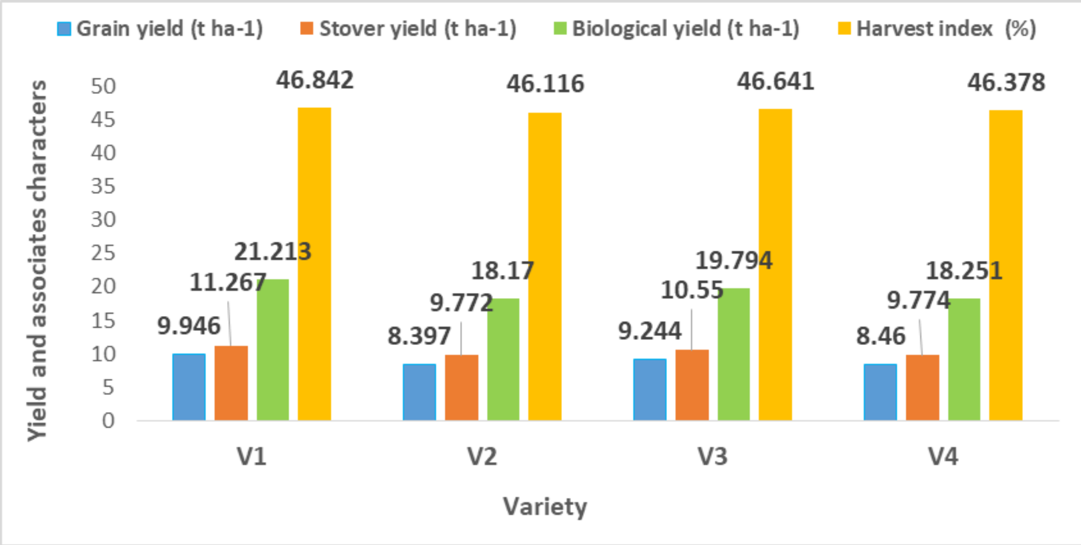
Biological yield is the total biomass produced by the plant during its life cycle. Different irrigation treatments showed statistically significant differences in terms of biological yield (Figure 4.8.10). The highest biological yield (22.080 t ha^{-1}) was found from, I_{wr} which was statistically similar with I_4 (20.767 t ha^{-1}) and followed by I_3 (18.866 t ha^{-1}). Again the lowest biological yield (8.503 t ha^{-1}) was recorded from I_2 (15.715 t ha^{-1}). It might be due to sufficient water enhanced more vegetative growth resulting more stover yield.

4.8.14.2 Impact of varieties

Biological yield showed statistically significant difference due to different white maize varieties (Figure 4.8.11). Data revealed that the highest biological yield (21.213 t ha^{-1}) was observed from V_1 and followed by V_3 (19.794 t ha^{-1}) while the lowest biological yield (18.170 t ha^{-1} and 18.251 t ha^{-1} respectively) was obtained from the treatments V_2 and V_4, which were statistically identical to each other.

4.8.14.3 Interaction effect of irrigation and varieties

Interaction effect of irrigation and white maize varieties showed significant differences on biological yield (Table 4.8.4). From their combinations, $I_{wr}V_1$ was significantly showed the maximum biological yield (23.707 t ha^{-1}), but statistically identical biological yield was found from $I_{wr}V_3$, I_4V_1, I_4V_3, and I_3V_1 (22.430 t ha^{-1}, 22.327 t ha^{-1}, 21.344 t ha^{-1} and 21.255 t ha^{-1} respectively) in this study. Again the treatment,V_1I_2 was achieved the minimum biological yield (13.438 t ha^{-1}) which was statistically at par with I_2V_4(15.047 t ha^{-1}). Results of present study are similar to the findings of Hanson *et al.* (2007) and Karasu *et al.* (2015) those who observed that deficit water in maize yield traits and biological yield. Dry matter yield of maize reduced severely with water deficit condition as reported by Karam *et al.* (2003).



Here, V_1 = PSC - 121, V_2 = Changnuo - 1, V_3 = Youngnuo - 30, V_4 = Changnuo - 6

Figure 4.8.8. Effect of variety on grain yield; stover yield; biological yield and harvest index

4.8.15. Harvest index

4.8.15.1. Impact of irrigation

Harvest index is an important parameter indicating the efficiency in partitioning of dry matter to economic part of the crop. Harvest index was varied significantly due to different levels of irrigation. (Figure 4.8.11). Among the various irrigation treatments, the highest harvest index was recorded from I_{wr} (46.882 %), which was statistically identical to I_4 (46.810 %) and followed by I_3 (46.467 %) while the lowest harvest index was found from I_2 (45.817 %).

4.8.15.2. Impact of varieties

Different white maize varieties showed statistically significant effect on harvest index (Figure 4.6.12). Among the varieties, V_1 was showed the highest harvest index (46.842 %), which was statistically similar to V_3 (46.641 %) and lowest harvest index was found from V_2 (46.116 %) which was statistically at par withV_4 (46.378 %) .

4.8.15.3. Interaction effect of irrigation and varieties

Harvest index was influenced significantly by the interaction effect of irrigation treatments and maize varieties (Table 4.8.4). $I_{wr}V_1$ was showed the highest harvest index (47.222 %) which was statistically identical with $I_{wr}V_3$, I_4V_1, I_4V_3, $I_{wr}V_4$ I_4V_2 and I_3V_1 respectively (47.087 %, 47.046 % , 46.916 % 46.895 % ,46.745 % and 46.873 % respectively) while I_2V_2 was significantly showed the lowest harvest index(45.071 % **)**

Table 4.8.4. Interaction effect of irrigation and variety on grain yield; stover yield; biological yield and harvest index of white maize.

Interactions (irrigation x variety)	Grain yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
I_2 V_1	8.120 f	9.444 e	17.565 f	46.227 fg
I_2 V_2	6.06 h	7.37 g	13.438 h	45.071 h
I_2 V_3	7.767 fg	9.044 ef	16.812 fg	46.154 fg
I_2 V_4	6.833 gh	8.144 fg	15.047 gh	45.814 g
I_3 V_1	9.966 bc	11.289 a-c	21.255 a-c	46.873 a-e
I_3 V_2	8.30 ef	9.622 de	17.930 ef	46.323 d-g
I_3 V_3	8.63 def	9.960 de	18.590 d-f	46.406 c-g
I_3 V_4	8.18 f	9.500 e	17.688 f	46.267 e-g
I_4 V_1	10.50 ab	11.822 ab	22.327 ab	47.046 a-c
I_4 V_2	9.5 b-e	10.822 b-d	20.332 b-e	46.745 a-f
I_4 V_3	10.015 a-c	11.329 a-c	21.344 a-c	46.916 a-d
I_4 V_4	8.87 c-f	10.191 c-e	19.065 c-f	46.535 b-f
I_{wr} V_1	11.196 a	12.511 a	23.707 a	47.222 a
I_{wr} V_2	9.711 b-d	11.267 bc	20.978 b-d	46.325 d-g
I_{wr} V_3	10.563 ab	11.867 ab	22.430 ab	47.087 ab
I_{wr} V_4	9.946 bc	11.260 bc	21.206 bc	46.895 a-e
LSD (0.05)	**1.15**	**1.20**	**2.38**	**0.62**
CV (%)	**7.63**	**6.93**	**7.70**	**0.88**

Here, V_1 = PSC, V_2 = Changnuo-1, V_3 = Youngnuo-30, V_4 = Changnuo-6
I_2 = 25 DAS + 75 DAS), I_3 = 25 DAS + 50 DAS +75 DAS, I_4 = 25 DAS + 50 DAS + 75 DAS +100 DAS,
I_{wr} = Irrigation when required
LSD = Least Significant Difference at 5% level; CV = Coefficient of Variation.
Means in column and row followed by the same letters are not significantly different at 5% level of significant.

4.9. Experiment 9: Performance of different white maize varieties as influenced by different levels of fertilizer at SAU, Dhaka (rabi 2016-17)

4.9.1 Plant height

4.9.1.1 Effect of fertilizer

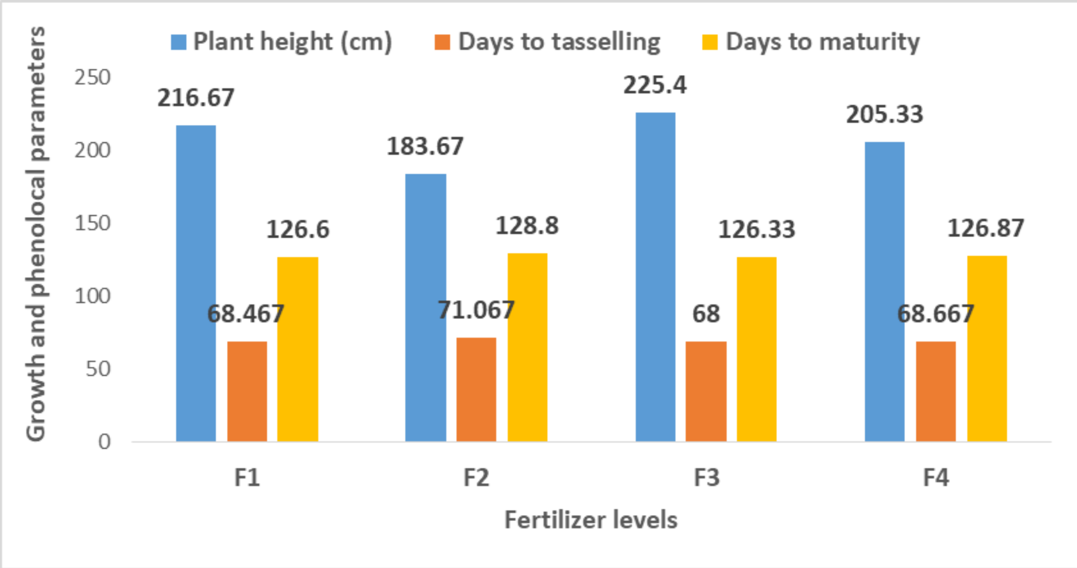
Different fertilizer doses showed significant effect on plant height (Figure 4.9.1). Among the fertilizer dose treatments, F_3 was significantly produced the tallest plants (225.40 cm) and F_2 was significantly showed the shortest (183.67 cm) plants. Likewise, F_1 was achieved longer plants (216.67 cm) than that of F_4 (205.33 cm).

4.9.1.2 Effect of variety

Plant height was influenced significantly due to different white maize variety (Figure 4.9.2).The maximum plant height (224.42 cm) was observed in V_3 while the minimum plant height was recorded in V_2 (187.00 cm). Likewise, V_5 had longer plants (213.67 cm) than that of F_1 (205.33 cm) and followed by F_4 (202.67 cm).

4.9.1.3 Interaction effect of fertilizer and variety

The interaction effect of fertilizer and variety showed significant differences on plant height (table 4.9.1). The longest plant height (242.33 cm) was observed from F_3V_3 and the shortest plant height (148.07 cm) was found from F_2V_2. Nitrogen in combination with P and K greatly influenced the vegetative growth and plant height. So, plant height was increased with respect to increase in NPK levels. Similar results that plant height increases with increasing levels of fertilizers were reported by Asghar *et al*.(2010), Maqsood *et al*.(2011).



Here, F_1 = Recommended fertilizer dose; F_2 = Half of recommended fertilizer fertilizer dose, F_3 = 25% more of recommended dose ; F_4 = 25% less of recommended fertilizer dose

Figure 4.9.1 Effect of fertilizer on plant height, days to tasseling, and days to maturity of white maize

4.9.2. Days to tasseling

4.9.2.1. Effect of fertilizer

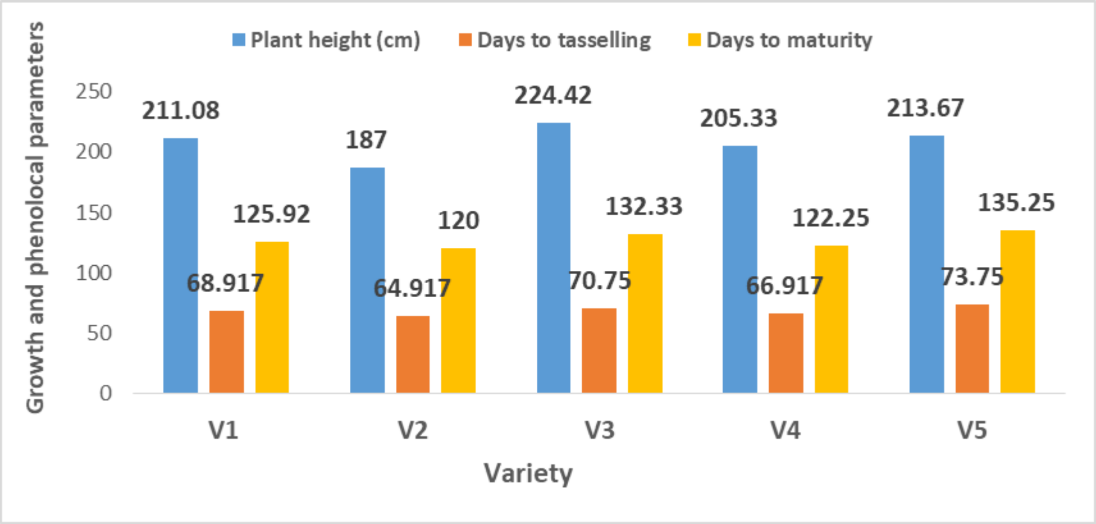
Days to tasseling showed statistically significant differences due to different fertilizer doses under the present trial. (Figure 4.9.1). Data revealed that, F_2 showed more days for tasseling (71.067 days) followed by F_1 (68.445 days) and F_4 (68.667 days) which were statistically similar to each other whereas F_3 was took minimum days for tasseling (68.00 days).

4.9.2.2. Effect of variety

Days to tasseling was significantly influenced by different white maize variety (Figure 4.9.2). Among the variety, V_5 took significantly more days for tasseling (73.750 days) while V_2 took significantly less days for tasseling (64.917days). Likewise V_3 took significantly more days for tasseling (70.750 days) than that of V_1 (68.917 days).

4.8.2.3. Interaction effect of fertilizer and variety

The combined effect of fertilizer and variety showed statistically significant effect on days to tasseling (table 4.9.1). The maximum days for tasseling (75.667 days) was observed from F_2V_5 whereas the minimum days for tasseling (64.000 days) was recorded from F_3V_2).



Here, V_1 = Changnuo -1; V_2 = Q- Xiangnuo -1; V_3 = PSC -121; V_4 = Changnuo -6, V_5 = Youngnuo -30

Figure 4.9.2. Effect of variety on plant height, days to tasseling, and days to maturity of white maize

4.9.3 Days to maturity

4.9.3.1 Effect of fertilizer

Days to maturity varied significantly due to different fertilizer doses (Figure 4.9.1). F_2 showed significantly the highest days to be matured (128.80 days) while F_3 showed the lowest days to be matured (126.17 days).

4.9.3.2 Effect of variety

Different variety showed statistically significant variations on days to maturity of white maize (Figure 4.9.2). V_5 took significantly the highest days to be matured (135.25 days) whereas V_2 showed significantly the lowest days to be matured (125.92 days). Likewise, V_3 required significantly more days for maturing (132.33 days) than that of V_1 (125.92 days) and followed by V_4 (122.25 days).

4.9.3.3 Combined effect of fertilizer and variety

Days to maturity significantly influenced by the combined effect of fertilizer and variety (table 4.9.1).The maximum days required to be matured (137.67 days) was recorded from F_2V_5 while the minimum days took to be matured (119.67 days) was observed from F_2V_1which was statistically similar with F_2V_4 (119.67 days).

Table 4.9.1. Interaction effects of fertilizer levels and variety on plant height, days to first tasseling, and days to maturity of white maize

Interactions (fertilizer x variety)	Plant height (cm)	Days to first tasselling	Days to maturity
F_1V_1	222.33 c	68.333 ef	125.33 e
F_1V_2	192.33 g	64.333 jk	119.67 h
F_1V_3	232.33 b	70.00 cd	131.67 c
F_1V_4	214.00 d	66.333 hi	121.67 fg
F_1V_5	222.33 c	73.333 b	134.67 b
F_2V_1	179.00 i	71.000 c	127.67 d
F_2V_2	170.67 j	67.000 gh	121.33 g
F_2V_3	201.00 ef	73.000 b	134.33 b
F_2V_4	180.00 i	69.333 de	123.00 f
F_2V_5	187.67 h	75.000 a	137.67 a
F_3V_1	230.67 b	68.000 fg	125.00 e
F_3V_2	202.33 e	64.000 k	119.33 h
F_3V_3	242.33 a	69.66 d	131.67 c
F3V_4	219.33 c	65.333 ij	121.67 fg
F_3V_5	232.33 b	73.000 b	134.00 b
F_4V_1	212.33 d	68.333 ef	125.67 e
F_4V_2	182.67 i	64.333 jk	119.67 h
F_4V_3	222.00 c	70.333 cd	131.67 c
F_4V_4	197.33 f	66.667 h	122.67 fg
F_4V_5	212.33 d	73.66 b	134.67 b
LSD (0.05)	**3.87**	**1.10**	**1.43**
CV (%)	**1.12**	**0.54**	**0.96**

Here, V_1 = Changnuo-1; V_2 = Q-Xiangnuo-1; V_3 = PSC-121; V_4 = Changnuo-6; V_5 =Youngnuo-30, F_1 = Recommended dose; F_2 = Half of recommended dose; F_3 = 25% more of recommended dose; F_4 = 25% less of recommended dose

LSD = Least Significant Difference at 5% level; CV = Coefficient of Variation. Means in column and row followed by the same letters are not significantly different at 5% level of significant

4.9.4. Cob length

4.9.4.1 Effect of fertilizer

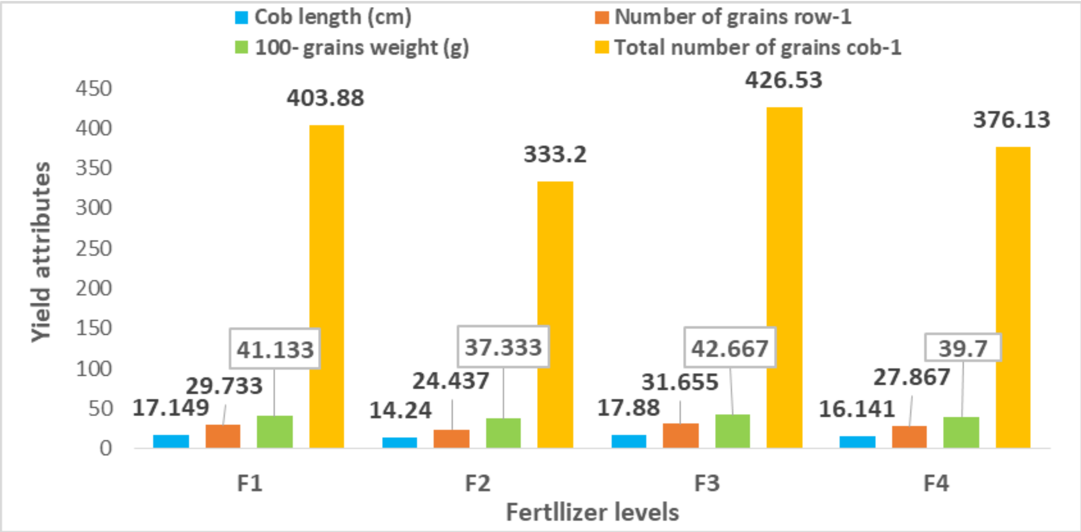
Cob length was significantly influenced due to different fertilizer doses (Figure 4.9.4). Cob length was increased with an increase in fertilizer doses. Among the various fertilizer treatments, F_3 was produced the longest cobs (17.833 cm) while the smallest cobs was found from F_2 (14.240 cm). Likewise, F_1 showed significantly taller cobs (17.149cm) than that of F_4 (16.141cm).

4.9.4.2 Effect of variety

Different variety showed significant effect on cob length of white maize (Figure 4.9.5). Maximum cob length (17.059 cm) was achieved with V_3 which was statistically similar to V_1 (16.667 cm) and V_5 (16.583 cm). The minimum (15.550 cm) cob length was produced with V_2.

4.9.4.3 Combined effect of fertilizer and variety

Statistically significant variation was observed due to the interaction effect of different fertilizer doses and variety (Table 4.9.2). F_3V_3 treatment showed the highest cob length (18.767 cm), which was statistically similar to F_3V_5 and F_3V_1 F_1V_5 (18.63 cm, 18.43 cm and 17.833 cm) while F_2V_2 showed the lowest cob length (13.333 cm). Cob length increased linearly with NPK application. Longest cob is due to highest amount of NP & K levels. This might be due to increased photosynthetic activity and better vegetative growth obtained under higher dose of nitrogen, which leads to production of better size and quality of cob as compared to other doses. These consequences are similar with the findings of Jerry et al., Mofunanya *et al.*(2015), Shamim *et al.* (2015).



Here, F_1 = Recommended dose; F_2 = Half of recommended dose; F_3 = 25% more of recommended dose; F_4 = 25% less of recommended dose

Figure 4.9.3. Effect of fertilizer on cob length, number of grains row,$^{-1}$ Number of grains per cob,$^{-1}$ 100-grains weight and grain yield per plant of white maize

4.9.5 Number of grains row^{-1}

4.9.5.1 Effect of fertilizer

Fertilizer doses treatments showed the significant effects on number of grains row^{-1}(Figure 4.9.4). Among the various treatments, F_3 produced the maximum number of grains row^{-1} (31.655) which was statistically similar to F_1 (29.733) and closely followed by F_4 (27.867) while the minimum number of grains row^{-1} (24.437) was recorded from F_2.

4.9.5.2 Effect of variety

Statistically significant difference was observed due to different white maize variety in terms of number of grains row^{-1} (Figure 4.9.5). The highest number of grains row^{-1} (30.569) was observed from V_3 which was statistically similar to V_1 (29.500) and the minimum number of grains row^{-1}(25.750) was also found from V_2. Likewise, V_5 produced significantly more number of grains row^{-1} (28.880) than that of V_4 (27.417).

4.9.5.3 Combined effect of fertilizer and variety

Statistically significant variation was observed due to the interaction effect of different fertilizer doses and variety in terms of number of grains row^{-1} (table 4.9.2). F_3V_3 treatment showed the highest number of grains row^{-1} (34.277) which was statistically similar to F_3V_1 F_3V_5, F_1V_1 and F_1V_3 respectively (32.667, 32.333, 32.333 and 31.33 respectively) while F_2V_2 showed the lowest number of grains row^{-1} (22.00).

4.9.6 Total number of grains cob^{-1}

4.9.6.1 Effect of fertilizer

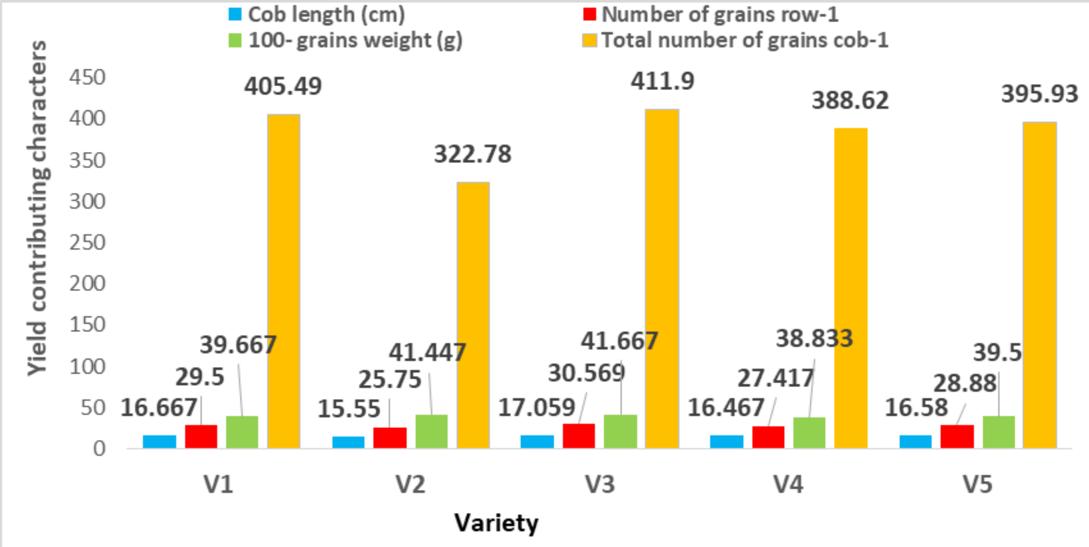
Number of grains per cob is an important yield determining component of maize. The data regarding number of grains per cob showed that various NPK application significantly affected no of grains per cob. Total number of grains cob^{-1} varied significantly due to fertilizer treatments (Figure 4.9.4). Among the treatments, the maximum number of grains cob^{-1} (426.53) was recorded from F_3 which was statistically similar to F_1 (403.88) followed by F_4 (376.13) while the minimum number of grains cob^{-1} (333.2) was found from F_2.

4.9.6.2 Effect of variety

Different white maize variety showed statistically significant difference on number of grains cob^{-1} (Figure 4.9.5). The highest number of grains cob^{-1} (411.90) was obtained from V_3 which was statistically similar to V_1 (405.49) while the minimum number of grains cob^{-1} (322.78) was found from V_2. Similarly, V_5 produced significantly more grains cob^{-1} (395.93) than that of V_4 (388.62).

4.9.6.3 Combined effect of fertilizer and variety

Statistically significant variation was observed due to the interaction effect of fertilizer treatments and variety in terms of number of grains cob^{-1} (table 4.9.2). F_3V_3 treatment showed the highest number of grains cob^{-1} (469.47) which was statistically identical with F_3V_1 and F_1V_3 (442.13 and 440.33) while the lowest number of grains cob^{-1} (293.2) was found from F_2V_2. It can be concluded from the data that higher levels of NPK will help to increase the size of cob and number of grains per cob. Similar results were also reported by Sahoo and Mahapatra (2014).



Here, V_1 = Changnuo-1; V_2 = Q-Xiangnuo-1; V_3 = PSC-121; V_4 = Changnuo - 6; V_5 = Youngnuo-30

Figure 4.9.4. Effect of variety on cob length, number of grains row,$^{-1}$total number of grains cob^{-1}100-grains weight and grain yield per plant

4.9.7 100-grain weight

4.9.7.1 Effect of fertilizer

Fertilizer levels showed statistically significant effects on 100- grain weight in white maize (Figure 4.9.4) where the maximum 100- grain weight (42.667 g) was found from F_3 and the minimum weight of 100-grain (37.333 g) was observed from the F_2 treatment. Likewise, F_1 showed more 100- grain weight (41.133 g) than that of F_4 (39.733 g).

4.9.7.2 Effect of variety

Different maize variety showed significant difference on 100- grain weight (Figure 4.9.5). The highest 100- grain weight was produced with V_3 (41.667 g) which was statistically at par V_1 (41.417 g) and followed by V_1 (39.667 g) and V_4 (39.500 g) which were statistically similar to each other, while the lowest was obtained fromV_4 (38.833 g).

4.9.7.3 Interaction effect of fertilizer and variety

Interaction effect of maize variety and fertilizer treatments showed significant differences on 100- grain weight (table 4.9.2). From their combinations, the maximum 100- grain weight (44.667 g) was achieved with F_3V_3 which was statistically similar to F_3V_2 (43.667 g). The minimum weight of 100-grain (37.000 g) was produced by the F_3V_2 treatments. It can be concluded from the data that higher levels of NPK increased 1000-grain weight producing well developed and bold grains. Similar results were also reported by Asghar *et al*. (2010), Sahoo and Mahapatra (2014).

Table 4.9.2. Interaction effect of fertilizer levels and variety on cob length, number of grains per row, total number of grains cob,$^{-1}$ 100-grains weight of white maize

Interactions (Fertilizer x variety)	Cob length (cm)	Number of grains row^{-1}	Total number of grains cob^{-1}	100-grains weight (g)
F_1V_1	17.167 cd	32.333 a-c	440.33 ab	41.000 d-f
F_1V_2	16.66 de	27.000 e-h	331.53 ghi	42.333 b-d
F_1V_3	16.680 de	31.33 a-d	423.07bcd	42.667 bc
F_1V_4	17.400 cd	28.333 d-g	402.67 b-e	39.667 f-h
F_1V_5	17.833 a-c	29.667 b-e	421.80 b-d	40.000 e-g
F_2V_1	14.700 hi	26.000 f-h	339.53 gh	37.00 ij
F_2V_2	13.333 j	22.00 i	293.2 i	38.333 hi
F_2V_3	14.300 h-j	25.33 gh	362.67 e-g	38.333 hi
F_2V_4	13.93 ij	24.000 hi	338.13 gh	36.333 j
F_2V_5	14.933 g-i	24.853 g-i	332.6 gh	36.667 j
F_3V_1	18.450 ab	32.333 a-c	442.13 ab	42.000 cd
F_3V_2	17.167 cd	28.333 d-g	357.60 fg	43.667 ab
F_3V_3	18.767 a	34.277 a	469.47 a	44.667 a
$F3V_4$	17.633 b-d	30.667 b-d	426.27 b-d	41.000 d-f
F_3V_5	18.633 ab	32.667 ab	437.20 bc	42.000 cd
F_4V_1	16.033 ef	29.667 b-e	398.27 c-f	38.667 gh
F_4V_2	15.033 f-h	25.667 gh	308.80 hi	41.333 c-e
F_4V_3	15.900 e-g	29.00 c-f	394.09 d-f	41.000 d-f
F_4V_4	16.900 c-e	26.667 e-h	387.40 d-f	38.333 hi
F_4V_5	16.837 c-e	28.333 d-g	392.07d-f	39.333 gh
LSD (0.05)	**1.00**	**3.19**	**31.37**	**1.61**
CV (%)	**3.70**	**6.67**	**4.90**	**2.45**

Here, V_1 = Changnuo-1; V_2 = Q-Xiangnuo-1; V_3 = PSC-121; V_4 = Changnuo-6; V_5 =Youngnuo-30, F_1 = Recommended dose; F_2 = Half of recommended dose; F_3 = 25% more of recommended dose ; F_4 =25% less of recommended dose

LSD = Least Significant Difference at 5% level; CV = Coefficient of Variation. Means in column and row followed by the same letters are not significantly different at 5% level of significant

4.9.8 Grain yield

4.9.8.1 Effect of fertilizer

Grain yield of white maize remarkably influenced by the different fertilizer treatments (Figure 4.9.7). For fertilizer treatments, the highest grain yield (13.846 t ha^{-1}) was significantly achieved with the treatment F_3 and the minimum grain yielder (10.481 t ha^{-1}) was F_2. Likewise, more grain yield (12.889 t ha^{-1}) was significantly found from F_1 than that of F_4 (11.989 t ha^{-1}).These results were in agreement with those of Talukder *et al.* (1999), Niazuddin *et al.* (2002) and Hossain *et al.* (2009). An increasing trend in grain yield was observed due to the lowering of water stress (Figure 4.9.7).

4.9.8.2 Effect of variety

Different maize variety showed statistically significant differences on grain yield (Figure 4.9.8). Maximum grain yield (13.104A t ha^{-1}) was significantly achieved with the variety, V_3 which was statistically similar to V_1 (12.667 t ha^{-1}) while the minimum grain yield (11.233 t ha^{-1}) was produced with the treatment V_2. Likewise, V_1 had significantly more grain yield (12.889 t ha^{-1}) than that of F_4 (11.989 t ha^{-1}).

4.9.8.3 Interaction effect of fertilizer and variety

Statistically significant variation was observed for different fertilizer treatments and maize variety in terms of grain yield (table 4.9.3) From their combinations, maximum grain yield was (14.844 t ha^{-1}) counted from F_3V_3 treatment and it was statistically similar to F_3V_1 and F_3V_5 (14.083, and 13.961 t ha^{-1}). Again the minimum grain yield was observed from F_2V_2 treatment (9.54 t ha^{-1}) which was statistically at par with F_2V_4 (10.394 t ha^{-1}). Similar effect of water regimes and variety on the grain yield of maize was also reported by Hossain *et al.* (2009).

4.9.9 Stover yield

4.9.9.1 Effect of fertilizer

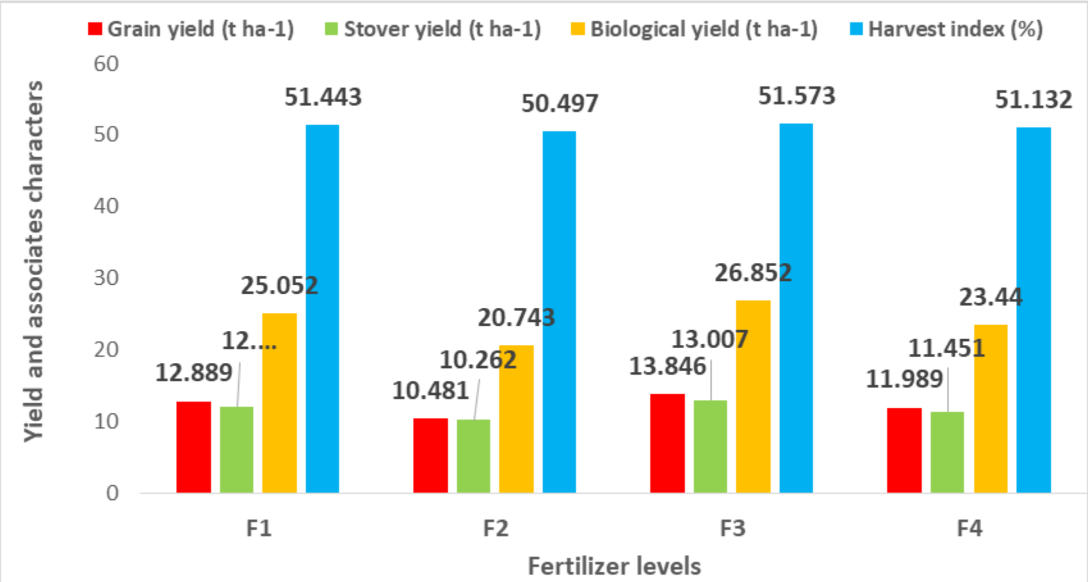
Stover yield varied significantly due to different fertilizer treatments (Figure 4.9.8). F_3 treatment was the highest stover yielder (13.007 t ha^{-1}), while F_2 treatment was the lowest stover yielder (10.262 t ha^{-1}). Similarly, F_1 produced more stover yield (12.163 t ha^{-1}) than that of F_4 (11.451 t ha^{-1}).

4.9.9.2 Effect of variety

Different maize variety showed statistically significant differences on stover yield (Figure 4.9.9). The highest stover yield (12.450 t ha^{-1}) was observed in V_3, which was statistically similar to V_1 (12.067 t ha^{-1}) and the minimum stover yield was found from V_2 (10.668 t ha^{-1}). Similarly, V_5 produced more stover yield (11.968 t ha^{-1}) than that of F_4 (11.451t ha^{-1}).

4.9.9.3 Interaction effect of fertilizer and variety

Interaction effect of maize variety and different fertilizer doses showed significant differences on stover yield (table 4.9.3). From the combinations, it was observed that the maximum stover yield (13.767 t ha^{-1}) was found from F_3V_3 which was statistically similar to F_3V_1, F_3V_5 and F_1V_3 (13.522 t ha^{-1}, 13.400 t ha^{-1} and 12.944 t ha^{-1}) whereas the minimum stover yield was obtained from F_2V_2 treatment (9.50 t ha^{-1}).



Here, F_1 = Recommended dose; F_2 = Half of recommended dose; F_3 = 25% more of recommended dose ;

F_4 = 25% less of recommended dose

Figure 4.9.5. Effect of fertilizer levels on grain yield; stover yield; biological yield and harvest index of white maize

4.9.10. Biological yield

4.9.10.1 Effect of fertilizer

Biological yield showed statistically significant difference due to different fertilizer treatments (Figure 4.9.8). Among various fertilizer doses, F_3 showed significantly the maximum biological yield (26.852 t ha^{-1}). Among the others, F_2 revealed the lowest

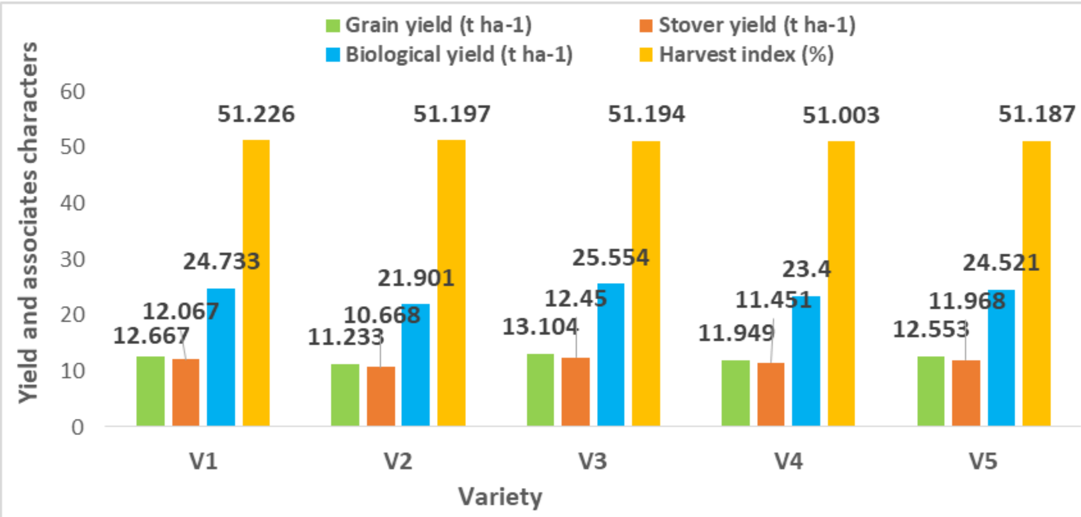
(20.743 t ha^{-1}). .Likewise, more biological yield (25.052 t ha^{-1}) was observed from F_1 than that of F_4 (23.440 t ha^{-1}).

4.9.10.2 Effect of variety

Different maize variety showed statistically significant differences on biological yield (Figure 4.9.9). Among the variety, V_3 produced highest biological yield (25.554 t ha^{-1}) which was statistically similar to V_1 (24.733 t ha^{-1}) and V_2 produced the minimum the biological yield (21.901 t ha^{-1}). Similarly, more biological yield (24.521 t ha^{-1}) was observed from V_5 than that of F_4 (23.400 t ha^{-1}).

4.9.10.3 Interaction effect of fertilizer and variety

Interaction effect of maize variety and different fertilizer doses showed significant differences on biological yield (table 4.9.3). From the combinations, it was observed that the maximum biological yield (28.611 t ha^{-1}) was counted from F_3V_3 which was



Here, V_1 = Changnuo-1; V_2 = Q- Xiangnuo-1; V_3 = PSC-121; V_4 = Changnuo- 6; V_5 =Youngnuo -30

Figure 4.9.6. Effect of variety on grain yield; stover yield; biological yield and harvest index of white maize

4.9.11. Harvest index (HI)

4.9.11.1. Effect of fertilizer

Harvest index showed statistically significant differences due to different fertilizer doses (Figure 4.1.17). Among the fertilizer treatments, F_3 had the highest harvest index (51.573 %), which was statistically similar to F_1 (51.443 %) and F_4 (51.132 %) while F_2 showed the lowest harvest index (45.564 %) (Figure 8).

4.9.11.2 Effect of variety

Different maize variety showed statistically non-significant difference on harvest index (Figure 4.9.9). The highest harvest index (51.226 %) was observed from V_1 and the lowest harvest index (51.003 %) was recorded from V_2.

4.9.11.3 Interaction effect of fertilizer and variety

Interaction effect of maize variety and fertilizer treatments showed significant differences on harvest index (table 4.9.3). From the combinations of maize variety and fertilizer treatments, it was observed that the maximum harvest index (51.852 %) was recorded from F_3V_3 which was statistically similar to other treatment combinations excepting F_4V_4 (50.346 %) F_2V_4 (50.306 %) which were statistically similar to each other while the minimum had F_2V_2 (50.02 %) and F_2V_3 (50.056 %) treatments which were statistically similar to each other.

Table-4.9.3. Interaction effect of fertilizer levels and variety on grain yield; stover yield; biological yield and harvest index of white maize

Interactions (Fertilizer x variety)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
F_1V_1	13.211 b-f	12.539 cd	25.750 c-f	51.317 a-c
F_1V_2	11.88 gh	11.156 fg	23.039 g-i	51.556 a-c
F_1V_3	13.761 b-d	12.944 a-c	26.706 b-d	51.519 a-c
F_1V_4	12.533 e-g	11.783 d-f	24.317 fg	51.520 a-c
F_1V_5	13.056 b-f	12.394 c-e	25.450 d-f	51.304 a-c
F_2V_1	10.850 hi	10.333 gh	21.183 jk	51.220 ab
F_2V_2	9.54 j	9.50 i	19.04 i	50.056 c
F_2V_3	10.894 hi	10.867 gh	21.761 ijk	50.026 c
F_2V_4	10.394 ij	10.267 hi	20.661 kl	50.306 bc
F_2V_5	10.722 i	10.344 gh	21.067 jk	50.877 a-c
F_3V_1	14.083 ab	13.522 a	27.606 ab	51.020 a-c
F_3V_2	12.794 d-g	11.756 ef	24.550 e-g	51.117 ab
F_3V_3	14.844 a	13.767 a	28.611 a	51.852 a
F_3V_4	13.544 b-e	12.589 b-d	26.133 b-e	51.839 ab
F_3V_5	13.961 a-c	13.400 ab	27.361 a-c	51.038 a-c
F_4V_1	12.522 e-g	11.872 d-f	24.394 e-g	51.345 a-c
F_4V_2	10.711 i	10.261 hi	20.972 jk	51.059 a-c
F_4V_3	12.917 c-g	12.222 c-e	25.139 d-f	51.381 a-c
F_4V_4	11.322 hi	11.167 fg	22.489 h-j	50.346 bc
F_4V_5	12.472 fg	11.73 ef	24.20 f-h	51.529 a-c
LSD (0.05)	**1.06**	**0.82**	**1.76**	**1.40**
CV (%)	**5.19**	**4.21**	**4.42**	**1.66**

Here, V_1 = Changnuo-1; V_2 = Q-Xiangnuo-1; V_3 = PSC-121; V_4 = Changnuo-6; V_5 =Youngnuo-30, F_1 = Recommended dose; F_2 = Half of recommended dose; F_3 = 25% more of recommended dose; F_4 = 25% less of recommended dose

LSD = Least Significant Difference at 5% level; CV = Coefficient of Variation. Means in column and row followed by the same letters are not significantly different at 5% level of significant

4.10. Experiment 10: Performance of white maize (var. PSC-121) under different fertilizer levels and planting geometry at SAU, Dhaka (rabi 2017-18)

4.10.1. Crop Phenology

4.10.1.1. Days to tasseling

Days to tasselling significantly influenced by the fertilizer levels, plant spacing and their combinations (Figure 4.10.1, 4.10.2 and 4.10.3). Results revealed that, F_2 treatment significantly took the maximum days to tasselling (73.667 days) followed by F_1 (72.333 days) (Figure 4.10.1).

Spacing S_4 took maximum days to tasselling (73.833 days) which was statistically similar to S_3 (73.333 days) while S_1 took minimum days (72.333 days) which was statistically similar to S_2 (73.500 days) (Figure 4.10.2).

On the other hand, for the combinations of fertilizer levels and plant spacing, F_2S_3 and F_2S_4 took maximum days to tasselling (74.333 days each) whereas F_1S_1 took the lowest days to tasselling (71.667 days) which was statistically similar to F_1S_2 (72.000 days) (Table 4.10.1).These results are in line with Amanullah *et al*. who stated that delay in days to tasseling was observed with increase in N rate and number of N splits (Kim *et al.,* 1990).

4.10.1.2. Days to silking

Fertilizer levels and \plant spacing treatments separately and their combinations were also used to observe their effects on days to silking of white maize (Figure 4.10.1, 4.10.2 and 4.10.3). It was found that, days to silking was significantly influenced by fertilizer treatments. Among the treatments, F_2 treatment statistically higher result (75.667 days) followed by F_1 (74.333 days) which was the lowest (Figure 4.10.1).

A range of plant spacing treatments were also used to observe days to silking of white maize (Figure 4.10.2). It was found S_4 showed more days (75.833 days) which was statistically similar to S_3 (75.333 days) whereas S_1 took minimum days (74.333 days) which were statistically similar to S_2 (74.500 days) (Figure 4.10.2).

On the other hand, for the combinations of fertilizer doses and plant spacing treatment it was found that F_2S_3 and F_2S_4 treatment took more days (76.333 days each). F_1S_1 revealed the lowest (73.667 days) which were statistically similar to F_1S_2 (74.000

days) (Table 4.10.1). These results are consistent with the finding of Amanullah *et al*. who stated that increasing N application delay silking in maize (Kim *et al.*, 1990).

4.10.1.3. Days to maturity

Days to maturity was significantly influenced by the fertilizer levels, plant spacing treatments and their combinations and the result was represented in figure 4.10.1, 4.10.2 and 4.10.3. For fertilizer treatments, F_2 took maximum days to be mature (132.58 days). On the other hand, F_1 took the lowest days (131.17 days).

For plant spacing treatments, S_4 required the highest days to be mature (132.83 days), whereas S_1 took the minimum days (130.83 days) to be mature.

Among the combinations, F_2S_4 showed the significantly highest days (133.67 days) to be mature, whereas F_1S_1 perform the lowest (129.67 days) (Table 4.10.1). My findings are lined with the observation of Dawadi and Sah, (2012) where they revealed that the densities whereas variety and nitrogen levels had a significant effect on physiological maturity. Shrestha (2007) also reported increased physiological maturity and seed fill duration with increasing levels of nitrogen in open pollinated varieties of maize. Delayed maturity at higher nitrogen was because the plant was staying green. Higher nitrogenous fertilizer delays the senescence of leaves and increased succulence of plants.

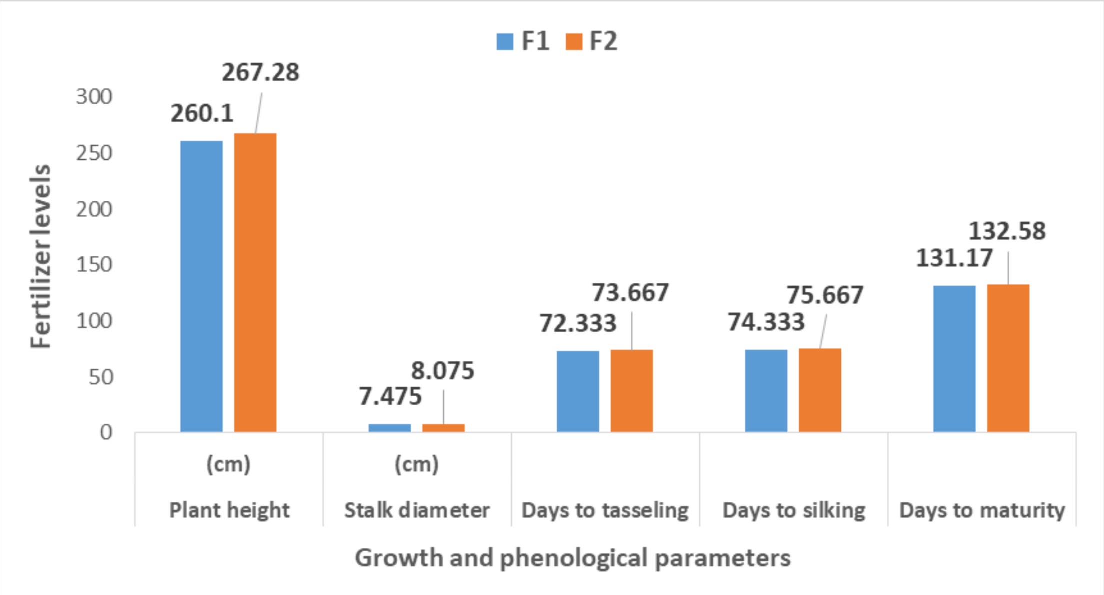
4.10.2. Growth parameters

4.10.2.1. Plant height

Various treatments such fertilizer doses, planting geometry and their combinations were used to observe their effects on plant height of white maize. Plant height was significantly influenced by fertilizer doses (Figure 4.10.1). F_2 produced the tallest plants (267.28 cm) while F_1 produced the shortest plant (260.10 cm). The increase in plant height with increase in the rate of nitrogen application could be attributed to positive effect of N on vigorous vegetative growth and inter-nodal extension due to more availability of N throughout the growing period. This increase in plant height in response to higher rates of nitrogen has been confirmed by the previous findings of Wajid *et al.* (2007); Gokmen *et al.* (2001); Woldesenbet and Haileyesus (2016).

Planting spacing had significant effect on plant height. Among the four planting treatments S_4 revealed the longest plants (271.00 cm), which was statistically similar to S_3 (267.83 cm). Whereas S_1 produced the shortest plants (254.73 cm) (Figure 4.10.2).

Their combinations had significant effect on plant height (Table 4.10.1). Among the observed treatments F_2S_4 showed the tallest plant (274.53 cm) which was statistically similar to V_1S_3, V_1S_4, V_2S_2 and V_2S_3 (265.20, 267.47, 265.33 and 270.47 cm respectively). However, V_1S_1 revealed the smallest plants (250.67 cm). Findings of present study are similar to the findings of Law-Ogbomo and Law-Ogbomo (2009), where they observed that plant height was increased with successive increment in fertilizer application rate and the tallest plants in those plants received the highest dose NPK ha^{-1} than those that received lower rate. These results agreed with Wajid *et al*., (2007) who investigated that higher nitrogen level influence plant height. .Higher N applications increase the cell division, cell elongation, nucleus formation as well as green foliage. It also encourages the shoot growth. Therefore, higher doses of nitrogen increased the chlorophyll content which increased the rate of photosynthesis and extension of stem resulting increased plant height (Thakur *et al*., 1997; Diallo *et al*., 1996).



Here, F_1 = Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

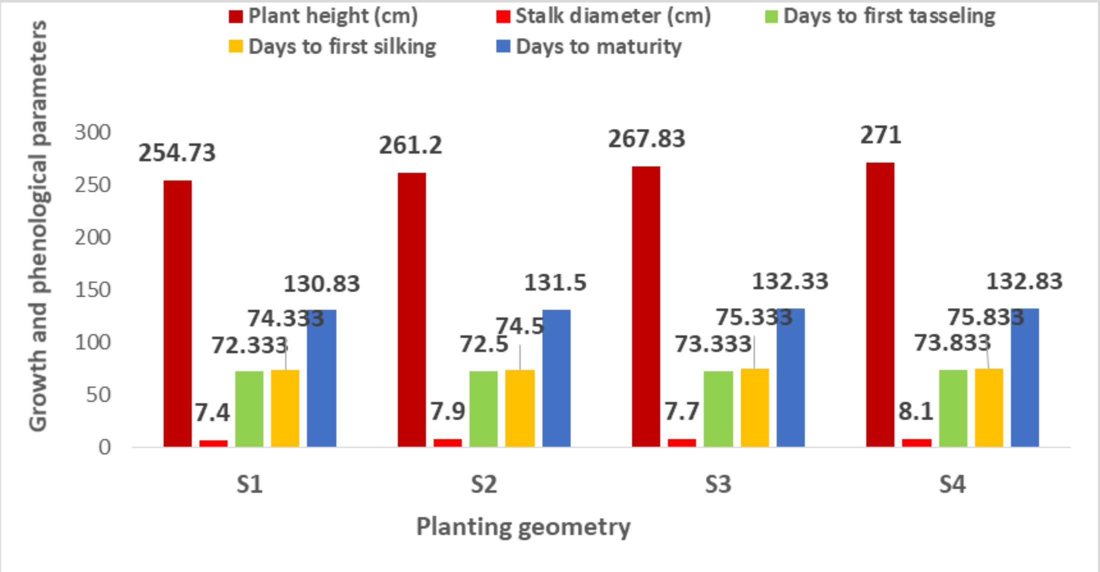
Figure4.10.1. Effect of fertilizer on plant height; stalk base circumference, days to first tasseling, days to first silking and days to maturity of white maize

4.10.2.2. Stalk base diameter

Stalk base diameter was significantly influenced by fertilizer application treatment, plant spacing treatment and their combination. Results interpreted in (Figure 4.10.1) revealed that maximum stalk base circumference was obtained from F_2 (267.28 cm) and minimum from F_1 (260.10 cm). The increase in stem diameter with increasing in nitrogen rate might attributed to the more increasing of cell size and growth due to nitrogen application, as it is a general truth that N enhances plant growth. This result was in accordance to Gözübenli, (2010) and Iqbal *et al*., (2015).

On the other hand, significant differences among the different plant spacing treatment were observed. Results plotted in (Figure 4.10.2) showed that S_4 (8.1000 cm) plant spacing are more superior than the other plant spacing treatment used in this experiment, which was statistically similar to S_2 (7.900 cm).whereas S_1(7.4000 cm) spacing treatments revealed the minimum stalk base circumference in this experiment. Reducing in stem diameter at lower planting spacing might be due to higher plant competition for available resources like solar radiation, nutrients, water, air and space. This result was in agreement with those of Sener *et al*., (2004) and Carpici *et al*., (2010).

Moreover, at the combination of the fertilizer dose and plant spacing treatment in (Table 4.10.1), it was observed that $F_2 S_4$ (8.400 cm) produced the highest stalk base circumference, which was statistically similar to $F_2 S_2$ (8.200 cm) and $F_2 S_3$ (8.000 cm) the interaction treatment $F_1 S_1$ (7.1000 cm) revealed the minimum stalk base circumference. Law-Ogbomo and Law-Ogbomo, (2009) also reported that NPK fertilizer application increased the stem girth or base circumference as the increase in stalk base circumference is a reflection of retention of appreciable amount of assimilates in the stem for leaf production.



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm

Figure 4.10.2. Effect of planting geometry on plant height, stalk base diameter, days to first tasseling, days to first silking and days to maturity of white maize

4.10.2.3. Correlation study between plant height and population density of white maize:

The planting geometries tested in this trial had varying spacings of 50 cm x 20 cm, 50 cm x 25 cm and 60 cm x 20 cm which represent the plant population per hectare respectively to 100000, 80000, 83333 and 66666. Regression analysis of the plant height with these population densities showed that plant height of maize was negatively dependent on the population density although it was linear showing a negative regression coefficient of – 0.0005 and R-squired value of 0.7802 (Figure 4.10.3).

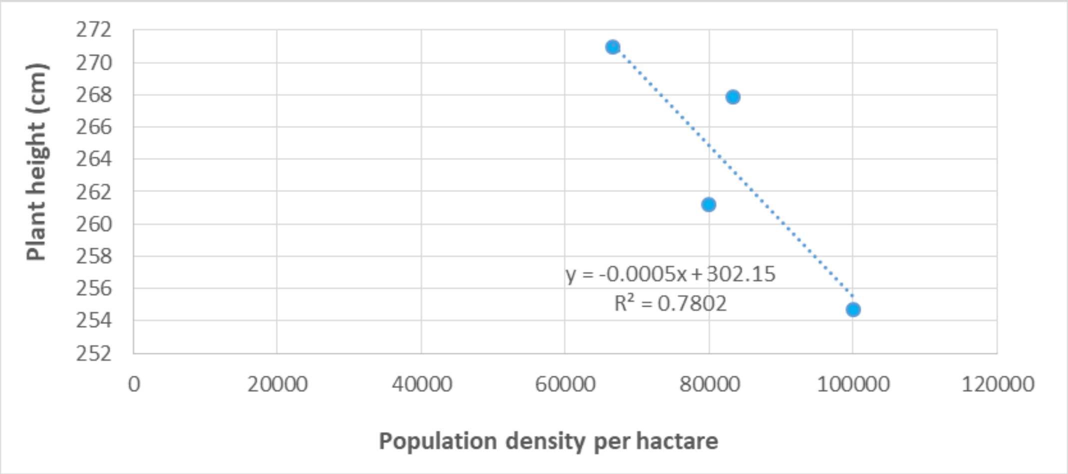


Figure 4.10.3. Correlation between plant height and population density of white maize

4.10.2.4. Correlation study between days to maturity and population density of white maize:

The planting geometries tested in this trial had varying spacings of 50cm x 20cm, 50cm x 25cm and 60cm x 20 cm which represent the plant population per hectare respectively to 100000, 80000, 83333 and 66666. Regression analysis of the days to maturity with these population densities showed that days to maturity of maize was negatively dependent on the population density although it was linear showing a negative regression coefficient of – 0.00005 and R-squired value of 0.77669 (Figure 4.10.4)

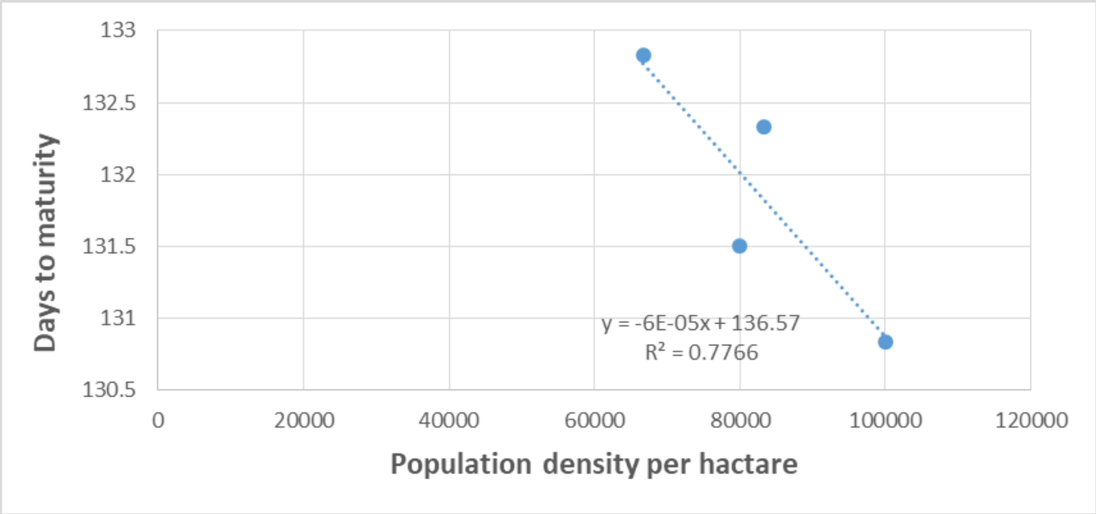


Figure 4.10.4. Relationship between days to maturity and population density of white maize

Table 4.10.1. Interaction effects of fertilizer levels and planting geometry on plant height; Stalk base diameter, days to first tasseling, days to first silking and days to matur*ity*

Interactions (Fertilizer× spacing)	Plant height (cm)	Stalk base diameter (cm)	Days to first tasseling	Days to first silking	Days to maturity
$F_1 S_1$	250.67 d	7.1000 d	71.667 d	73.667 d	129.67 d
$F_1 S_2$	257.07 cd	7.6000 c	72.000 d	74.000 d	131.00 c
$F_1 S_3$	265.20 a-c	7.4000 cd	72.333 cd	74.333 cd	132.00 b
$F_1 S_4$	267.47 a-c	7.8000 bc	73.333 b	75.333 b	132.00 b
$F_2 S_1$	258.80 b-d	7.7000 bc	73.000 bc	75.000 bc	132.00 b
$F_2 S_2$	265.33 a-c	8.2000 a	73.000 bc	75.000 bc	132.00 b
$F_2 S_3$	270.47 ab	8.0000 ab	74.333 a	76.333 a	132.67 b
$F_2 S_4$	274.53 a	8.4000 a	74.333 a	76.333 a	133.67 a
LSD(0.05)	**11.39**	**0.39**	**0.82**	**0.82**	**0.70**
CV (%)	**2.73**	**3.28**	**0.63**	**0.64**	**0.30**

Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm

F_1= Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

LSD = Least Significant Difference at 5% level; CV = Coefficient of Variation. Means in column and row followed by the same letters are not significantly different at 5% level of significant

4.10.2.5. Leaf area per plant (cm^2)

Leaf area per plant was influenced significantly by the different fertilizer levels, plant spacing and their combinations as observed from 30 days after sowing (DAS) to harvest at 30 days interval.

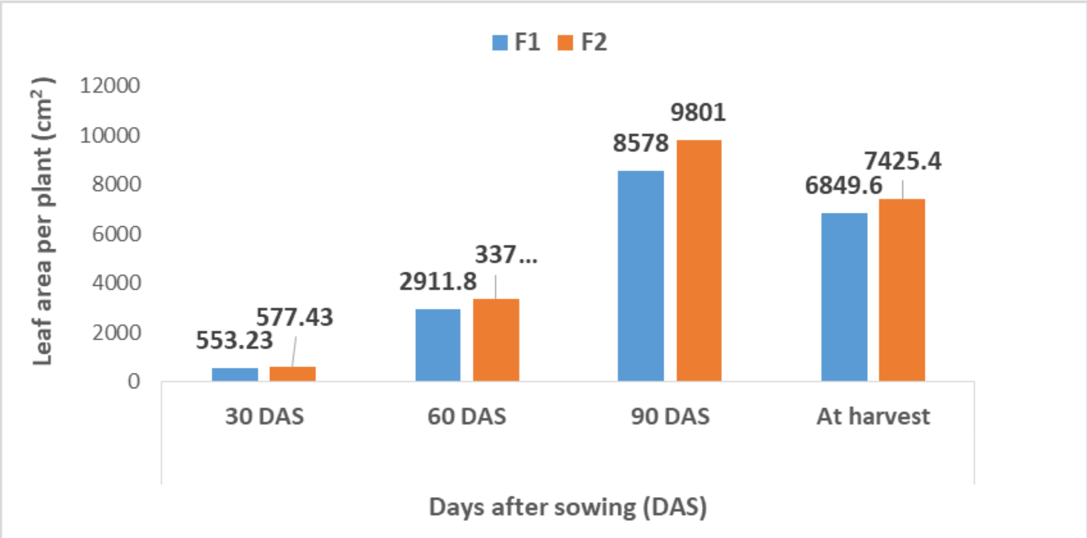
Figure 4.10.4 shows the effect of fertilizer levels on leaf area plant^{-1}**.** Leaf area plant^{-1} was affected significantly by fertilizer levels at all stages (60 DAS, 90 DAS and at harvest) except 30 DAS (Figure 4.10.5). 25% more of the recommended fertilizer dose (F_2) produced the maximum leaf area plant^{-1} (80387 cm^2 at 90 DAS) while the minimum leaf area plant^{-1} (2159.9 cm^2 at 30 DAS) was recorded from recommended fertilizer dose (F_1).

Planting geometry had a significant effect on leaf area plant^{-1} at all for stages (30 DAS, 60 DAS, 90 DAS and at harvest) (Figure 4.10.6). A gradual increase in leaf area plant^{1}

was recorded with a decrease in planting density. The maximum leaf area palnt^{-1} (655.787 cm^2, 3547.0 cm^2, 10409 cm^2 and 7666.8 cm^2 at 30 DAS, 60 DAS, 90 DAS and at harvest respectively) was observed from S_4. On the other hand, the minimum leaf area plant^{-1} (492.30 cm^2, 2725.2 cm^2, 8100.0 cm^2 and 6511.8 cm^2 at 30 DAS, 60 DAS, 90 DAS and at harvest respectively) was recorded from S_1 due to crowding effect of the plant and higher intra specific competition for resources and due to less competition for assimilates at lower plant density. Leaf area reduced with higher plant density and this might be due to less competition for assimilates at lower plant density, hence more average leaf area were lower population density. In this experiment it was also observed that leaf area plant^{-1} slowly increased at the early stage of plant growth and 30 days after sowing leaf area increased continuously up to 90 DAS. After that a sharp fall in leaf area plant^{-1} was observed toward harvest. This result was in agreement with Ahmad *et al.* (2006) who reported maximum leaf area of maize under wider row spacing (75 cm) and (65 cm) than in narrower (55 cm) spacing. Moreover, Sangoi *et al*. (2001) showed that higher leaf area of maize (7258 cm2) was attained at row spacing of 75 cm than at 50 cm (6118 cm2).

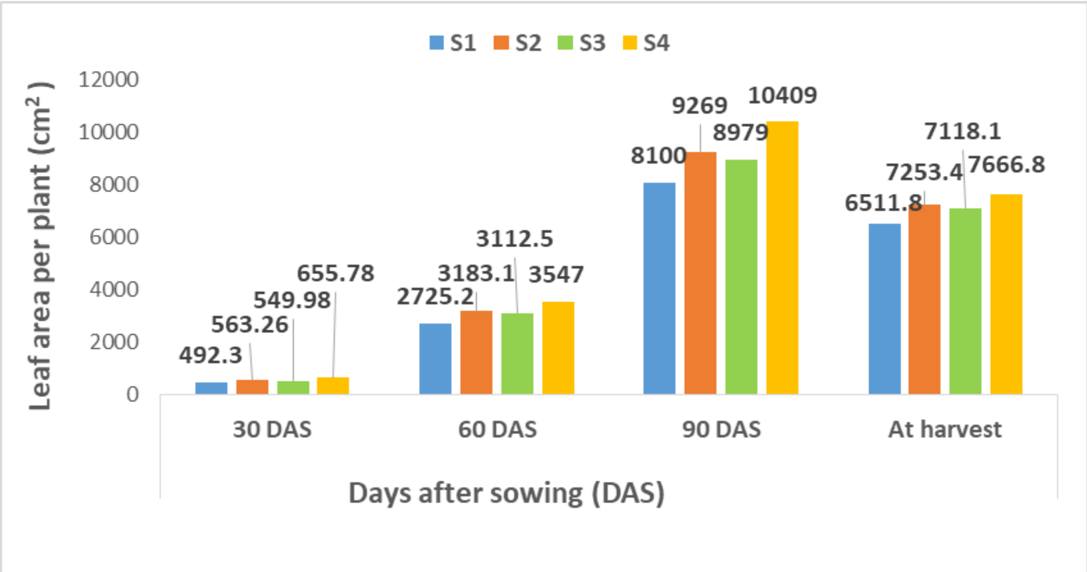
Interaction effect of different doses of fertilizer and planting geometry on leaf area plant^{-1} is placed in the figure 4.10.7. From the experiment it was found that the maximum leaf area palnt^{-1} (668.09 cm^2, 3810.2 cm^2, 11033 cm^2 and 8002 cm^2 at 30

DAS, 60 DAS, 90 DAS and at harvest respectively) was given by $F_2 S_4$. However, the minimum leaf area plant^{-1} (483.66 cm^2, 2540.9 cm^2, 7543.0 cm^2 and 6267.2 cm^2 at 30 DAS, 60 DAS, 90 DAS and at harvest respectively) was recorded from F_1S_1. Here is also a gradual increase in leaf area plant^{-1} up to 90 DAS was observed at first and then a noticeable fall towards harvest.



Here, F_1 = Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

Figure 4.10.5 Effect of fertilizer levels on leaf area per plant at different days after sowing (DAS) of white maize



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm

Figure 4.10.6 Effect of planting geometry on leaf area per plant at different days after sowing (DAS) of white maize

4.10.2.6. Correlation study between leaf area and population density of white maize:

The planting geometries tested in this trial had varying spacings of 50cm x 20cm, 50cm x 25cm and 60cm x 20 cm which represent the plant population per hectare respectively to 100000, 80000, 83333 and 66666. Regression analysis of the leaf area per plant at 90 DAS with these population densities showed that days to maturity of maize was negatively dependent on the population density although it was linear showing a negative regression coefficient of – 0.0687 and R-squired value of 0.9772.(Figure 4.10.7)

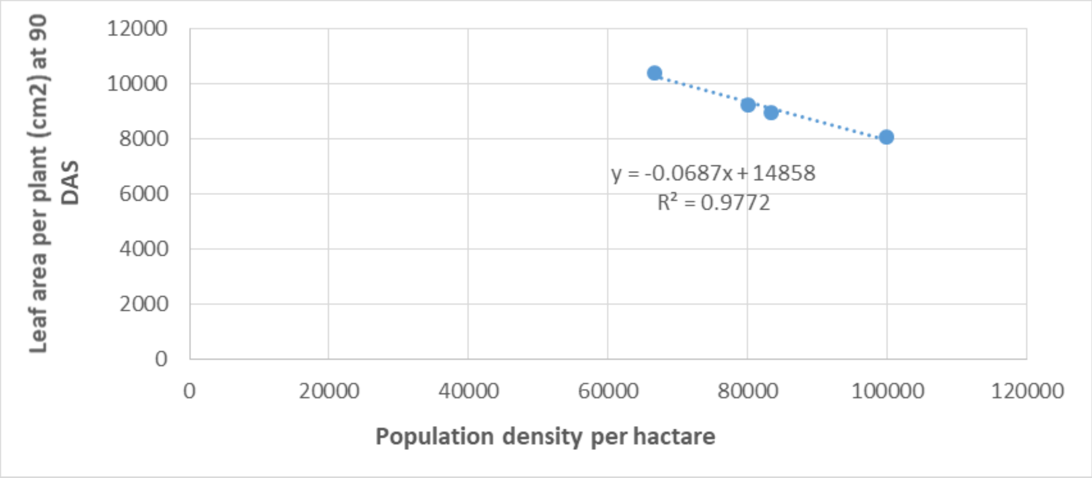
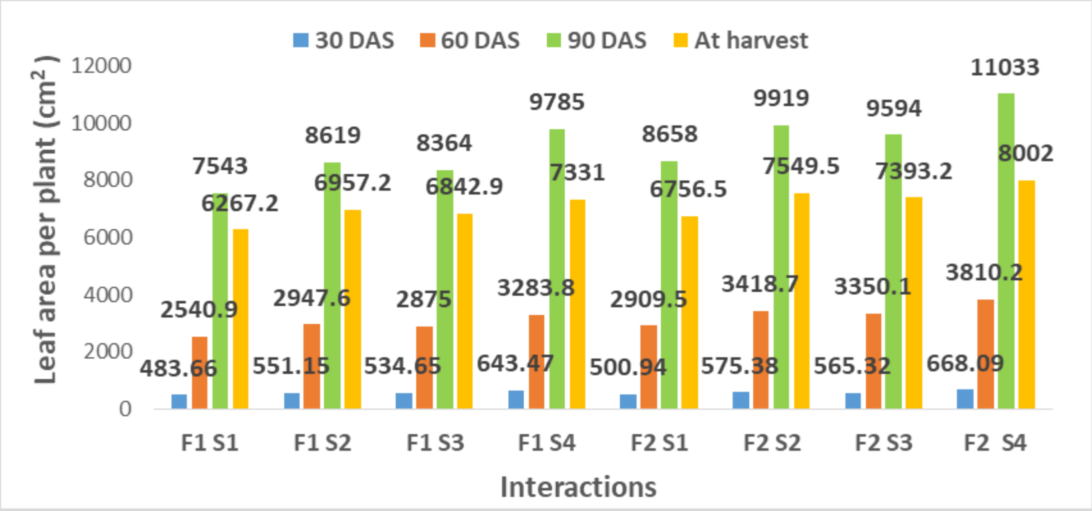


Figure 4.10.7. Relationship between leaf area and population density of white maize



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25cm
F_1= Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

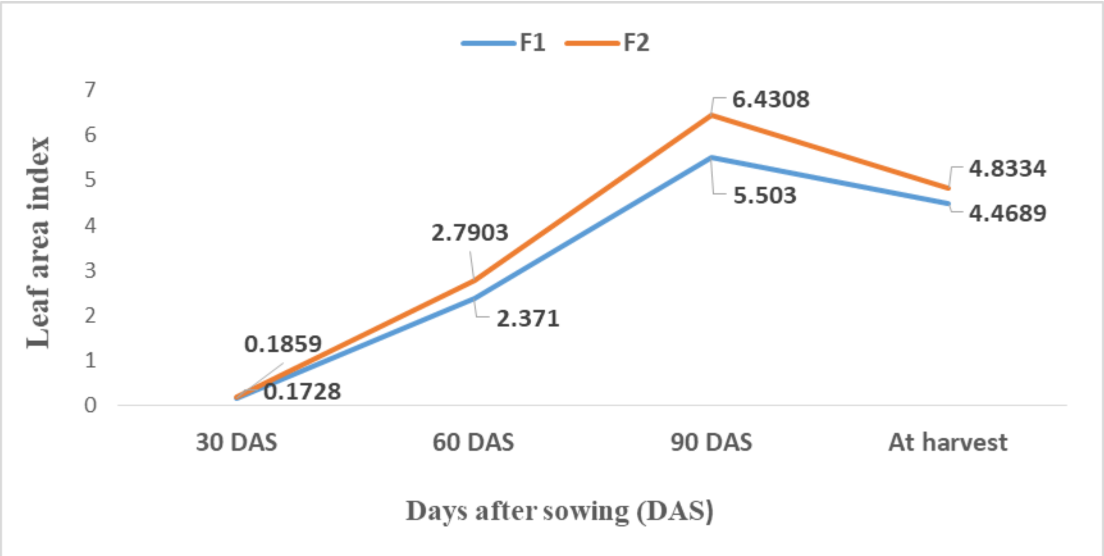
Figure 4.10.8. Interaction effects of fertilizer levels and planting geometry on leaf area per plant at different days after sowing (DAS) of white maize

4.10.2.7. Leaf area index (LAI)

Figure 4.10.9 shows the effect of fertilizer doses on leaf area index. From the experiment it was found that fertilizer doses had a significant effect leaf area index at 60 and 90 DAS, whereas, at 30 DAS and harvest the effect was insignificant. The maximum leaf area index (0.1859, 2.7903, 6.4308 and 4.8334 at 30, 60, 90 DAS and harvest respectively) was recorded from F_2. On the other hand, the minimum leaf area index (0.1728, 2.3710, 5.5030 and 4.4689 at 30, 60, 90 DAS and harvest respectively) was obtained from F_1. The leaf area index gradually increased up to 90 DAS then decreased toward harvest. These increases in LAI can possibly the result of improved leaf expansion in plants due to optimum nitrogenous fertilizers. These results coincided with the findings of Moosavi, (2012) and Imran *et al*., (2015).

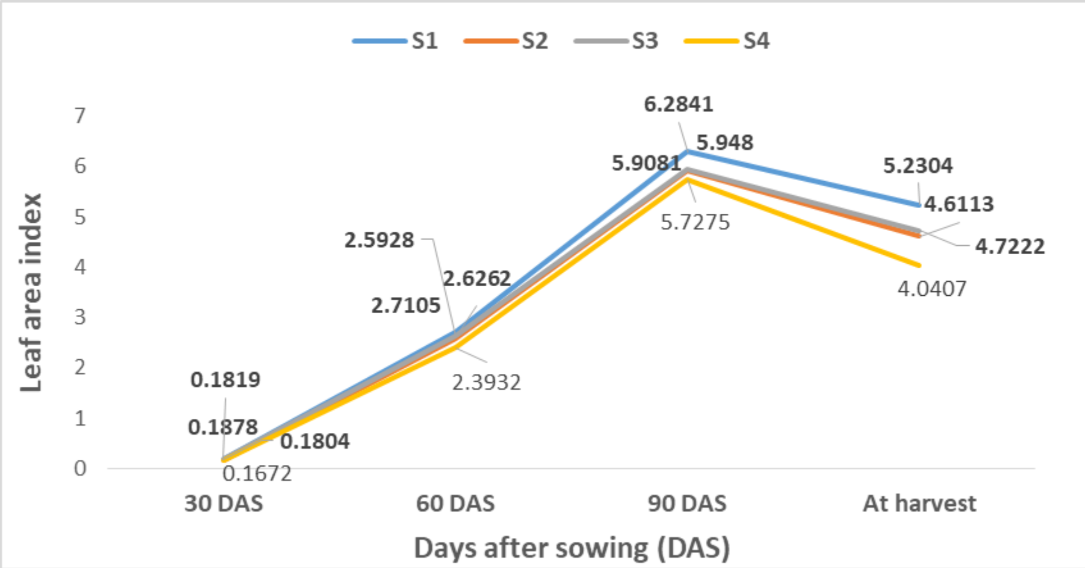
Figure 4.10.10 shows the effect of planting geometrys on leaf area index. Planting geometry affected leaf area index insignificantly. Numerically the highest leaf area index (0.1878, 2.7105, 6.2841 and 5.2304 at 30, 60, 90 DAS and harvest respectively) was given by S_1. However, the minimum leaf area index (0.1672, 2.3932, 5.7275 and 4.0407 at 30, 60, 90 DAS and harvest respectively) was recorded from S_4. Leaf area index values were increased progressively starting from 30 DAS and up to 90 DAS and afterwards declined in the same way till maturity. However, an increase in leaf area index was observed with a decrease in spacing (increasing planting density) most probably due to its higher number of plant population per unit area. Leaf area index decreased with increase in intra and inter-row spacing. Similarly Abuzar *et al*., (2011) reported that LAI was significantly affected and increased in linear fashion with increase in plant population. The declining of leaf area index after attaining a peak value was due to leaf rolling and senescence with aging. Similar result was reported by (Tan *et al*., 2005; Lee *et al*.2005 and Hussaini *et al*., 2001). This result was in agreement with Ahmad *et al*. (2006) who reported higher leaf area index of maize (6.45) under narrower row spacing (55 cm) unlike at wider row spacing (75cm and 65 cm). Yousaf *et al.* (2007) reported that a difference in LAI between maize row spacing was significant and the highest value of 5.33, 5.83 and 6.19 were recorded at 75 cm, 60 cm and 45 cm row spacing, respectively. Similarly, Sangoi *et al*. (2001) reported higher leaf area index (4.6) at 50 cm than at 75 cm (3.64).
Interaction effect of fertilizer doses and different planting geometry on leaf area index is placed in the Figure 4.10.11. In the experiment it was found that the interaction had

a significant on leaf area index of all stages studied except 30 DAS. The maximum leaf area index (0.1923, 2.8801, 6.8673 and 5.4837 at 30, 60, 90 DAS and harvest respectively) was given by $F_2 S_1$. On the other hand, the minimum leaf area index (0.1621, 2.1892, 5.2187 and 3.8691 at 30, 60, 90 DAS and harvest respectively) was given by $F_1 S_4$. The leaf area index gradually increased up to 90 DAS then decreased toward harvest. These results are similar with Jasemi *et al*.,(2013) who reported that higher LAI associated with nitrogen treated plants have been probably due to increased leaf production and leaf area duration. Valadabadi and Farahani (2010) also reported that leaf area is influenced by genotype, plant population, climate and soil fertility. They further reported that highest physiological growth indices are achieved under high plant density because photosynthesis increases by development of leaf area. In this research, the increase in LAI explains the general crop trends that increasing plant density increases leaf area index on account of more area. Previous research findings also indicated that in high maize density, leaf area index, total dry weight and crop growth rate increased than low maize density throughout crop growth season (Saberali, 2007).



Here, F_1 = Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

Figure 4.10.9. Effect of fertilizer on leaf area index (LAI) at different days after sowing (DAS) of white maize



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm

Figure 4.10.10. Effect of planting geometry on leaf area index (LAI) at different days after sowing (DAS) of white maize

4.10.2.8. Correlation study between leaf area index and population density:

The planting geometries tested in this trial had varying spacings of 50cm x 20cm, 50cm x 25cm and 60cm x 20 cm which represent the plant population per hectare respectively to 100000, 80000, 83333 and 66666. In contrast to the plant height and leaf area per plant, the regression analysis of the leaf area index at 90 DAS with these population densities showed that leaf area index of maize was positively dependent on the population density and it was linear showing a regression coefficient of 0.005 and R-squired value of 0.9839.(Figure 4.10.11).

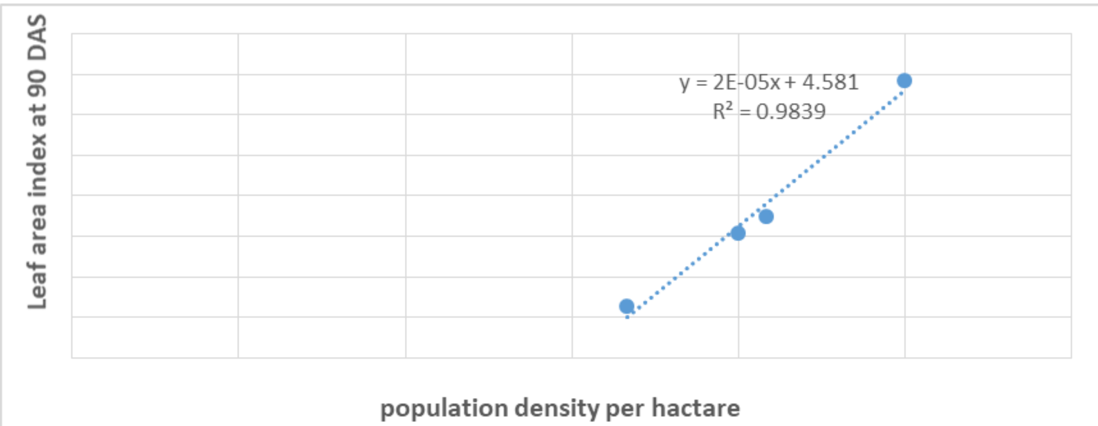
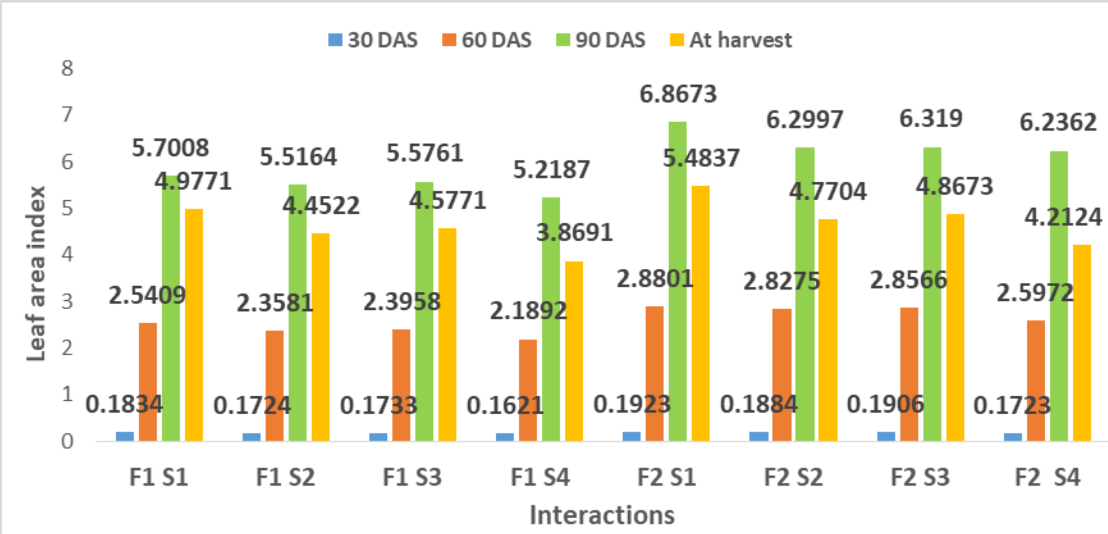


Figure 4.10.11. Relationship between leaf area index and population density of white maize



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm
F_1 = Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

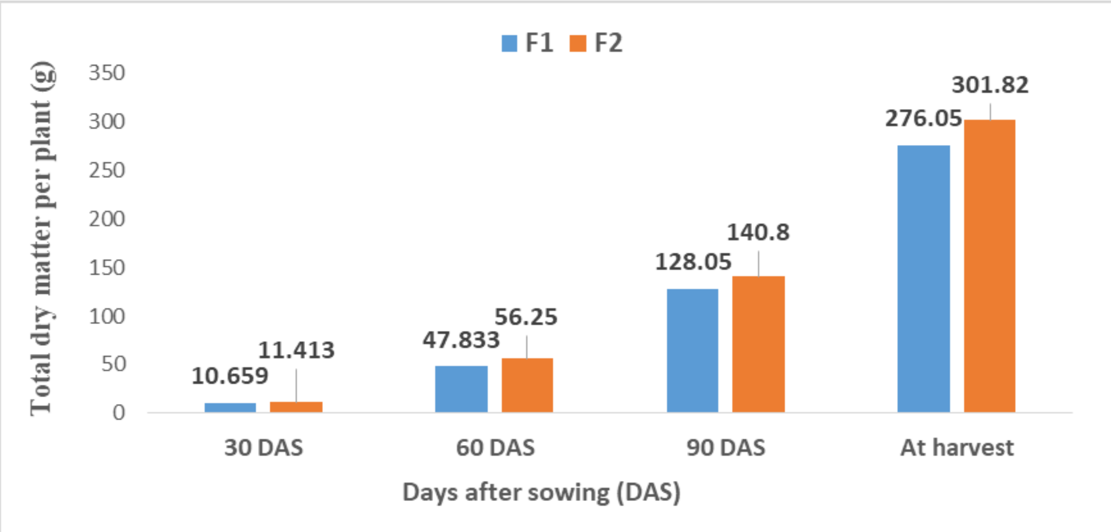
Figure 4.10.12. Interaction effects of fertilizer levels and planting geometry on leaf area index (LAI) at different days after sowing (DAS)

4.10.2.9. Total dry matter per plant (TDM)

Figure 4.10.13 shows the effect of different doses of fertilizer on total dry matter per plant of white maize at different days after sowing (DAS). Fertilizer doses showed a significant effect on total dry matter plant^{-1} in all stages studied in the experiment. The highest total dry matter plant^{-1} (11.41 g, 56.25 g, 140.80 g and 301.82 g at 30, 60, 90 DAS and harvest respectively) was given by F_2. On the other hand, the lowest total dry matter plant^{-1} (10.65 g, 47.83 g, 128.05 g and 276.05 g m^{-2} at 30, 60, 90 DAS and harvest respectively) was given by F_1.

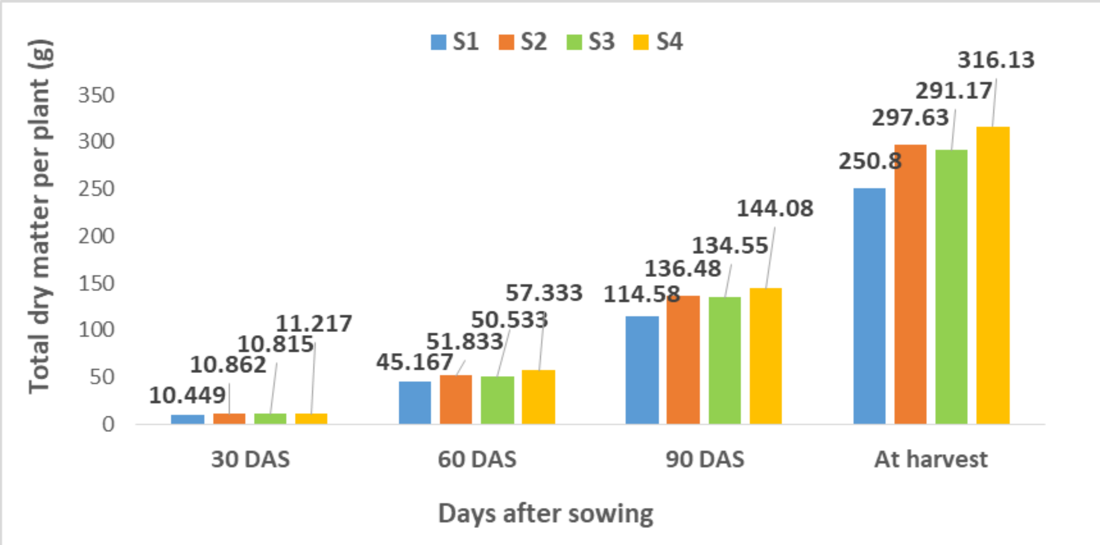
Figure 4.10.14 shows the effect of different planting geometrys on total dry matter per plant of white maize at different days after sowing (DAS). Fertilizer doses showed a significant effect on total dry matter plant^{-1} in all stages studied in the experiment except 30 DAS where the effect was insignificant. The highest total dry matter plant^{-1} (11.21 g, 57.33 g, 142.08 g and 316.13 g at 30, 60, 90 DAS and harvest respectively) was given by S_4. On the other hand, the lowest total dry matter plant^{-1} (10.44 g, 45.16 g, 112.58 g and 250.80 g at 30, 60, 90 DAS and harvest respectively) was given by S_1. Total dry matter production varied significantly due to different spacing of maize. It was observed that TDM increased gradually from 30 DAS to 60 DAS and thereafter increased sharply with the advancement of growth period. However, result indicated that TDM increased with the decreasing of plant density till harvest. Higher dry matter accumulation was observed among the plants of higher population densities. Higher dry matter per unit area was obtained due to higher number of plants of the area but dry matter per plant was lower in relation to lower plant densities. In all cases, S_1 (50 cm x 20 cm) produced higher TDM and S_4 (65 cm x 25 cm) produced lower TDM. Similar result was reported by (Vadivel *et al*., 2001, Cathcart R.J, and Swanton C.J., 2004) in maize.

Figure 4.10.16 shows the interaction effect of fertilizer doses and spacing geometrys on total dry matter plant^{1}. Fertilizer doses showed a significant effect on total dry matter plant^{-1} in all stages studied in the experiment. The highest total dry matter plant^{-1} (11.81 g, 58.00 g, 147.97 and 329.53 g at 30, 60, 90 DAS and harvest respectively) was given by F_2 S_4. On the other hand, the lowest total dry matter plant^{-1} (10.02 g, 42.00 g, 106.83 g and 241.13 g at 30, 60, 90 DAS and harvest respectively) was given by F_1S_1.



Here, F_1 = Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

Figure 4.10.13. Effect of fertilizer levels on total dry matter per plant different days after sowing (DAS) of white maize



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm

Figure 4.10.14. Effect of planting geometry on total dry matter per plant at different days after sowing (DAS) of white maize

4.10.2.10. Correlation study between total dry matter (TDM) per plant and population density of white maize:

The planting geometries tested in this trial had varying spacings of 50cm x 20cm, 50cm x 25cm and 60cm x 20 cm which represent the plant population per hectare respectively to 100000, 80000, 83333 and 66666. Like the plant height and leaf area per plant, the regression analysis of the total dry matter at harvest with these population densities showed that total dry matter at harvest of maize was negatively dependent on the population density and it was linear showing a negative regression coefficient of 0.002 and R-squired value of 0.9743 (Figure 4.10.15)

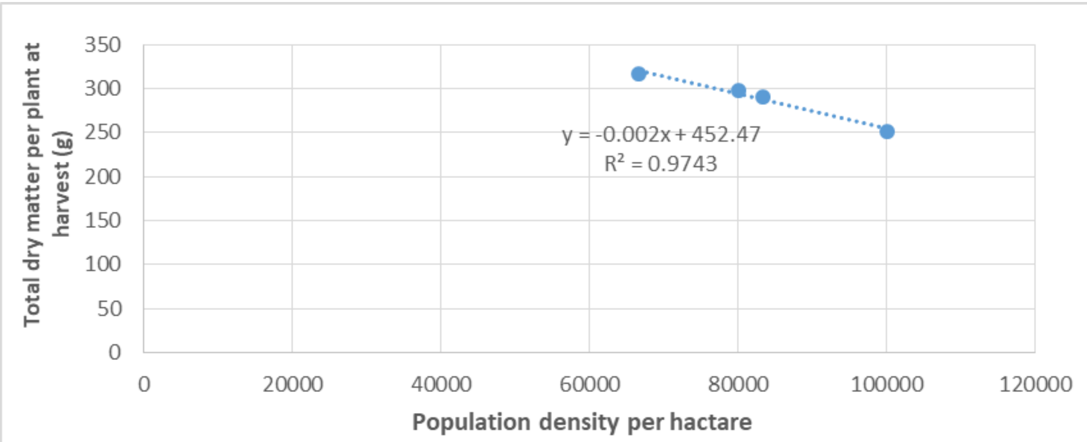
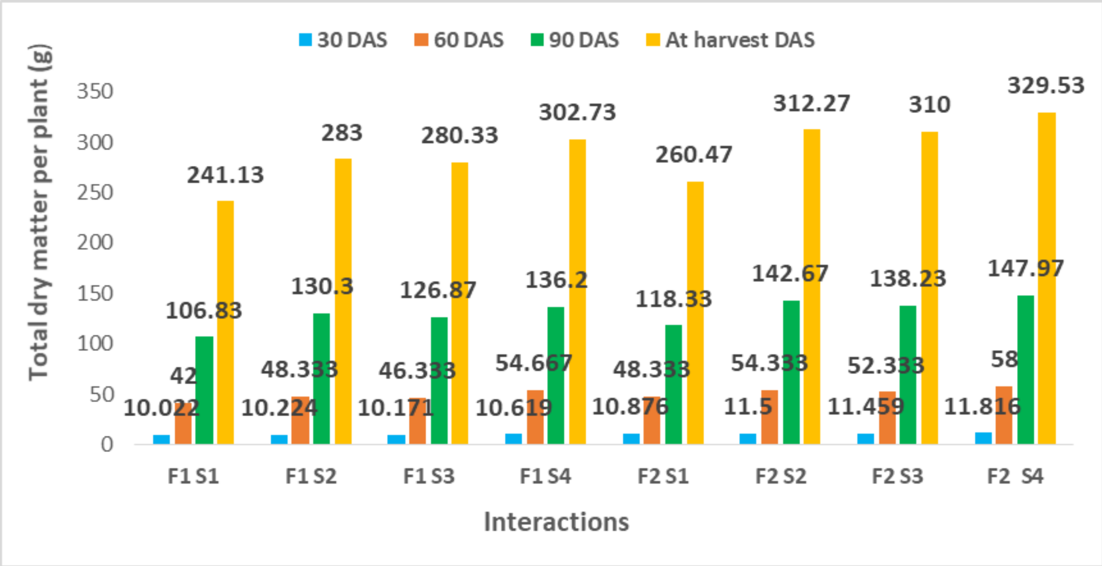


Figure 4.10.15. Relationship between total dry matter per plant and population density of white maize



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm
F_1 = Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

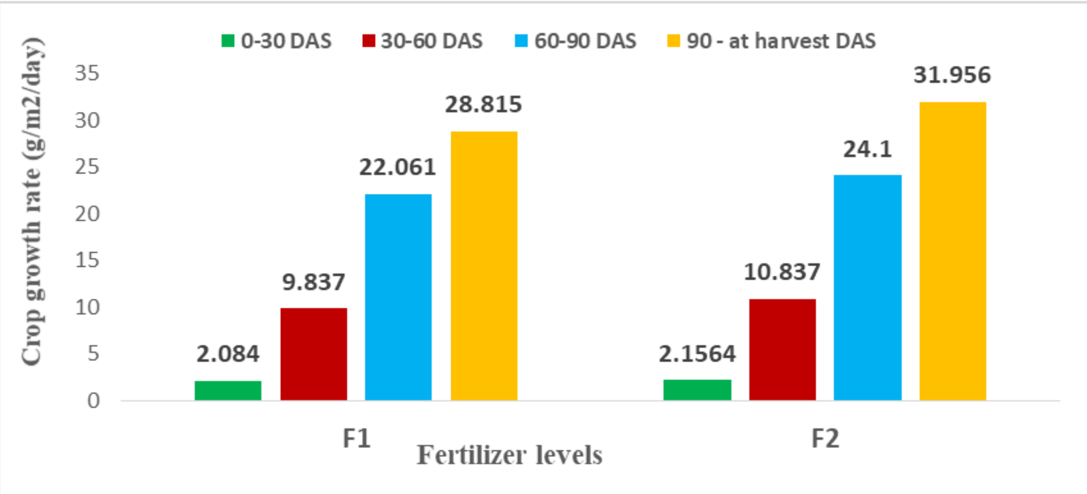
Figure 4.10.16. Interaction effects of fertilizer and planting geometry on total dry matter per plant at different days after sowing (DAS)

4.10.2.11. Crop growth rate (CGR)

Results regarding the effect of different fertilizer doses on crop growth rate are represented in the Figure 4.10.17. There was no significant difference between the fertilizer doses in terms of their effect on crop growth rate. In the experiment, the maximum crop growth rate (2.156 g m^{-2} day^{-1}, 10.83 g m^{-2} day^{-1}, 24.10 g m^{-2} day^{-1} and 31.95 g m^{-2} day^{-1} at 0-30 DAS, 30-60 DAS, 60-90 DAS and 90-harvest, respectively) was found from F_2, whereas, the minimum result (2.084 g m^{-2} day^{-1}, 9.83 g m^{-2} day^{-1}, 22.06 g m^{-2} day^{-1} and 28.81 g m^{-2} day^{-1} at 0-30 DAS, 30-60 DAS, 60-90 DAS and 90-harvest, respectively) was found from F_1. A continuous increase in relative growth rate was recorded from 30 DAS to toward harvest.

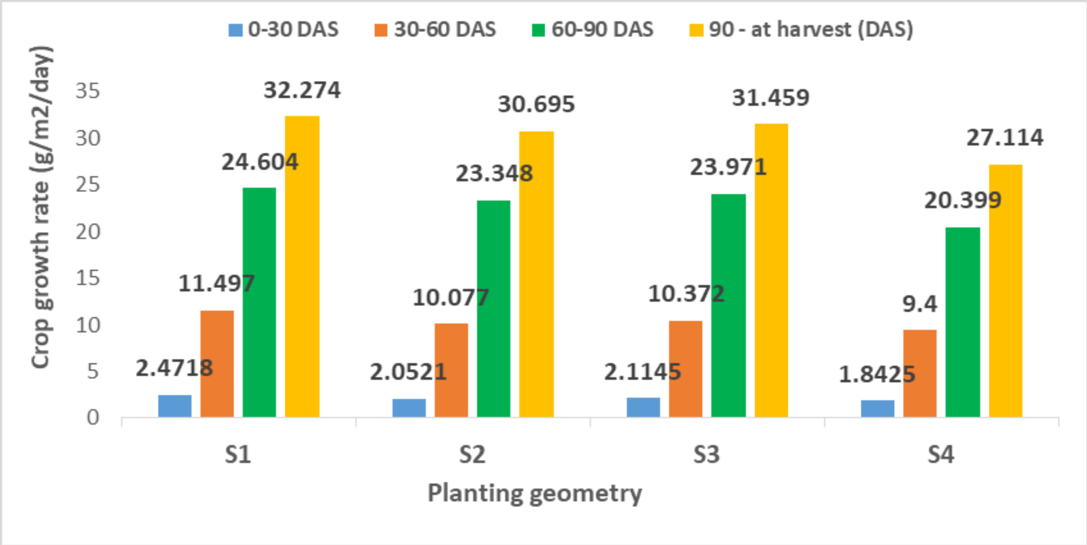
Results regarding the effect of different planting geometrys on crop growth rate are represented in the figure 4.10.18. There was a significant effect of planting geometry on crop growth rate. In the experiment, the maximum crop growth rate (2.4718 g m^{-2} day^{-1}, 11.49 g m^{-2} day^{-1}, 24.60 gm^{-2} day^{-1} and 32.27 g m^{-2} day^{-1} at 0-30 DAS, 30-60 DAS, 60-90 DAS and 90-harvest, respectively) was given by S_1. On the other hand, the minimum result (1.8425 g m^{-2} day^{-1}, 9.40 g m^{-2} day^{-1}, 20.39 g m^{-2} day^{-1} and 27.11 g m^{-2} day^{-1} at 0-30 DAS, 30-60 DAS, 60-90 DAS and 90-harvest, respectively) was found from S_4. A continuous increase in relative growth rate was recorded from 30 DAS to toward harvest. Crop growth rate was significantly influenced due to plant spacing of maize. At the early stages of plant growth CGR was very low than increased sharply up to 90 DAS. In Similar result was reported by Ibeawuchi *et al*.,(2008); Valadavadi and Farhani (2009) and Maqbool *et al*, (2006) in maize. They reported that CGR increased with the highest population per m^2.

Results regarding the interaction effect of fertilizer doses and different planting geometrys on crop growth rate are represented in the figure 4.10.20. There was a significant effect of fertilizer doses and different planting geometrys interactions on crop growth rate. In the experiment, the maximum crop growth rate (2.5252 g m^{-2} day^{-1}, 12.24 g m^{-2} day^{-1}, 25.74 gm^{-2} day^{-1} and 34.15 g m^{-2} day^{-1} at 0-30 DAS, 30-60 DAS, 60-90 DAS and 90-harvest, respectively) was given by F_2 S_1. On the other hand, the minimum result (1.8189 g m^{-2} day^{-1}, 8.98 g m^{-2} day^{-1}, 19.53 g m^{-2} day^{-1} and 25.94 g m^{-2} day^{-1} at 0-30 DAS, 30-60 DAS, 60-90 DAS and 90-harvest, respectively) was found from F_1 S_4. A continuous increase in relative growth rate was recorded from 30 DAS to toward harvest. Crop growth rate depends on the amount of radiation intercepted by the crop and on the efficiency of conversion of intercepted radiation into dry matter. Vigorous vegetative growth, greater dry matter accumulation and photo-assimilates partitioning from vegetative to reproductive phase are the main indicators of physiological indices.



Here, F_1 = Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

Figure 4.10.17. Effect of different doses of on crop growth rate (CGR) at different days after sowing (DAS) of white maize



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm

Figure 4.10.18. Effect of planting geometry on crop growth rate (CGR) at different days after sowing (DAS) of white maize

4.10.2.12. Correlation study between Crop growth rate (CGR) and population density:

The planting geometries tested in this trial had varying spacings of 50cm x 20cm, 50cm x 25cm and 60cm x 20 cm which represent the plant population per hectare respectively to 100000, 80000, 83333 and 66666. In contrast to the plant height and leaf area per plant, the regression analysis of the crop growth rate at 90 DAS to harvest with these population densities showed that crop growth rate at 90 DAS to harvest of maize was positively dependent on the population density and it was linear showing a negative regression coefficient of 0.0002 and R-squired value of 0.9743 (Figure 4.10.19)

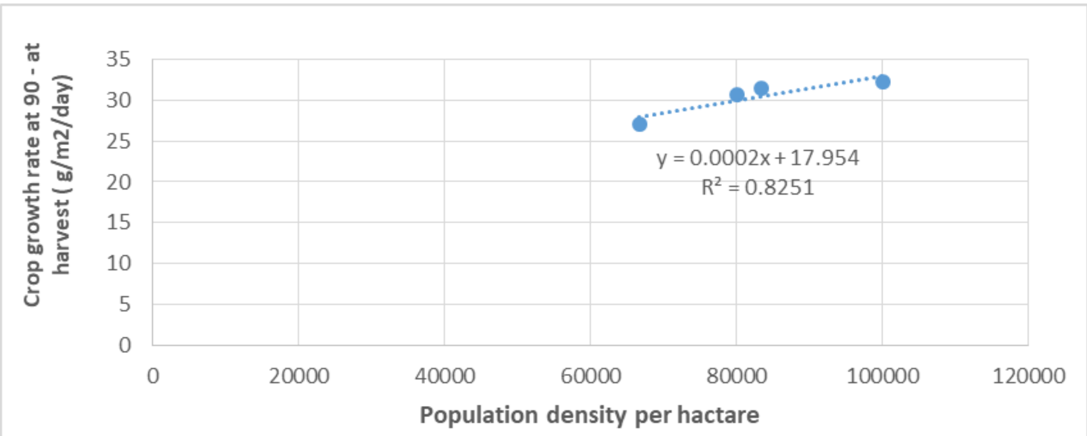
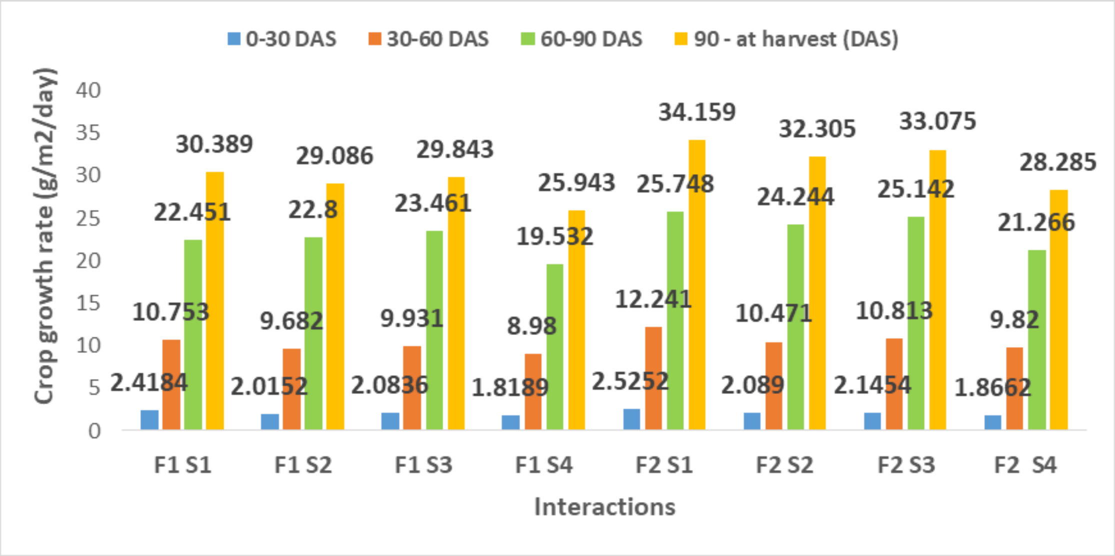


Figure 4.10.19. Relationship between crop growth rate and population density of white maize



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm
F_1 = Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

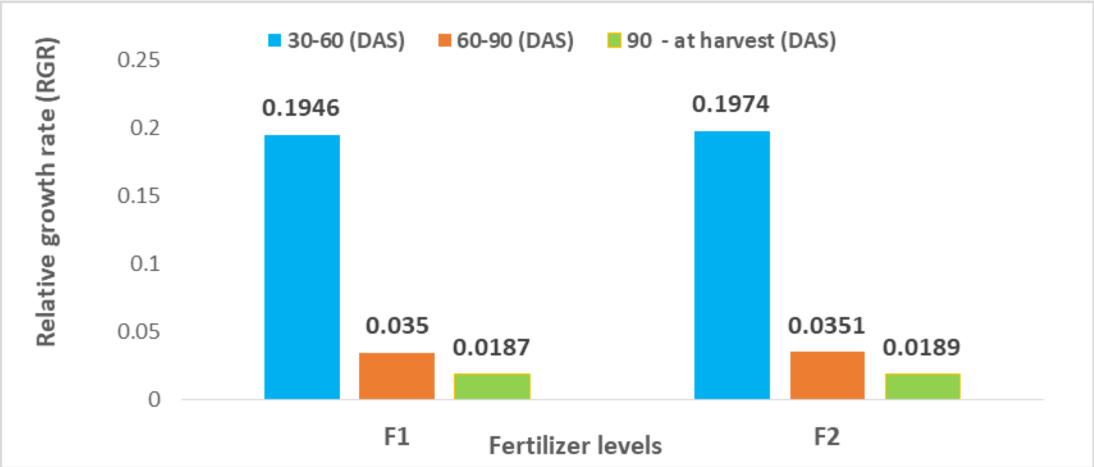
Figure 4.10.20. Interaction effects of fertilizer and planting geometry on crop growth rate (CGR) at different days after sowing (DAS) of white maize

4.10.2.13. Relative growth rate (RGR)

Results regarding the effect of different fertilizer doses on relative growth rate are represented in the figure 4.10.21. There was no significant difference between the fertilizer doses in terms of their effect on relative growth rate. In the experiment, the maximum relative growth rate (0.1974 g m^{-2} day^{-1}, 0.0351 g m^{-2} day^{-1} and 0.0189 g m^{-2} day^{-1} at 30-60 DAS, 60-90 DAS and 90-harvest respectively) was found from F_2, whereas, the minimum result (0.1946 g m^{-2} day^{-1}, 0.0350 g m^{-2} day^{-1} and 0.0187 g m^{-2} day^{-1} at 30-60 DAS, 60-90 DAS and 90-harvest respectively) was found from F_1. A continuous decrease in relative growth rate was recorded from 30 DAS to toward harvest as a core finding in the experiment.

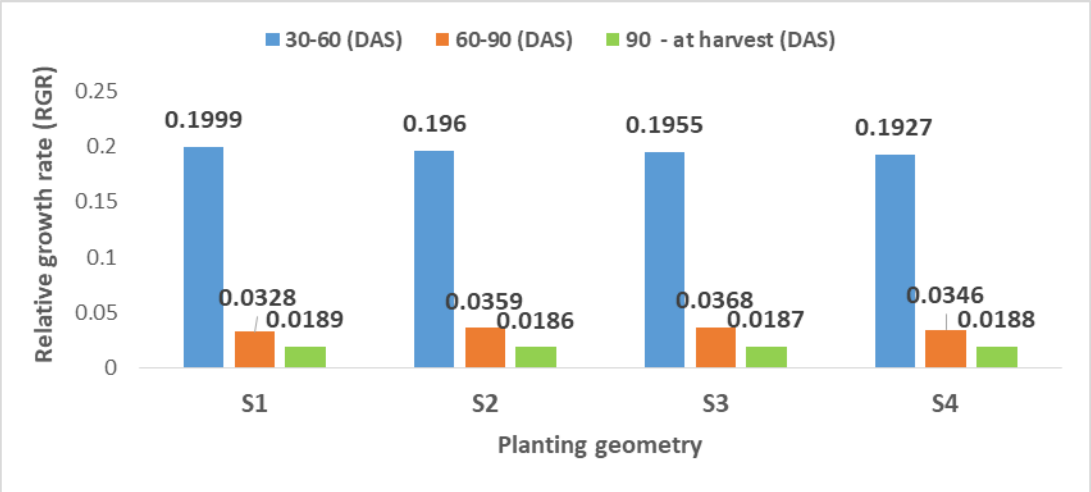
Figure 4.10.22 shows the effect of planting geometry on relative growth rate. The effect was found insignificant at 60-90 DAS and 90-harvest, whereas, it was significant at 30-60 DAS. The highest relative growth rate (0.1999 gm^{-2} day^{-1} and 0.0189 at 30-60 DAS and 90-harvest respectively) was found from S_1. On the other hand, the highest relative growth rate (0.0368 gm^{-2} day^{-1}) at 60-90 DAS was recorded from S_3. However, the minimum relative growth rate (0.1927 gm^{-2} day^{-1}, 0.0328 gm^{-2} day^{-1} and 0.0186 gm^{-2} day^{-1} at 30-60 DAS, 60-90 DAS and 90-harvest respectively) was obtained from S_4, S_1 and S_2 respectively. A decreasing trend of relative growth rate from 30 DAS to harvest was noticed in the experiment.

The findings regarding interaction effects of different doses of fertilizer and planting geometry on relative growth rate are represented in the figure 4.10.24. The effect was found insignificant at 60-90 DAS and 90-harvest, whereas, it was significant at 30-60 DAS. The highest relative growth rate (0.2018 gm^{-2} day^{-1} and 0.0191 gm^{-2} day^{-1} at 30-60 DAS and 90-harvest respectively) was found from F_2 S_1. On the other hand, the highest relative growth rate (0.0371 gm^{-2} day^{-1}) at 60-90 DAS was recorded from F_2 S_3. However, the minimum relative growth rate (0.1914 gm^{-2} day^{-1}, 0.0324 gm^{-2} day^{-1} and 0.0185 gm^{-2} day^{-1} at 30-60 DAS, 60-90 DAS and 90-harvest respectively) was obtained from F_1 S_4, F_2 S_1 and F_1 S_2 respectively. A decreasing trend of relative growth rate from 30 DAS to harvest was noticed in the experiment.



Here, F_1 = Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

Figure 4.10.21. Effect of fertilizer levels on relative growth rate (RGR) at different days after sowing (DAS) of white maize



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm

Figure 4.10.22. Effect of planting geometry on relative growth rate (RGR) at different days after sowing (DAS) of white maize

4.10.2.14. Correlation study between relative growth rate (RGR) and population density of white maize:

The planting geometries tested in this trial had varying spacings of 50cm x 20cm, 50cm x 25cm and 60cm x 20 cm which represent the plant population per hectare respectively to 100000, 80000, 83333 and 66666. In contrast to the plant height and leaf area per plant, the polynomial regression analysis of relative growth rate at 30 DAS with these population densities showed that relative growth rate of maize was positively dependent on the population density and it was linear showing a regression coefficient of 0.005 and R-squired value of 0.9706.(Figure 4.10.23).

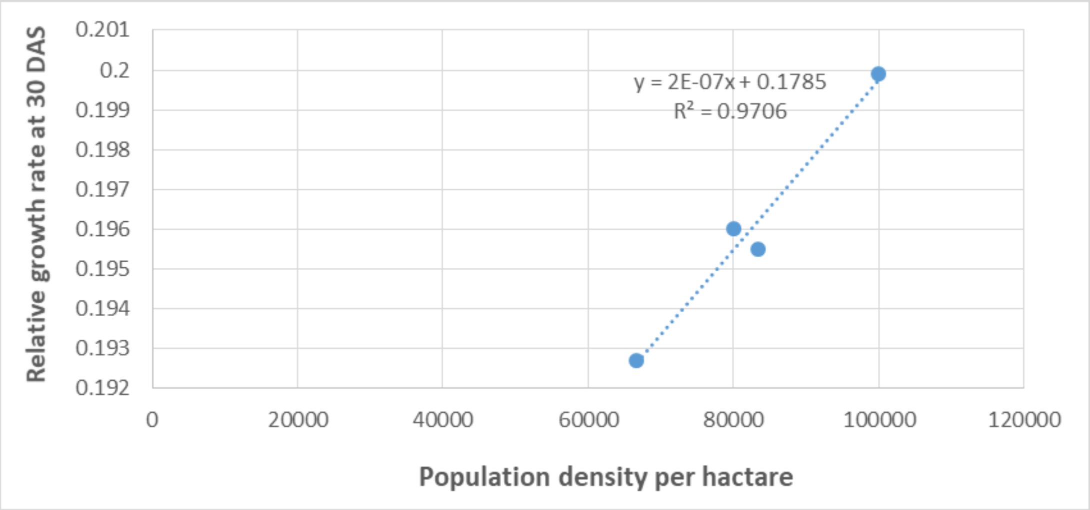
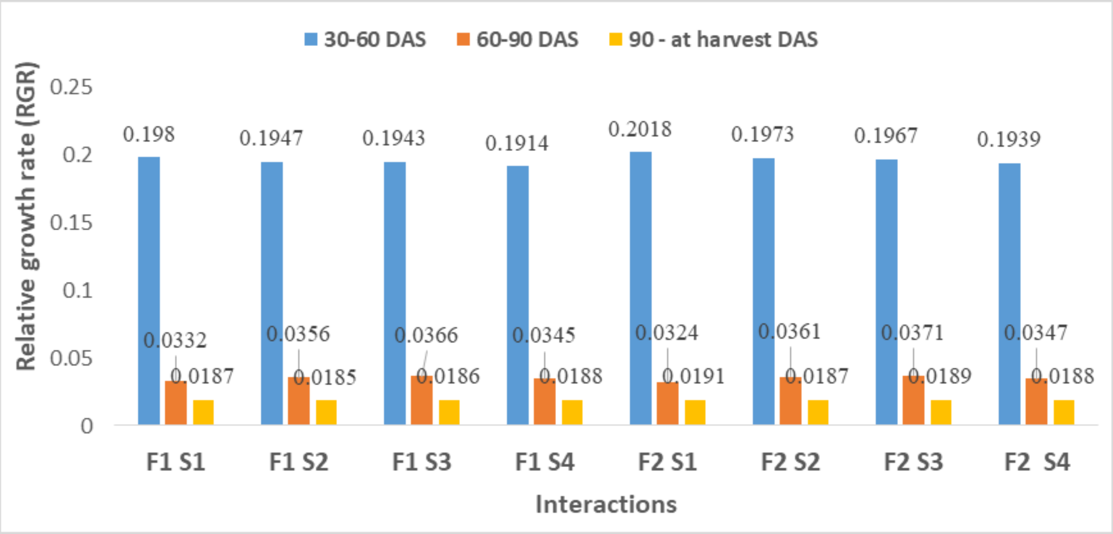


Figure 4.10.23. Relationship between relative growth rate and population density of white maize



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm
F_1 = Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

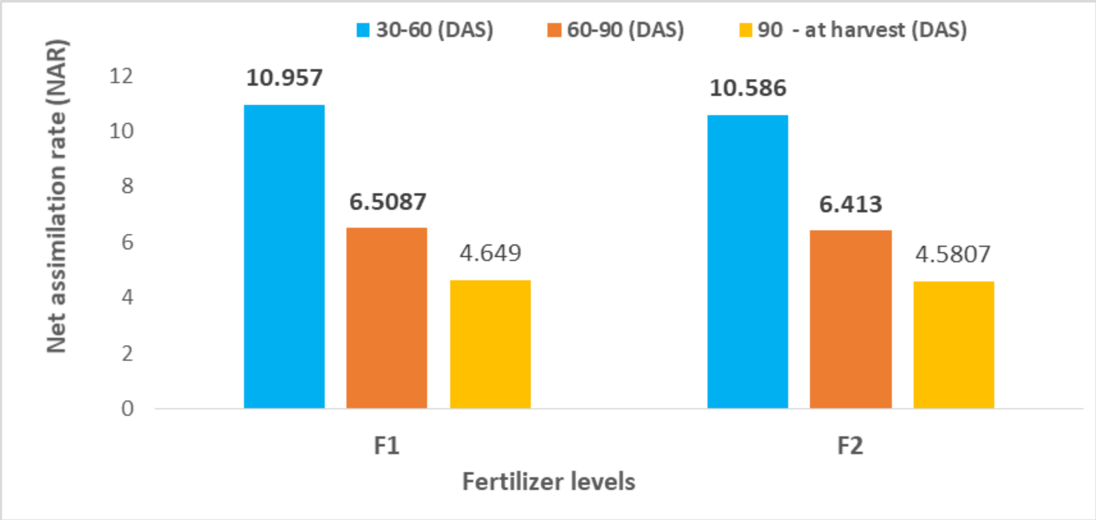
Figure 4.10.24. Interaction effects of fertilizer levels and planting geometry on relative growth rate (RGR) at different days after sowing (DAS) of white maize

4.10.2.15. Net assimilation rate (NAR)

Results regarding the effect of different fertilizer doses on net assimilation rate are represented in the figure 4.10.25. There was no significant difference between the fertilizer doses in terms of their effect on net assimilation rate. In the experiment, the maximum net assimilation rate (10.95 g m^{-2} day^{-1}, 6.50 g m^{-2} day^{-1} and 4.64 g m^{-2} day^{-1} at 30-60 DAS, 60-90 DAS and 90-harvest respectively) was found from F_1, whereas, the minimum result (10.58 g m^{-2} day^{-1}, 6.41 g m^{-2} day^{-1} and 4.58 g m^{-2} day^{-1} at 30-60 DAS, 60-90 DAS and 90-harvest respectively) was found from F_2. A continuous decrease in net assimilation rate was recorded from 30 DAS to toward harvest as a core finding in the experiment.

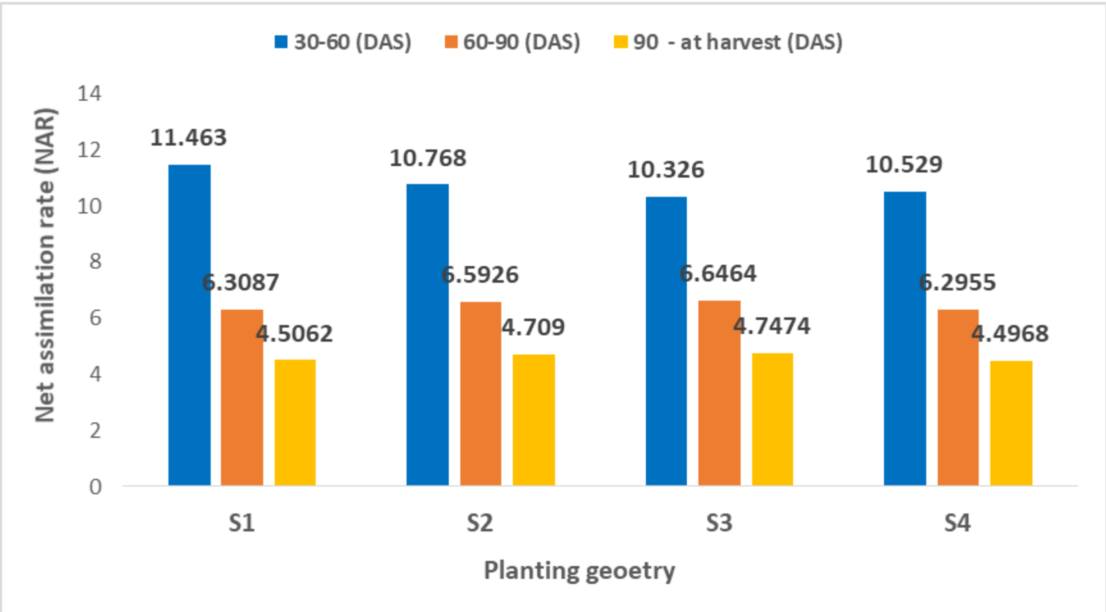
Figure 4.10.26 shows the effect of planting geometrys on net assimilation rate. The effect was found insignificant. Numerically the highest value of net assimilation rate (11.463 gm^{-2} day^{-1}) at 30-60 DAS was recorded from S_1. On the other hand, the maximum net assimilation rate of 6.64 g m^{-2} day^{-1} and 4.74 g m^{-2} day^{-1} at 60-90 DAS and 90-harvest respectively was recorded from S_3. However, the minimum net assimilation rate at 30-60 DAS (10.32 gm^{-2} day^{-1}) was obtained from S_3, whereas, at 60-90 DAS and 90-harvest the minimum net assimilation rate (6.29 gm^{-2} day^{-1} and 4.49 gm^{-2} day^{-1}) was recorded from S_4. A decreasing trend of net assimilation rate from 30 DAS to harvest was noticed in the experiment.

The findings regarding Interaction effects of different doses of fertilizer and planting geometry on net assimilation rate (NAR) are represented in the figure 4.10.28. In the experiment it was found that there was no significant effect of fertilizer doses and planting geometry interaction on net assimilation rate. Numerically the maximum net assimilation rate at 30-60 DAS (11.68, 6.67 gm^{-2} day^{-1}) was given by F_2 S_1. On the other hand, at 60-90 DAS and harvest the maximum net assimilation rate (6.67 and 4.76 gm^{-2} day^{-1} respectively) was showed by F_2 S_3. However, the minimum net assimilation rate at 30-60 DAS (9.49 gm^{-2} day^{-1}) was obtained from F_2 S_3, whereas, at 60-90 DAS and 90-harvest the minimum net assimilation rate (6.22 gm^{-2} day^{-1} and 4.44 gm^{-2} day^{-1}) was recorded from F_2 S_1. A decreasing trend of net assimilation rate from 30 DAS to harvest was noticed in the experiment.



Here, F_1 = Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

Figure 4.10.25. Effect of fertilizer levels on net assimilation rate (NAR) at different days after sowing (DAS) of white maize



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm

Figure 4.10.26. Effect of planting geometry on net assimilation rate (NAR) at different days after sowing (DAS) of white maize

4.10.2.16. Correlation study between net assimilation rate (NAR) and population density of white maize

The planting geometries tested in this trial had varying spacings of 50cm x 20cm, 50cm x 25cm and 60cm x 20 cm which represent the plant population per hectare respectively to 100000, 80000, 83333 and 66666. In contrast to the plant height and leaf area per plant, the polynomial regression analysis of the net assimilation rate at 90 DAS to harvest with these population densities showed that net assimilation rate at 90 DAS to harvest of maize was positively dependent on the population density and it was linear showing a positive regression coefficient of 0.0002 and R-squired value of 0.9925. The fitted curve was parabola (Fig.4.10.27)

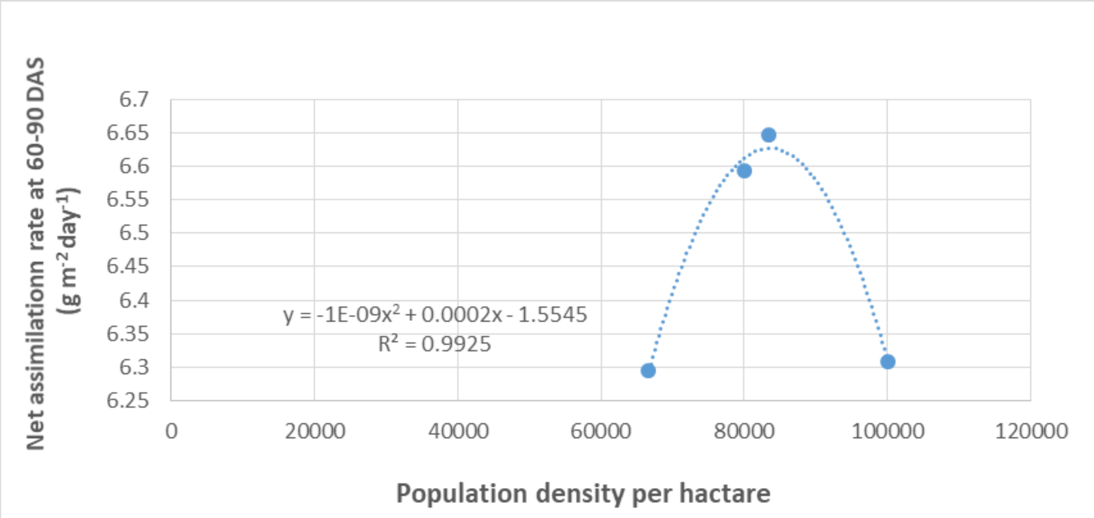
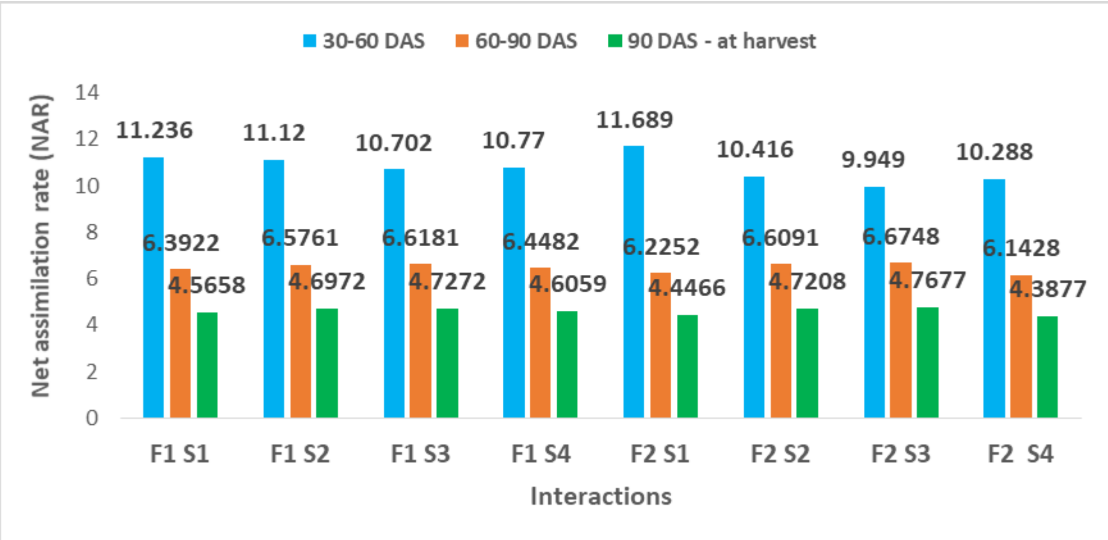


Figure 4.10.27. Relationship between net assimilation rate and population density of white maize



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm,
F_1 = Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

Figure 4.10.28. Interaction effects of fertilizer levels and planting geometry on net assimilation rate (NAR) at different days after sowing (DAS) of white maize

4.10.3. Yield and Yield Components

4.10.3.1. Cob length

Significant differences was observed among the fertilizer treatments on the production of cob length (Figure 4.10.29). Maximum cob length (16.575 cm) was achieved with F_2 and the minimum (15.275 cm) was achieved with F_1.These results are similar with the results of Akram *et al*., (2010) who reported that cob length increases with increase in nitrogen level.

Significant difference was found among the various plant spacings. S_4 produced tallest cobs (16.900 cm) which was statistically similar with S_2 (16.480 cm) while S_1 produced the shortest cobs (15.172 cm) (Figure 4.10.30). Similar results were also obtained by Khah *et al*., (2012) reported that ear length reduced with increasing plant population

Moreover, from the combination of fertilizer dose and plant spacings it was observed that F_2 S_4 (17.650 cm) showed the longest cobs, which was statistically similar to F_2 S_2 (17.033 F_1 S_1showed the shortest cob length (14.733 cm) (Figure 4.10.31). Similar findings were reported by Abuzar *et al.*,(2011). They observed a positive relationship among the spacing and fertilizer application with cob length. Their analyzed data indicated that there had a significant ($p<0.05$) effect on cob length of maize.

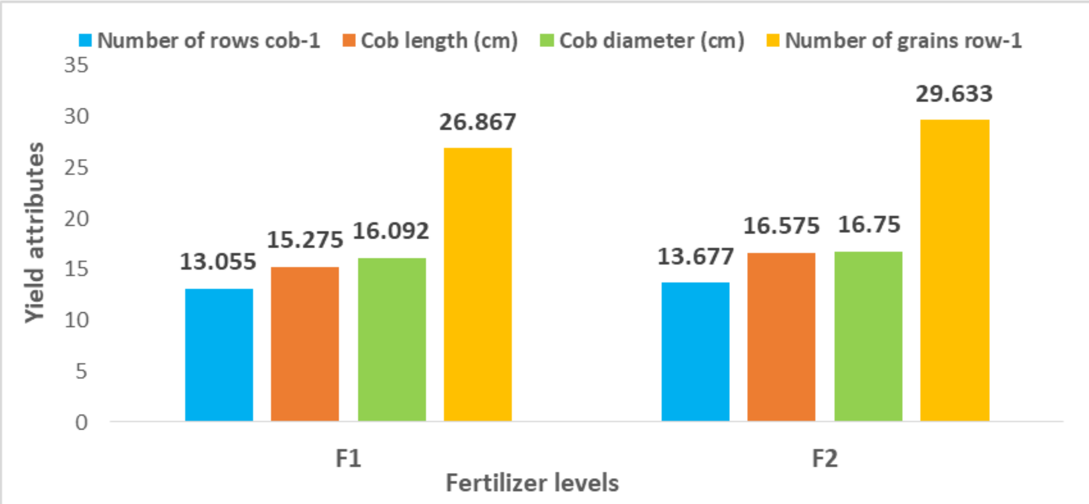
4.10.3.2. Cob diameter (cm)

Among the fertilizer treatments significant difference was found on the production of cob diameter in maize (Figure 4.10.29). Maximum cob diameter (16.750 cm) was achieved with F_2 which was statistically dissimilar to F_1 (16.092 cm) and also was the minimum.

Cob diameter was increased with the various plant spacings (Figure 4.10.30). Among the various treatments, S_4 produced tallest cobs (16.950 cm), which was statistically similar to S_2 (16.750 cm) and S_3 (16.283 cm). S_1 produced the shortest cobs (15.700 cm).

Moreover, from the combination of fertilizer and plant spacings it was observed that F_2S_4 (17.433 cm) showed the longest cobs, which was statistically similar to F_1S_2 (16.367 cm), F_1S_4 (16.467 cm), F_2 S_2 (17.133 cm) and F_2S_3 (16.567 cm). F_1S_1 (15.533 cm) showed the shortest cob which was statistically similar to F_2 S_1 (15.867 cm)

(Figure 4.10.31).This significantly increased cob diameter may probably be attributed to NPK that promote higher photosynthetic activities leading to the production of enough assimilate for subsequent translocation to various sinks and hence the production of higher yield and yield components of maize like cob diameter and others ((Jaliya *et al.*, 2008).



Here, F_1 = Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

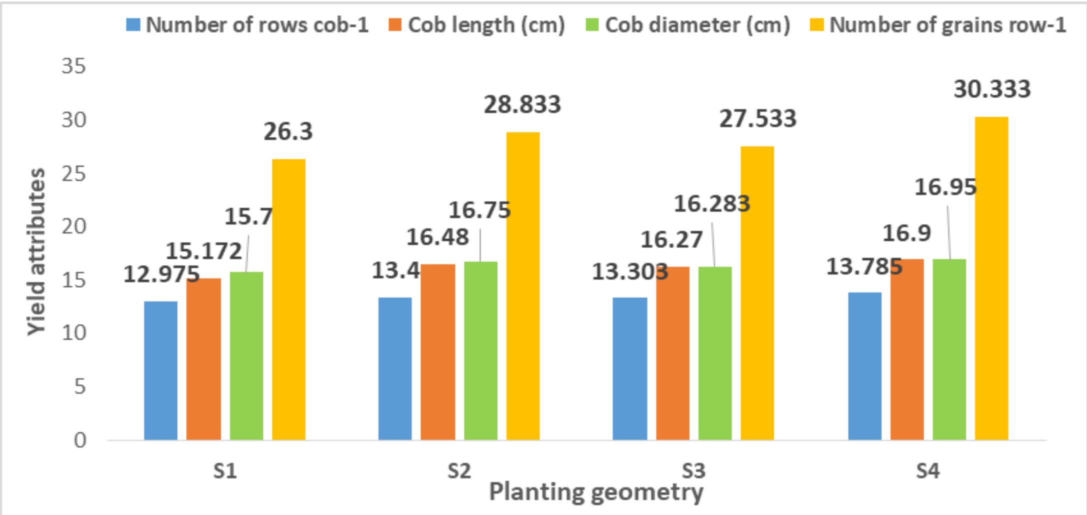
Figure 4.10.29. Effect of fertilizer on cob length; cob diameter, number of rows per cob and number of grains per rows of white maize

4.10.3.3. Number of rows per cob

Total number of rows cob^{-1} was significantly influenced by plant spacings and their combinations but was not significantly influenced by fertilizer doses. In white maize fertilizer dose treatments showed the significant effects on number of rows cob^{-1}(Figure 4.10.29). The maximum number of rows cob^{-1} (13.677) was found in F_2 treatment which was statistically dissimilar to F_1 (13.055) and also was the minimum.

However, the maximum number of rows cob^{-1} (13.785) was achieved with S_4, which was statistically similar to S_2 and S_3 (13.400 and 13.303). S_1 was the lowest performer among others (12.975) (Figure 4.10.30).

Moreover, their combination revealed that F_2S_4 showed the highest number of rows cob^{-1} (14.033), which was statistically similar to F_2S_2 (13.800). F_2 S_2 and F_1S_4 showed medium number of rows cob^{-1}(13.6037, 13.537), F_1S_1 which showed the very minimum number of rows cob^{-1}(12.683) (Figure 4.10.31). Number of grain rows per cob increased with increasing plant spacing. The result was supported by Shams *et al.*, (2002). The number of grain rows per cob decreased as the plant population increased. Usually under high population stress, the late developing distal spikelets fail to set kernels and when the slow growing silks finally emerge, little or no pollen is available for fertilization. Also, high stand density reduces ear shoots growth, which results in fewer spikelets primordial was transformed into functional florets by the time of flowering. The limited carbon and nitrogen supply to the cob finally stimulates young kernel abortion immediately after fertilization Sangoi *et al.*, (2001). Valadabadi and Farahani, (2010) studied to evaluate number of row per cob and other yield contributing characters of maize as influenced by spacing and fertilizer application. They observed that as population density decreased, there was acceleration in number of rows per cob, which was alike with the revealed results.



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm

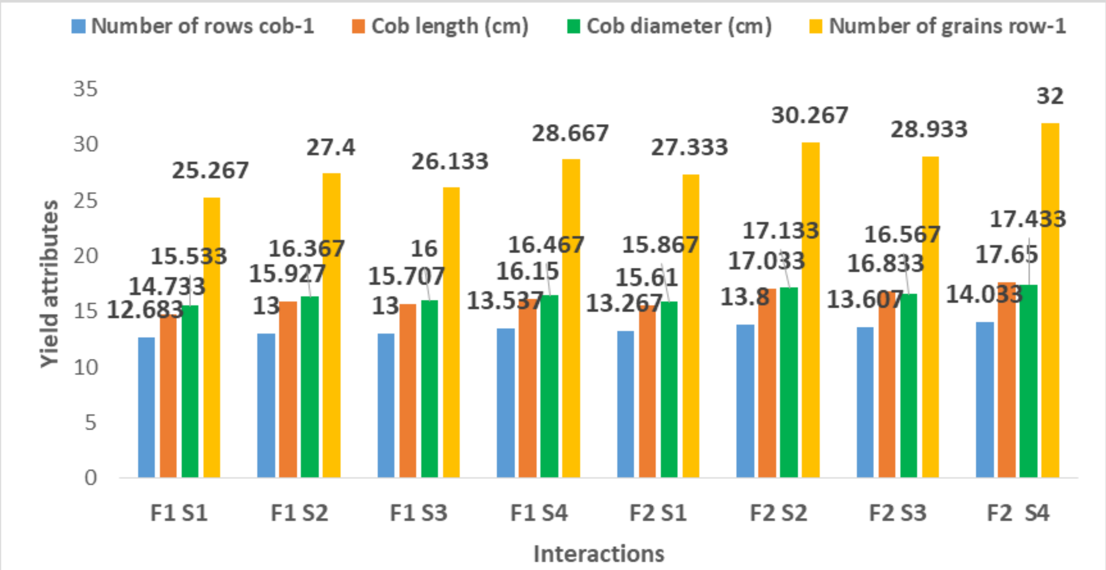
Figure 4.10.30. Effect of planting geometry on cob length; cob diameter, number of rows per cob and number of grains per rows of white maize

4.10.3.4. Number of grains per row

Total number of grains row^{-1} was significantly influenced by fertilizer doses, plant spacings and their combinations. The maximum number of grains row^{-1} (29.633) was reported from the treatments having F_2 and F_1 was the lowest performer among others (26.867) (Figure 4.10.29).

However, in white maize plant spacings treatments showed the significant effects on number of grains row^{-1}. Among the various treatments, S_4 produced highest number of grains row^{-1}(30.333) which were statistically similar S_2 (28.833) and the lowest (26.300) was produced from S_1 (Figure 4.10.30).

Moreover, their combination revealed that F_2S_4 showed the highest number of grains row^{-1}(32.000) than the other combinations, which were statistically similar F_2S_2 (30.267) and F_2S_3 (28.933). Among the treatments F_1S_1 showed the minimum number of grains row^{-1} (25.267), which was statistically dissimilar to others (Figure 4.10.31).



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm

F_1= Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer

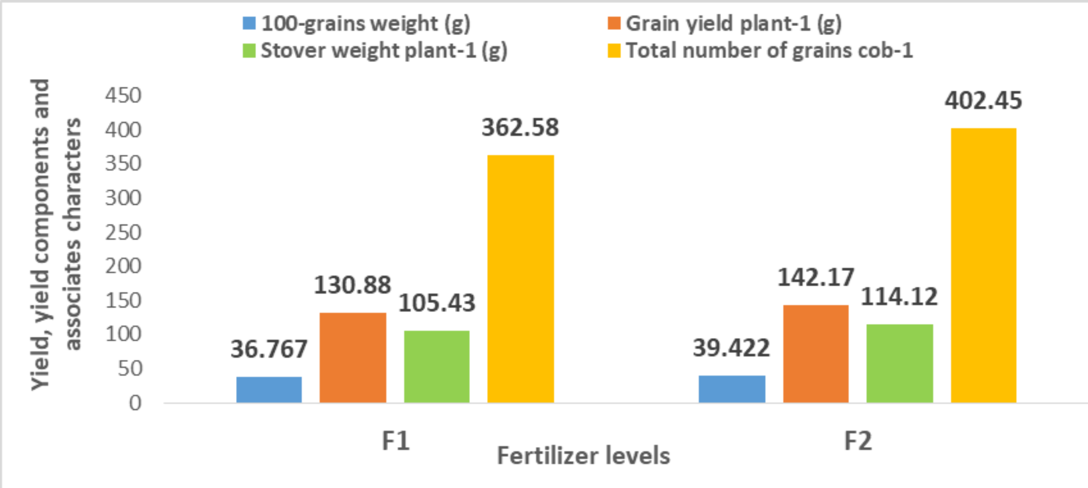
Figure 4.10.31. Interaction effects of fertilizer and plant spacing on cob length, cob diameter; number of rows cob,$^{-1}$ number of grains row^{-1} of white maize

4.10.3.5. Total number of grains per cob

Total number of grains cob^{-1} was significantly influenced by fertilizer levels, plant spacings and their combinations. The maximum number of grains cob^{-1} was reported from the treatments having F_2 (402.45) and F_1 (362.58) was the lowest performer (Figure 4.10.32). These results are in line with Rizwan *et al*.(2003) who observed that number of grains per cob increased significantly with increasing nitrogen rates.

However, in white maize plant spacings treatments showed the significant effects on number of grains cob^{-1}. Among the various treatments, S_4 produced highest number of grains cob^{-1}(405.41), which was statistically similar to S_2 and S_3 (387.07 and 387.07) and the lowest was produced from S_1 (360.97) (Figure 4.10. 34).These results are further endorsed by Abuzar *et al*., (2011) who reported that increase in plant population decreased grains ear^{-1}

Moreover, their combination revealed that. F_2S_4 showed the highest number of grains cob^{-1}(429.81) than the other combinations, which were statistically similar to F_1S_4, F_2S_2 and F_2S_3 (381.01, 408.36 and 394.32). Among the treatments F_1S_1 showed the very minimum number of grains cob^{-1}(344.64) (Figure 4.10.37).This might be due to proper translocation of sugar and starch in the grain by nitrogen fertilization. A similar result was also reported by Shakarami and Rafiee (2009) and Pandey *et al*. (2002).The higher degree of infertility under lower (50 kg N ha^{-1}) application might be attributed to poor development of sinks and reduced translocation of photosynthates. Under nitrogen stress conditions there may be big chance to asynchronous flowering and seed infertility, thus reduction in the number of seeds cob-^{1}. Gungula *et al*. (2007) reported that there will be more synchrony in flowering with higher nitrogen, thus reducing the rate of infertility during grain filling period. This result is alike with the findings of Jaliya *et al*., (2008), where they observed that increase in fertilizer rate increased number of grains/cob. This may probably be attributed to NPK being part of the essential nutrients required for the promotion of the meristematic and physiological activities and so the number of grains cob^{-1} was increased. A similar trend of yield attributes were reported by Dawadi and Sah (2012). There was an increasing trend was observed in the yield attributes with increasing nitrogen level. The lowest values for yield attributes in closer spacing were due to high competition for the resources such as sun light, moisture, nutrient and air. Similar trend was reported elsewhere (Hashemi *et al*. 2005; Dawadi and Sah 2012). They reported the negative relationship between yields attributes with increasing plant density. In case of closest spacing of 50 cm × 20 cm with high plant densities decreased the yield attributes due to the absence of the usual sink for the assimilate supply and limiting optimum conservation of light energy.



Here, F_1 = Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

Figure 4.10.32. Effect of fertilizer on 100-grains weight; total number of grains cob^{-1}, grain yield plant-^{1} and stover weight plant-^{1} of white maize

4.10.3.6. Relationship between total grains per cob and population density:

The planting geometries tested in this trial had varying spacings of 50cm x 20cm, 50cm x 25cm and 60cm x 20 cm which represent the plant population per hectare respectively to 100000, 80000, 83333 and 66666. Like the plant height and leaf area per plant, the regression analysis of the number of total grains per cob with these population densities showed that number of total grains per cob of maize was positiely dependent on the population density and it was linear showing a negative regression coefficient of 0.0013 and R-squired value of 0.9704 (Figure-4.10.33)

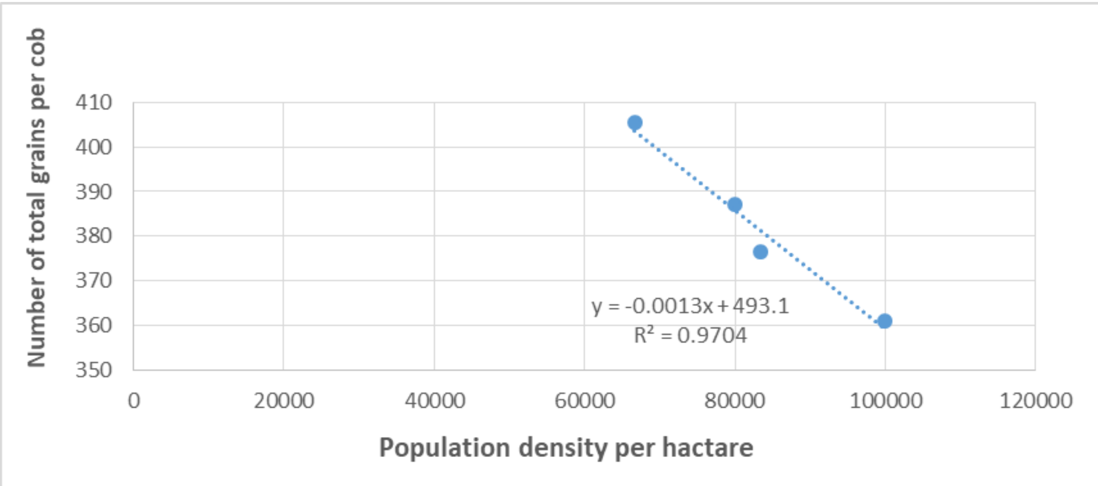


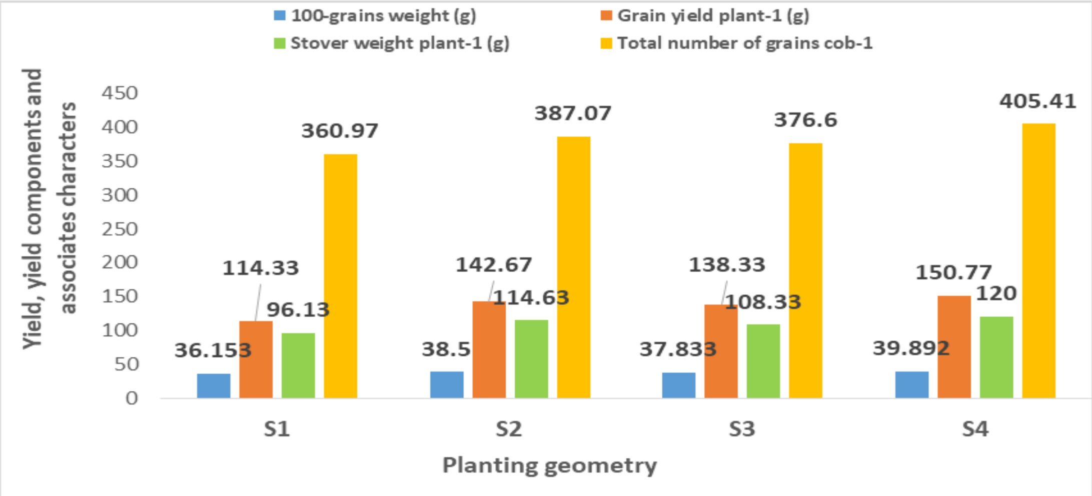
Figure 4.10.33. Relationship between total grains per cobs and population density of white maize

4.10.3.7. 100-grain weight

The fertilizer doses, plant spacing and their combination also influenced the weight of 100-grains in white maize .The highest 100- grain weight was produced with F_2

(39.422 g) and the lowest with F_1 (36.767 g) (Figure 4.10.32). These results are in line with Arif *et al*. (2010) who reported maximum thousand grains weight (254.1 g) with 160 kg N ha^{-1}.

Plant spacing treatments showed the significant effects on 100- grain weight, where the maximum weight (39.892 g) was found for S_4 which was statistically similar to S_2(38.500 g) and the minimum weight of 100-grain was produced by the S_1 treatment (36.153 g) (Figure 4.10. 34). These results are in agreement with the finding of Radma and Dagash (2013) who reported that thousand grain weight increases with the increase in nitrogen level. For their combination, the highest 100- grain weight was produced with F_2S_4 (41.560 g), which was statistically similar to F_2S_2 (40.000 g) and the minimum weight of 100-grain was produced by F_1S_1 (35.180 g) (Figure 4.10. 37). In agreement with the results of the present study, increased in thousand grain weight has been reported with increase in nitrogen levels (Niazuddin *et al*., 2002; Dawadi and Sah, 2012).This might be due to proper translocation of sugar and starch in the grain by nitrogen fertilization. This result is alike with the findings of Law-Ogbomo and Law-Ogbomo, (2009), where they observed that NPK fertilizer treated plants produced significantly higher relative grains and 100-seeds weight than the untreated plants at levels of application. Jaliya *et al*., (2008) also observed that increase in fertilizer rate increased 100-grain weight. This may probably be attributed to NPK being part of leading to an efficient absorption and translocation of water and nutrients, interception of solar radiation and assimilation of carbon dioxide.



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm

Figure 4.10.34. Effect of Planting geometry on 100-grains weight; total number of grains cob^{-1}, grain yield plant^{-1}and stover weight plant-^{1} of white maize

4.10.3.8. Correlation study between 100-grains weight and population density:
The planting geometries tested in this trial had varying spacings of 50cm x 20cm, 50cm x 25cm and 60cm x 20 cm which represent the plant population per hectare respectively to 100000, 80000, 83333 and 66666. Like the plant height and leaf area per plant, the regression analysis of the 100-grain weight with these population densities showed that 100-grain weight of maize was positively dependent on the population density and it was linear showing a negative regression coefficient of 0.0001 and R-squired value of 0.9938. (Figure-4.10.35)

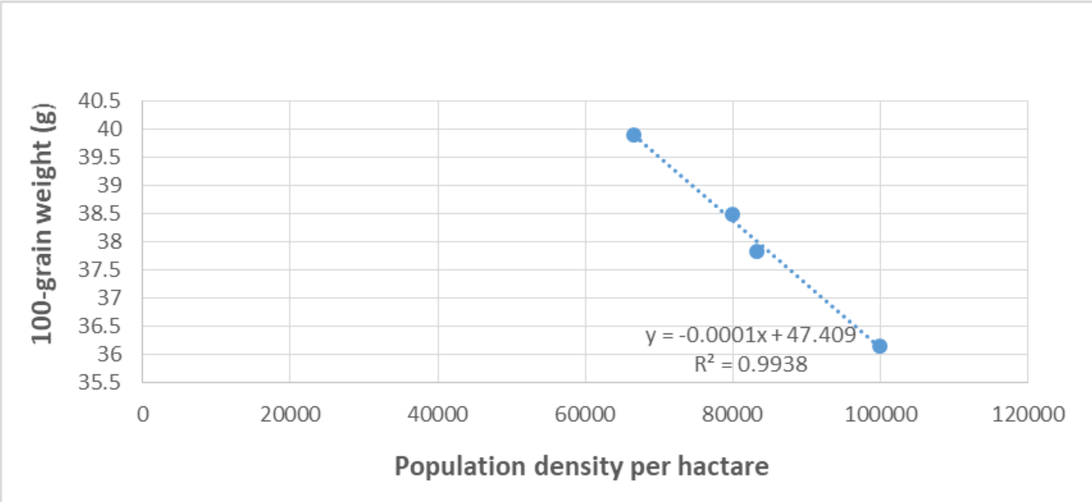


Figure 4.10.35. Relationship between 100-grains weight and population density of white maize

4.10.3.9. Grain yield per plant (g)

The fertilizer doses, plant spacing and their combination remarkably influenced the grain yield plant^{-1} (g) in white maize. Maximum grain yield plant^{-1} was significantly achieved with the treatment F_2 (142.17 g) and the minimum grain yield plant^{-1} was significantly achieved with the treatment F_1 (130.00 g) (Figure 4.10.32). Jaliya *et al.*, (2008) observed that increasing fertilizer rates from 0:0:0 to 150:26:50 kg NPK/ha significantly increased grain yield per plant.

For plant spacing treatments, maximum grain yield plant^{-1} was significantly obtained with the treatment S_4 (150.77 g).Treatments, S_2 (142.67 g) and S_3 (138.33 g) produced moderate grain yield plant^{-1}which were statistically similar to each other. The minimum per plant grain yielder was S_1 (114.33 g) (Figure-4.10.34)

For their combination, the highest grain yield plant^{-1} was significantly produced with F_2S_4 (156.67 g), which was statistically similar to F_2S_2 (148.67 g) and F_1S_4 (144.87 g) and closely followed byF_2S_3 (144.67 g).The minimum grain yield plant^{-1}was significantly found by F_1S_1 (110.00 g) (Figure-4.10.37). Due to closer spacing grain yield gradually decreased. Under closer planting spacing, the rate of yield reduction was in response to decreasing solar radiation, nutrient, moisture and air. This result is in agreement with that of Ramulu *et al*. (2006). It is well known that plants grown under less competition have higher potential yields than those under dense plantings and the grain yield of a single corn plant is reduced by the proximity to its neighbors. The yield reduction per plant may be due to the effects of interplant competition for light, water, nutrients and other yield-limiting environmental factors (Wajid *et al*., 2007).

4.10.3.10. Relationship between grain yield per plant and population density:

The planting geometries tested in this trial had varying spacings of 50cm x 20cm, 50cm x 25cm and 60cm x 20 cm which represent the plant population per hectare respectively to 100000, 80000, 83333 and 66666. Like the plant height and leaf area per plant, the regression analysis of the grain yield per plant with these population densities showed that grain yield per plant of maize was positively dependent on the population density and it was linear showing a negative regression coefficient of 0.001 and R-squired value of 0.949 (Figure 4.10.36)

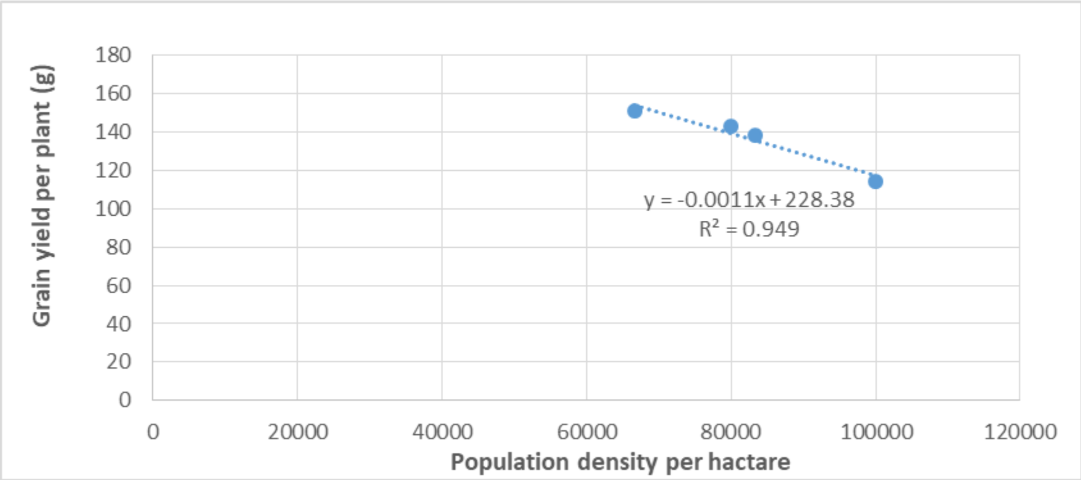
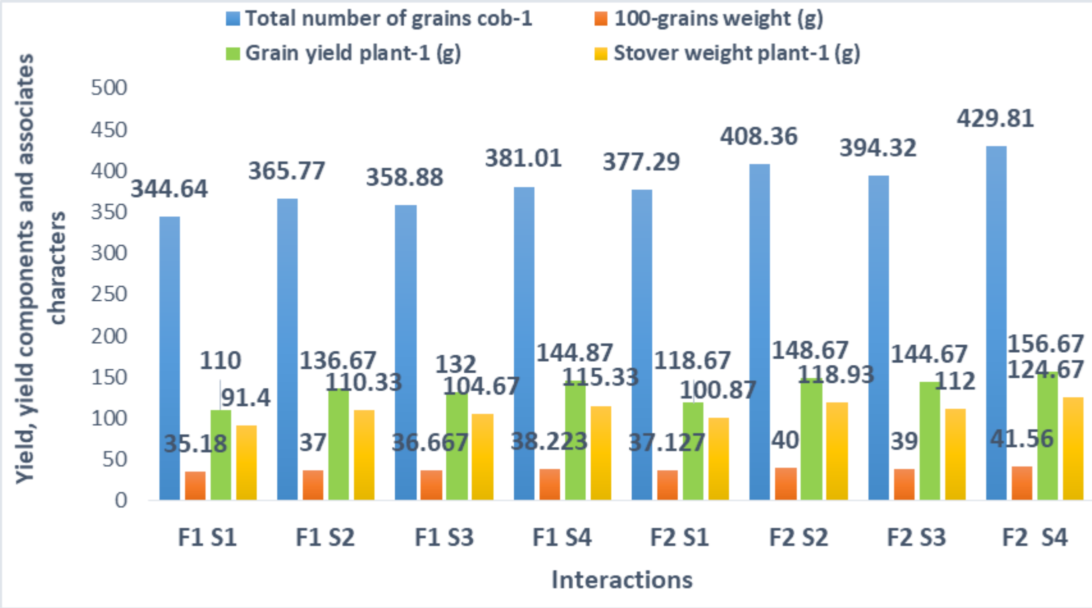


Figure 4.10.36. Relationship between grain yield per plant and population density of white maize



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm
F_1 = Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

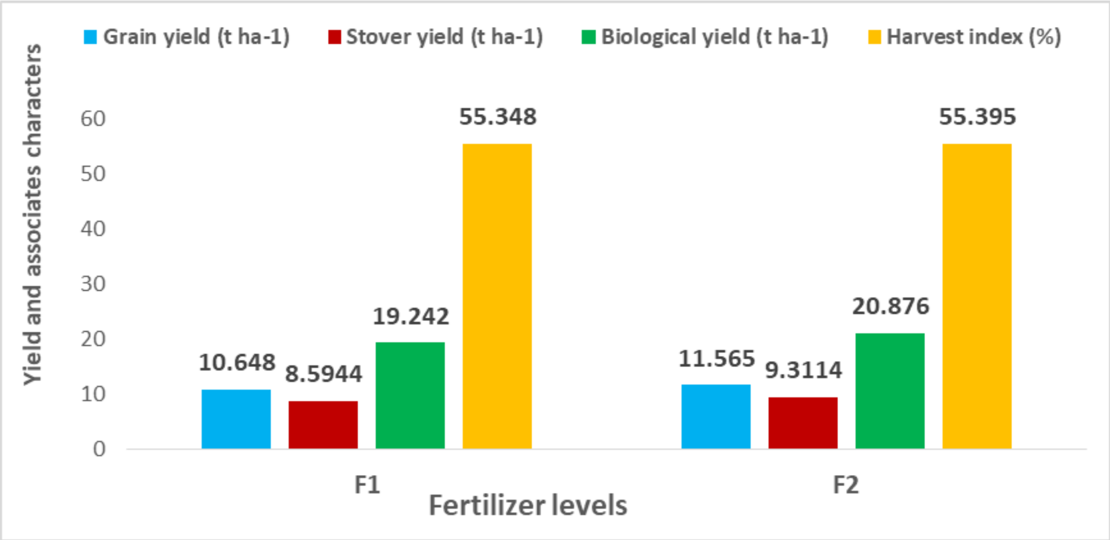
Figure-4.10.37. Interaction effects of fertilizer and planting spacing on 100-grains weight; total number of grains cob^{-1}, grain yield plant^{-1} and stover weight plant^{-1} of white maize

4.10.3.11. Grain yield per hectare

The fertilizer doses, plant spacing and their combination remarkably influenced the grain yield in white maize (Figure 4.10.38, 4.10.42 and 4.10.44). Maximum grain yield was achieved with the treatment F_2 (11.565 t ha^{-1}). The minimum grain yield was achieved with the treatment F_1 (10.648 t ha^{-1}). These results are in line with Sharifi *et al.*(2009) who reported that increase in nitrogen significantly increased grain yield.

For plant spacing treatments, maximum grain yield was achieved with the treatment S_3(11.528 t ha^{-1}), which was statistically similar to S_2 and S_1(11.413 and 11.433 t ha^{-1}). The minimum grain yielder was S_4 (10.051 t ha^{-1}). These results are supported by Aziz *et al.*(2007) who stated that increase in grain yield at optimum planting densities may be due to the availability of more nutrients which led to more growth and higher assimilates translocation to grains.

For their combination, maximum grain yield counted from treatment F_2 S_3 (12.056 t ha^{-1}), which was statistically similar to F_2 S_2 and F_2 S_1 (11.893 t ha^{-1}and 11.867 t ha^{-1}). From others treatments combinations the minimum grain yield was observed from F_1S_4 treatment (9.658 t ha^{-1}). The increased in maize grain yield under decreased spacing might be due to efficient utilization of available resources (nutrient water and light). Higher grains yield at higher nitrogen levels might be due to the lower competition for nutrient and positive effect of N on plant growth, leaf area expansion and thus increase solar radiation use efficiency that ultimately increases in grain yield. These results are in line with that of (Gozubenli, 2010; Shrestha, 2013). Application of NPK fertilizer at the different levels used in the study of Law-Ogbomo and Law-Ogbomo, (2009) revealed that all the fertilizer in increasing level had significant effect on the growth and yield of maize. Farnham revealed that, corn grain yield was increased from 10.1 to 10.8 t ha^{-1} as plant density increased from 59000 to 89000 plant ha^{-1} .Grain yield increased with increasing plant densities up to 90000 plants ha^{-1} (10973 kg ha^{-1} mean), but decreased in higher plant densities and there were no significant differences among 90000 plants ha^{-1} and 105000 plants ha^{-1}densities. Dawadi and Sah (2012) found the positive relationship between grain yield and plant density due to the high number of cobs harvested from high number of plants unit^{-1} area. Singh *et al.* (2000) indicated the similar result where they stated that grain yield increased with the increase in nitrogen level from 0-200 kg/ha. Grain and stover yield increased with increase in nitrogen levels was reported elsewhere (Ullah *et al*., 2007; Dahmardeh, 2011; Dawadi and Sah, 2012)



Here, F_1 = Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

Figure 4.10.38. Effect of fertilizer on grain yield; stover yield; biological yield and harvest index of white maize

4.10.3.12. Correlation study between grain yield and population density:

The planting geometries tested in this trial had varying spacings of 50cm x 20cm, 50cm x 25cm and 60cm x 20 cm which represent the plant population per hectare respectively to 100000, 80000, 83333 and 66666. In contrast to the plant height and leaf area per plant, the polynomial regression analysis of the grain yield per hectare with these population densities showed that grain yield per hectare of maize was positively dependent on the population density and it was linear showing a negative regression coefficient of 0.0005 and R-squired value of 0.999. The fitted curve was a parabola. From this graph, it may be decided that the possible highest yield of maize would happen at the population density of 90000 per hectare **(**Figure-4.10.39).

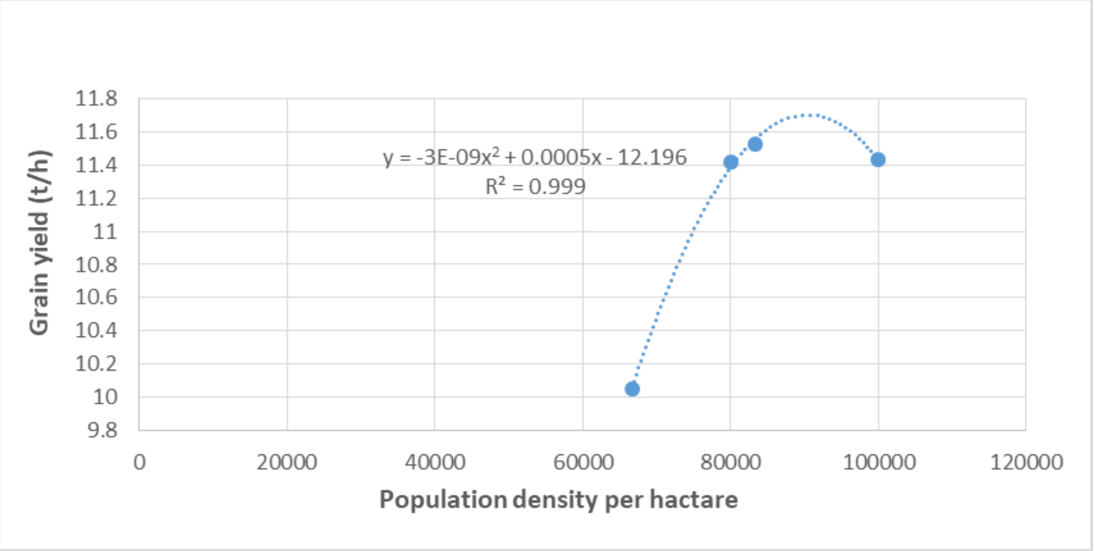


Figure 4.10.39. Relationship between grain yield and population density of white maize

4.10.3.13. Stover yield per plant (g)

The fertilizer doses, plant spacing and their combination remarkably influenced the stover yield plant^{-1} (g) in white maize. Maximum stover yield plant^{-1} was significantly achieved with the treatment F_2 (114.12 g) and the minimum stover yield plant^{-1} was significantly achieved with the treatment F_1 (105.43 g) (Figure 4.10.38).

For plant spacing treatments, maximum stover yield plant^{-1} was significantly obtained with the treatment S_4 (120.00 g) which was statistically similar to S_2 (114.63 g) followed byS_3 (108.33 g) while the minimum per plant stover yielder was S_1 (96.13 g). (Figure 4.10.42).

For their combination, the highest stover yield plant^{-1} was significantly obtained from F_2S_4 (124.67 g), which was statistically similar to F_2S_2 (118.93 g) and closely followed by F_1S_4 (115.33 g) and F_2S_3 (112.00 g) whereas the minimum stover yield plant^{-1} was significantly found by F_1S_1 (91.40 g) (Figure 4.10.44).

4.10.3.14. Correlation study between Stover yield per plant and population density:

The planting geometries tested in this trial had varying spacings of 50cm x 20cm, 50cm x 25cm and 60cm x 20 cm which represent the plant population per hectare respectively to 100000, 80000, 83333 and 66666. Like the plant height and leaf area per plant, the regression analysis of the stover yield per plant with these population densities showed that stover yield per plant of maize was negatively dependent on the population density and it was linear showing a negative regression coefficient of 0.0007 and R-squired value of 0.9608 (Figure 4.10.40) .

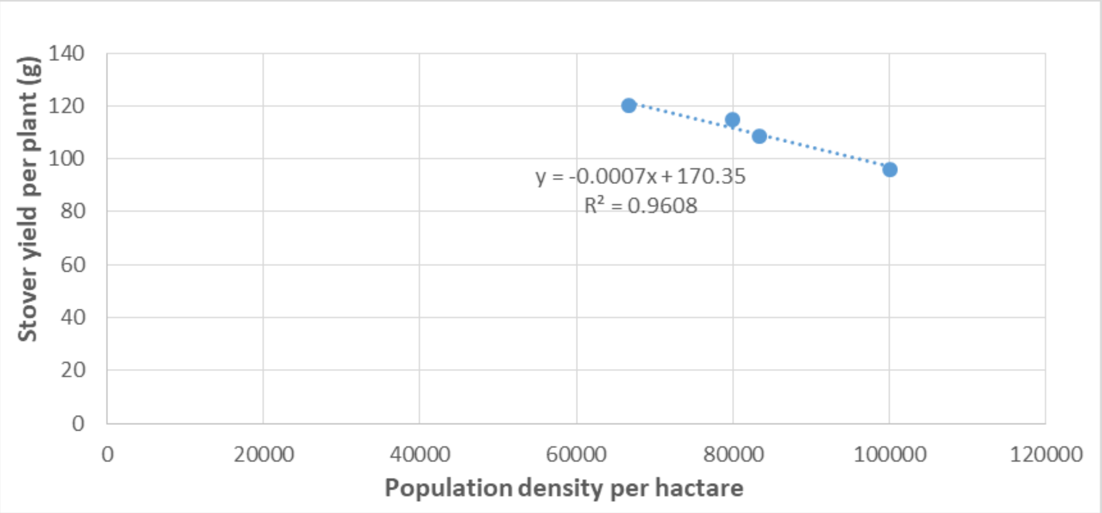


Figure 4.10.40. Relationship between stover yield per plant and population density of white maize

4.10.3.15. Stover yield per hectare

It was observed that stover yield indicated significant effects at fertilizer doses, plant spacing and their combinations in white maize (Figure 4.10.38, 4.10.42 and 4.10.44). The highest stover yield was observed in F_2 (9.311 t ha^{-1}) followed by F_1 (8.5994 t ha^{-1}) which was also the lowest yielder.

In the plant spacing treatments, S_1 treatment was significantly the highest stover yielder (9.613 t ha^{-1}), which was statistically similar to S_2 (12.853t ha^{-1}) and followed by S_3 9.03 t ha^{-1}) while S_4 treatment (8.00 t ha^{-1}) was the lowest stover yielder.

However, from the combination of fertilizer doses and plant spacing, it was observed that the maximum stover yield was produced by F_2S_1 (10.087 t ha^{-1}), which was statistically similar to F_2S_2 (9.515 t ha^{-1}) and F_2S_3 (9.333 t ha^{-1}). Among others F_1S_4 (7.689 t ha^{-1}) was the lowest yielder. Singh *et al.*, (2000) indicated the similar result where they stated that grain and stover yield increased with the increase in nitrogen level from 0-200 kg/ha. Ullah *et al.*, (2007) also reported the increased stover yield with increasing nitrogen levels. Scarsbrook and Doss (1973) reported that stover yields of hybrid maize usually increased with each increment of plant population up to 80,000 plants/ha.

4.10.3.16. Correlation study between stover yield and population density:

The planting geometries tested in this trial had varying spacings of 50cm x 20cm, 50cm x 25cm and 60cm x 20 cm which represent the plant population per hectare respectively to 100000, 80000, 83333 and 66666. In contrast to the plant height and leaf area per plant, the polynomial regression analysis of the stover yield per hectare with these population densities showed that stover yield per hectare of maize was positively dependent on the population density and it was linear showing a positive regression coefficient of 0.0003 and R-squired value of 0.9639. The fitted curve was parabola (Figure 4.10.41)

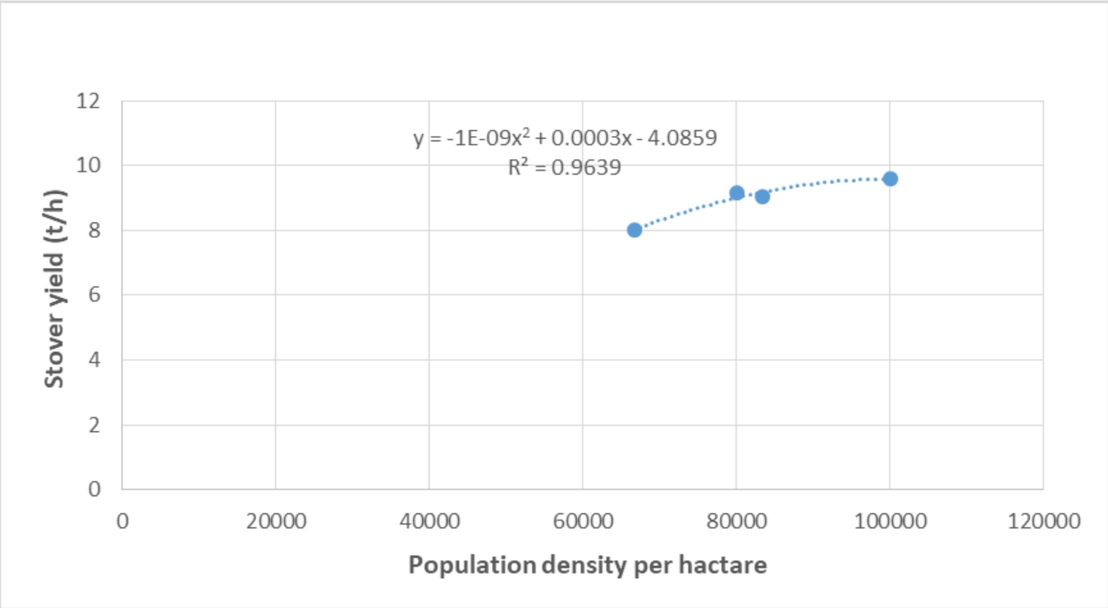
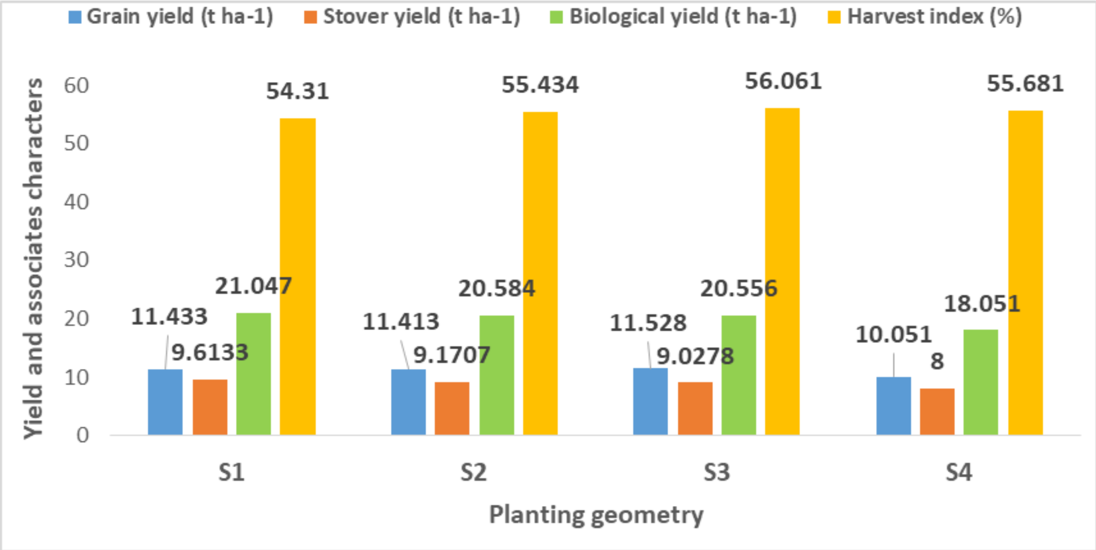


Figure 4.10.41. Relationship between stover yield and population density of white maize



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm

Figure 4.10.42. Effect of plant spacing on grain yield; stover yield; biological yield and harvest index of white maize

4.10.3.17. Biological yield

Biological yield also increased significantly with the different fertilizer doses, plant spacing both separately and in combination (Figure 4.10.38, 4.10.42 and 4.10.44) For fertilizer doses, F_1 was significantly produced the highest biological yield (20.876 t ha^{-1}) and F_2 produced the minimum biological yields (19.242 t ha^{-1}). These results are in line with Arif *et al*., (2010) who found that increase in nitrogen levels increased biological yield.

Moreover, among the plant spacing treatments, S_1 showed the maximum biological yield (21.047 t ha^{-1}), which was statistically identical to S_2 and S_3 (20.584 and 20.556 t ha^{-1}) while S_4 (18.051 t ha^{-1}) was the lowest biological yielder. These results are in line with Bhatt (2012) who reported higher biological from higher planting density.

However, from the combination of fertilizer doses and plant spacing it was observed that the maximum biological yield was produced by F_2S_1 (21.953 t ha^{-1}), which was statistically similar to F_2S_2 (21.408 t ha^{-1}) and F_2S_3 (21.389 t ha^{-1}). Among others F_1S_4 (27.347 t ha^{-1}) was the lowest biological yielder. The effect of NPK fertilizer application on fresh cob yield followed the same trend as in Biological yield (TDM) (Law-Ogbomo and Law-Ogbomo, 2009). The availability of sufficient growth nutrients from inorganic fertilizers lead to improved cell activities, enhanced cell multiplication and enlargement and luxuriant growth (Fashina *et al*., 2002). Luxuriant growth resulting from fertilizer application leads to larger Biological yield (dry matter production) (Obi *et al*., 2005) owing better utilization of solar radiation and more nutrient (Saeed *et al*., 2001). This may probably be attributed to NPK promote higher photosynthetic activities leading to the production of enough assimilate for subsequent translocation to various sinks and hence the production of higher yield and yield components of maize (Jaliya *et al.*, 2008).

4.10.3.18. Correlation study between biological yield and population density:

The planting geometries tested in this trial had varying spacings of 50cm x 20cm, 50cm x 25cm and 60cm x 20 cm which represent the plant population per hectare respectively to 100000, 80000, 83333 and 66666. In contrast to the plant height and leaf area per plant, and like total stover and seed yield per hectare, the polynomial regression analysis of the biomass yield per hectare with these population densities showed that biomass yield per hectare of maize was positively dependent on the population density and it was linear showing a positive regression coefficient of 0.0005 and R-squired value of 0.999. The fitted curve was parabola (Figure-4.10.43).

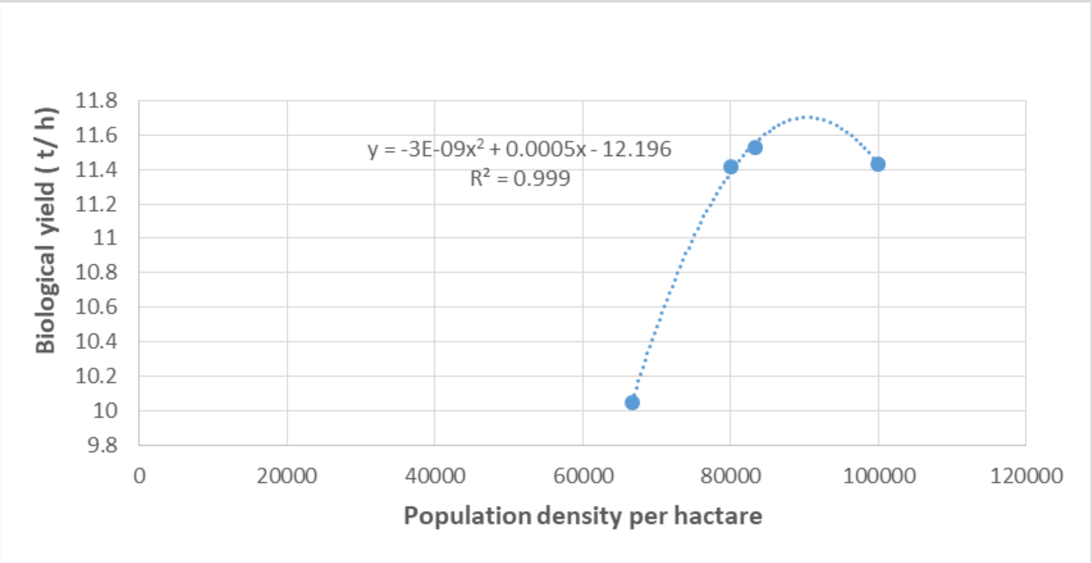


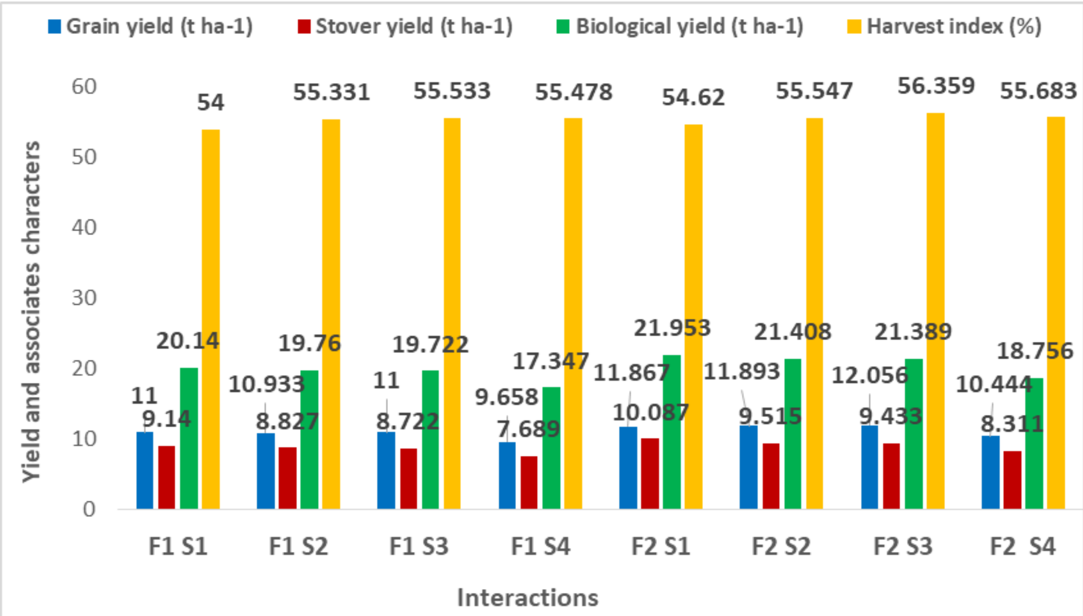
Figure 4.10.43. Relationship between biological yield and population density of white maize

4.10.3.19. Harvest index

Fertilizer dose treatments showed non-significant effect on harvest index. Among the treatments, F_2 (55.395%) showed the highest HI and F_1 (55.348 %) was the lowest (Figure 4.10.38) and they were statistically similar to each other.

Harvest index was non-significantly influenced by planting spacing. Although the values were non-significantly, S_3 showed the highest harvest index (56.061%) and S_1 (54.310 %) showed the lowest harvest index (Figure 4.10.42). These results are supported by Bahadar *et al*., (1999) who reported higher harvest index with optimum plant population.

Interaction between different fertilizer doses and planting spacing were also non-significant effect on harvest index. Data revealed that, F_2S_3 treatment showed the highest harvest index (46.077 %) while F_1S_1 (54.000%) showed the lowest harvest index (Figure 4.10.44). Harvest invest affected by interaction between planting date and plant density (UIllah *et al*., 2016) (1). The combined effect of variety with planting density produced highest harvest index (Abuzar *et al*., 2011). Sahar *et al*. (2005) stated that grain and stalk yield were significantly influenced by the increased rate of nitrogen thus increased the harvest index. Grain yield is the product of crop dry matter accumulation and the proportion of the dry matter allocated to the grain (i.e., harvest index) and harvest index in corn declines when plant density increases above the critical plant density. Our findings are in good agreement with the reports of many studies. Tollenaar *et al*., (1994) and Porter *et al*., (1997) reported inconsistent optimal plant density levels ranging from 86000 to 101270 plants ha^{-1} for corn grain yield across three Minnesota locations.



Here, S_1 = 50 cm × 20 cm; S_2 = 50 cm × 25 cm; S_3 = 60 cm × 20 cm; S_4 = 60 cm × 25 cm
F_1 = Recommended fertilizer dose; F_2 = 25% more of recommended fertilizer dose

Figure 4.10.44. Interaction effects of fertilizer levels and plant spacing on grain yield; stover yield; biological yield and harvest index of white maize

GENERAL DISCUSSION

Ten field trials were conducted at three different locations; Shere-e-Bangla Agricultural University (SAU) of Dhaka, Dhamrai Upazilla Dhaka and Rangpur Sadar, to optimize planting geometry for the production of white maize in Bangladesh for three consecutive rabi seasons of 2015-16 through 2017-18.

In this trial the good performing planting geometry in most of the cases were found to be 50cm x 20cm, 50cm x 25cm, 60cm x 20cm especially in term of showing significantly higher grain yields and the plant to plant and row distance exceeding these limits caused to decrease the yields along with those of stover and whole biomass. Such findings have been established by the previous workers. Generally grain yield increases with increasing planting density (Zamir *et al*., 2011), as higher plant densities enhance light interception and dry matter accumulation (Edwarws *et al*., 2005). Maize grain yield per unit area shows a curvilinear response to plant population (Olson *et al*., 1988; Sarlangue *et al*., 2007), presenting a maximum yield at the optimum plant density. Potential higher yields of modern hybrids obtainable with higher population encouraged planting maize at narrower spacing (Tollenaar, 1991). Grain yield of individual plant of sparsely planted maize crop is usually high but because of low population the total grain yield per unit area remains low. However, several reports (Liu *et al.*, 2004 and Alford *et al.*, 2004) indicated that row spacing had no influence on maize plant height, LAI, dry matter accumulation, net assimilation, HI and grain yield. High plant densities have been found to reduce kernel number per unit land area, decrease the number of kernels per ear (Andrade *et al*., 2005], reduce harvest index and the overall grain yield (Tollenaar, 1991). In Bangladesh, a population density of 83,000 planted in rows at 60 cm x 20 cm geometry gave the highest grain yield (Biswas *et al*., 20140). Optimum plant density, however, depends largely on genotype, season, available growth resources and agronomic management conditions.

This study revealed the fact that white maize fertilizer dose at or more importantly 25% above that as was recommended for hybrid maize by BARI (2016). This finding has a basis of reality as the soil of different plots may had varying range of soil fertility. Application of fertilizer is one of the major agronomic practices regulating potential yield in maize, since sufficient and timely nutrient supply affects both grain number and mean grain weight through adjusting grain formation, filling rate and duration (Liu *et al*., 2014). Bender *et al.* (2013) demonstrated that a modern hybrid maize with moderate yield potential takes up 287 kg N, 50 kg P, 167 kg K, 26 kg S, 8 kg Zn and 1.3 kg B per ha.

Maize needs irrigation ranging from 2-4 in its life season depending on the rainfall, humidity, sunshine and especially the ambient temperature. In this study four irrigations or above gave significantly higher yields. The trial to assess irrigation frequency was made at SAU campus which is mostly at the center of Dhaka city. In general a city may have 2-4 degree Celsius higher temperature compared to that in the village crop field area. So, on this context, this finding is obvious as increased temperature irrigation frequency increases.

The planting geometries tested in this trial had varying spacings of 50 cm x 20 cm, 50cm x 25 cm and 60 cm x 20 cm which represent the plant population per hectare respectively to 100000, 80000, 83333 and 66666.

From the regression analysis it was observed that plant height, days to maturity, leaf area per plant, dry matter per plant, number of grains per cob, 100-grain weight and per plant grain weight was negatively related. That is, with the increase in population density the values of these parameters decreased. This relationship is an established fact as due to the increased population density the inter plant competition increases reducing the values of the respective plant parameter. In this case the regression coefficient values were in the range of (-) 0.00005 to (-) 0.687 while the R2 (R-squired) values were in the range of 0.7766 to 0.9990. Dawadi and Sah (2012) in their study observed that plant height was significantly influenced by the densities and varieties. Extra space availability and luxury consumption of nutrient at the wider spacings probably enhanced the plant height. However, the results of affecting the phenological attributes by the spacing treatments is not supported by Dawadi and Sah (2012) who reported that tasseling, silking and physiological maturity were not significantly influenced by plant density. This might be due to the reason that different crop cultivars take their normal time to develop different vegetative and reproductive structure and attain maturity. Increase in number of grains per cob of this study is in line with Esechie (1992) and Zada (1998) who found that the number of grains ear-^{1} decreased with increasing plant density which they attributed to be due to source sink relationship and competition among maize plants for nutrients. The decrease in the grain yield per plant, individual grain weight or 100 grain weight with the increase in the population density (with closer spacing) agrees well with the works of other previous scientists (Abuzar *et al.*,2011; Akcin *et al.*, 1993; Rogers and Lomman, 1988; Konuskan, 2000 and Gozubenli *et al.*, 2001) who stated that there were varietal differences in 100-grain weight, which increased with increasing plant spacing owing to more partitioning of assimilate towards grain under lower competitions.

In contrast to these relationships, a positive dependency was observed with the population density of leaf area index, crop growth rate, net assimilation rate at 90 DAS to maturity, seed yield per hectare and biomass per hectare showing the regression coefficient values from 0.0005 to 0.002 and R_2 values from 0.8251 to 0.999. A polynomial regression was found to be suitable to fit the data of net assimilation rate, and yields per hectare and in such cases the curve resembled a parabola.

In contrast to the plant height and leaf area per plant, and like total stover and seed yield per hectare, the polynomial regression analysis of the biomass yield per hectare with these population densities showed that biomass yield per hectare of maize was positively dependent on the population density and it was linear showing a positive regression coefficient of 0.0005 and R-squired value of 0.999. The fitted curve was parabola. Such relationships were also previously manifested by many workers. In general although the values of most of the per plant parameters decreased under closer spacings, on the community basis that is the per hectare values increased. This was obvious as these values were the accumulated of those of the per plant ones which increased with the increase in population density. Such situation was supported by the previous workers (At the closer spacing the number of plants in a given area is higher than at the sparse spacing. In general the closer spacing enhances the seed yield through increasing the potentials of yield attributes provided the population density at that level does not become competitive (Dawadi and Sah, 2012; Ullah *et al.*, 2016; Tollenaar *et al.*, 1997).

CHAPTER V

SUMMERY AND CONCLUSION

Ten field experiments were carried out at three different locations of Bangladesh namely, Sher-e-Bangla Agricultural University (SAU), Dhaka, Suapur of Dhamrai Upazilla of Dhaka and Thakurpara of Rangpur Sadar Upazilla of Rangpur in three consecutive rabi seasons of 2015-16, 2016-17 and 2017-2018. To investigate the performance of different white maize varieties, different plant spacing, levels of fertilizer and levels of irrigation in respect of phenology, growth, yield components and yield. The white maize varieties responded positively to the different plant spacing, different fertilizer doses and different levels of irrigation. White maize variety (PSC -121) with plant spacing (60 cm x 20 cm) with 25% more of recommended fertilizer dose and 4-irrigations (25 DAS + 50 DAS + 75 DAS + 100 DAS) gave higher yield which was a great achievement.

First year experiments

The first experiment conducted by employing a factorial RCBD design with three replications to evaluate the effect of two plant spacing viz. (T_1=70 cm×25 cm and T_2 = 60 cm×25 cm) on four white maize varieties i.e. (V_1 =Changnau-1, V_2 = Q-Xiangnau-1 V_3 = Changnau-6 and V_4 = Youngnau-7) by assigning variety in main plots and plant spacing in sub-plots. In second experiment, treatments arranged in factorial RCBD design with three replications to investigate the effect of three plant spacing viz. (T_1 = 50 cm × 25 cm, T_2 = 60 cm × 25 cm and T_3=70 cm×25 cm) on two white maize varieties i.e. (V_1=PSC-121 and V_2 = KS-510) by assigning variety in main plots and plant spacing in sub-plots. In third experiment, treatments arranged in factorial RCBD design with three replications to investigate the effect of three plant spacing viz. (T_1=50 cm × 25 cm, T_2= 60 cm×25 cm and T_3= 70 cm × 25 cm) on two white maize varieties i.e. (V_1 = PSC-121 and V_2 = KS-510) by assigning variety in main plots and plant spacing in sub-plots. In fourth experiment, treatments arranged in factorial RCBD design with three replications to investigate the effect of three plant spacing viz. (T_1 = 50 cm × 25 cm, T_2 = 60 cm×25 cm and T_3=70 cm×25 cm) on two white maize varieties i.e. (V_1 = PSC-121 and V_2 = KS-510) by assigning variety in main plots and plant spacing in sub-plots.

Second year experiments

In fifth experiment, treatments arranged in RCBD design with three replications to investigate the effect of four plant spacing viz. (T_1 = 50 cm × 20 cm, T_2 = 50 cm × 25 cm T_2 = 60 cm × 20 cm and T_3 = 60 cm × 25 cm) on one white maize variety (PSC -121). In sixth experiment, treatments arranged in RCBD design with three replications to investigate the effect of four plant spacing viz. (T_1 = 50 cm × 20 cm, T_2 = 50 cm × 25 cm T_2 = 60 cm × 20 cm and T_3 = 60 cm × 25 cm) on one white maize variety (PSC -121). In seventh experiment, treatments arranged in RCBD design with three replications to investigate the effect of four plant spacing viz. (T_1 = 50 cm × 20 cm, T_2 = 50 cm × 25 cm T_2 = 60 cm × 20 cm and T_3 = 60 cm × 25 cm) on one white maize variety (PSC -121). The eighth experiment conducted by employing a split-plot design with three replications to investigate the effect of 4 irrigation levels viz; I_2 = 25 DAS +75 DAS, I_3 = 25 DAS + 50 DAS + 75 DAS, I_4 = 25 DAS + 50 DAS + 75 DAS + 100 DAS and I_{wr} = Irrigation when necessary on four white maize varieties i.e. V_1 = PSC, V_2 = Changnuo-1, V_3 = Youngnuo-30 and V_4 = Changnuo-6 by assigning irrigation in main plots and variety laid in sub-plots. The ninth experiment conducted by employing a split-plot design with three replications to investigate the effect of 4 levels of fertilizer viz; F_1 = Recommended fertilizer dose, F_2 = Half of recommended fertilizer dose, F_3 = 25% more of recommended fertilizer dose, F_4 = 25% less of recommended fertilizer dose on five white maize varieties i.e. V_1 = Changnuo-1; V_2 = Q -Xiangnuo-1; V_3 = PSC -121; V_4 = Changnuo-6 and V_5 = Youngnuo -30 by assigning fertilizer in main plots and variety laid in sub-plots.

Third year experiment

The tenth experiment conducted by employing a split-plot design with three replications to investigate the impact of 2 levels of fertilizer viz; F_1 = Recommended fertilizer dose, F_2 = 25% more of recommended fertilizer dose on four planting configurations viz, T_1 = (50 cm × 20 cm), T_2 = (50 cm × 25 cm), T_3 = (60 cm ×20 cm) and T_4 = (60 cm ×25 cm) by assigning fertilizer in main plots and planting configurations laid in sub-plots ,where variety, PSC -121was used.

The findings of ten experiments are summarized below:

Experiment no. 1

A significant variation was observed among the four white maize varieties to growth, yield and yield attributes such plant height, number of leaves per plant, days to maturity, days to 1st tasseling, days to 1st silking, cob length, cob breadth, number of rows per cob, number of grains row^{-1}, total number of grains cob^{-1}, 100- grain weight, grain yield plant^{-1}, Stover yield plant^{-1}, grain yield, stover yield, biological yield and harvest Index. V_1 variety produced the highest plant height (234.17 cm), number of leaves per plant(17.33), days to 1st tasseling(72.500 days), days to 1st silking (75.00 days), days to maturity (128.00 days) and V_3 variety achieved the maximum cob length (17.54 cm), cob breadth (15.370 cm), number of rows per cob (12.717), number of grains row^{-1} (32.35), total number of grains cob^{-1}(418.36), grain yield plant^{-1} (135.47 g), stover yield plant^{-1} (157.0 g), grain yield (8.37 t ha^{-1}), stover yield (9.69 t ha^{-1}), biological yield (18.06 t ha^{-1}) and harvest Index (46.32 %) were found from V_3 variety but the maximum 100- grain weight (23.33 g) was recorded from V_2 variety. The lowest plant height (179.00 cm), number of leaves per plant (12.33), days to 1st tasseling (62.00 days), days to 1st silking (64.67 days), days to maturity (112.00 days), cob length (12.68 cm), cob breadth (12.91 cm), number of rows per cob (12.25), number of grains row^{-1} (21.37), total number of grains cob^{-1} (247.53), 100- grain weight (23.83), grain yield plant^{-1} (78.57 g), stover yield plant^{-1} (99.50 g), grain yield (4.846 t ha^{-1}), stover yield (6.1349 t ha^{-1}), biological yield (10.982 t ha^{-1}) and harvest Index (44.085 %)) were obtained from V_4 variety. Plant spacing S_1 (70 cm x25 cm) showed significantly the maximum plant height (219.50 cm), number of leaves per plant (16.083), days to 1st tasseling (68.500 days), days to 1st silking (71.167 days), days to maturity (122.92 days), cob length (16.097 cm), cob breadth (14.601 cm), number of rows per cob (12.783), number of grains row^{-1} (29.404), total number of grains cob^{-1} (361.48), 100- grain weight (31.42 g), grain yield plant^{-1} (116.59 g), stover yield plant^{-1} (139.25 g) but produced less grain yield (6.664 t ha^{-1}), stover yield (7.96 t ha^{-1}) and biological yield (14.62 t ha^{-1}). Plant spacing S_2 (60 cm x 25 cm) produced the minimum plant height (213.92 cm), number of leaves per plant(15.00), days to 1st tasseling (68.167 days), days to 1st silking (70.917 days), days to maturity (122.75 days), cob length (15.09 cm), cob breadth (13.98 cm) number of rows per cob (12.25), number of grains row^{-1} (26.36), total number of grains cob^{-1} (339.39), 100- grain weight (

30.50 g), grain yield plant^{-1}(109.35 g), Stover yield plant^{-1} (128 83 g) and less grain yield (7.2901 t ha^{-1}), stover yield (8.5889 t ha^{-1}) and biological yield (15.879 t ha^{-1}) was observed from S_1 treatment. No significant variation was observed in harvest index with plant spacing. Interaction effect of variety and plant spacing as V_1S_1 (V_1 variety with plant spacing, 70 cm x 25 cm) showed the maximum plant height (236.67 cm), number of leaves per plant (18.00), days to 1st tasseling (72.667 days), days to 1st silking (75.00 days) and days to maturity (128.00 days) and $V_3 S_1$ (V_1 variety with plant spacing, 70 cm x 25 cm)treatment combination achieved the maximum cob length (18.07 cm), cob breadth (15.61 cm), number of rows per cob (13.07), number of grains row^{-1} (33.97), total number of grains cob^{-1}(430.04), grain yield plant^{-1} (139.46 g), stover yield plant^{-1} (162.67 g) but $V_3 S_1$ treatment (V_3 variety with plant spacing, 60 cm x 25 cm) combination produced the highest grain yield (8.7645 t ha^{-1}), stover yield (10.089 t ha^{-1}), biological yield (18.853 t ha^{-1}) and harvest Index (46.487 %) but maximum 100- grain weight (34.667 g) was recorded from V_2S_1 treatment combination. The lowest plant height (181.17 cm), number of leaves per plant(12.667), days to 1st tasseling (62.167 days), days to 1st silking (64.667 days) and days to maturity (112.17 days), cob length (12.00 cm), cob breadth (12.38 cm), number of rows per cob (12.17), number of grains row^{-1} (20.00), total number of grains cob^{-1} (237.95), 100- grain weight (23.33 g), grain yield plant^{-1} (75.07 g), stover yield plant^{-1} (94.33 g) were obtained from $V_4 S_2$ treatment combination but more grain yield (5.45 t ha^{-1}), stover yield (6.28 t ha^{-1}), biological yield (11.29 t ha^{-1}) and harvest Index (44.268 %) were obtained from $V_4 S_1$ than that of $V_4 S_2$ treatment combination.

Experiment no. 2

A significant variation was observed among the two white maize varieties to growth, yield and yield attributes such plant height, days to 1st tasseling, days to 1st silking, days to maturity, cob length, cob breadth, number of rows per cob, number of grains row^{-1}, total number of grains cob^{-1}, 100- grain weight, grain yield plant^{-1}, Stover yield plant^{-1}, grain yield, stover yield, biological yield and harvest Index.V_1 variety showed the highest plant height (238.11 cm), cob length (15.456 cm), number of rows per cob (13.40), number of grains row^{-1} (27.046), total number of grains cob^{-1}(370.75), 100- grain weight (27.869g) ,grain yield plant^{-1} (127.73 g), stover yield plant^{-1} (159.56 g), grain yield (8.6214 t ha^{-1}), stover yield (10.788 t ha^{-1}), biological yield

(19.342 t ha^{-1}) and harvest Index (45.731 %) but V_2 variety took more days to 1^{st} tasseling (77.889 days), days to 1^{st} silking (81.111 days), days to maturity (138.11 days), while the lowest plant height (209.46 cm), cob length (13.974 cm), number of rows per cob (12.844), number of grains row^{-1} (25.20), total number of grains cob^{-1} (350.08), 100- grain weight (25.283 g), grain yield $plant^{-1}$ (120.38 g), stover yield $plant^{-1}$ (151.78 g), grain yield (8.1052 t ha^{-1}), stover yield (10.221 t ha^{-1}), biological yield (18.893 t ha^{-1}) and harvest Index (42.942 %)) were obtained from V_2 variety but V_1 variety took minimum days to 1^{st} tasseling (72.111 days), days to 1^{st} silking 75.111 days) and days to maturity (132.11 days). Plant spacing S_3 (70 cm x 25 cm) showed the maximum plant height (222.58 cm), cob length (15.375 cm), number of rows per cob (13.35), number of grains row^{-1} (27.683), total number of grains cob^{-1} (376.31), 100- grain weight (28.043 g), grain yield $plant^{-1}$ (131.73 g), stover yield $plant^{-1}$ (163.83 g) but produced the minimum grain yield (7.527 t ha^{-1}), stover yield (9.362 t ha^{-1}) and biological yield (16.89 t ha^{-1}). Plant spacing S_1 (50 cm x 25 cm) showed the lowest plant height (213.92 cm), cob length (13.878 cm), cob breadth (13.98 cm) number of rows per cob (12.25), number of grains row^{-1} (26.36), total number of grains cob^{-1} (339.39), 100- grain weight (25.372 g), grain yield $plant^{-1}$(115.00 g), Stover yield $plant^{-1}$ (145.50 g) but achieved the highest grain yield (9.200 t ha^{-1}), stover yield (11.64 t ha^{-1}) and biological yield (20.840 t ha^{-1}). No significant variation occurred in days to 1^{st} tasseling, days to 1^{st} silking and days to maturity with different plant spacing. Interaction effect of variety and plant spacing as V_1S_3 (V_1 variety with plant spacing, 70 cm x 25 cm) produced the tallest plant (244.50 cm) but V_2 S_3 (V_2 variety with plant spacing, 70 cm x 25 cm) treatment combination took maximum days to 1^{st} tasseling (78.531 days), days to 1^{st} silking (81.6323 days),days to maturity (138.33 days) and V_1 S_3 (V_1 variety with plant spacing, 70 cm x 25 cm) treatment combination was achieved the maximum cob length (16.25 cm), number of rows per cob (13.767), number of grains row^{-1} (28.567), total number of grains cob^{-1}(386.33), 100- grain weight (29.313 g), grain yield $plant^{-1}$ (134.67 g), stover yield $plant^{-1}$ (167.00 g) but V_1 S_1 treatment (V_1 variety with plant spacing, 50 cm x 25 cm) combination produced the highest grain yield (9.60 t ha^{-1}), stover yield (12.027 t ha^{-1}), biological yield (21.627 t ha^{-1}) and harvest Index (46.015 %). The lowest plant height (188.67 cm) was found from V_2 S_1 treatment combination and minimum days to 1^{st} tasseling (72.000 days), days to 1^{st} silking (75.00 days) and days to maturity (131.50 days) was recorded from V_1 S_1

treatment combination while $V_2 S_1$ treatment combination produced the lowest cob length (13.500 cm), number of rows per cob (12.733), number of grains row^{-1} (23.667), total number of grains cob^{-1} (331.57), 100- grain weight (23.743 g), grain yield plant^{-1} (110.00 g), stover yield plant^{-1} (150.33 g) but $V_2 S_3$ treatment combination produced more grain yield (7.360 t ha^{-1}), stover yield (9.581 t ha^{-1}) and biological yield (16.941 t ha^{-1}) than that of $V_2 S_1$ treatment combination, and the lowest harvest Index (43.151 %) was obtained from $V_2 S_1$ treatment combination.

Experiment no. 3

A significant variation was observed among the two white maize varieties to growth, yield and yield attributes such plant height, days to 1st tasseling, days to 1st silking, days to maturity, cob length, cob breadth, number of rows per cob, number of grains row^{-1}, total number of grains cob^{-1}, 100- grain weight, grain yield plant^{-1}, Stover yield plant^{-1}, grain yield, stover yield, biological yield and harvest Index.V_1 variety showed the highest plant height (231.67 cm), cob length (17.011 cm), cob breadth (16.444 cm), number of rows per cob (13.181), number of grains row^{-1} (28.689), total number of grains cob^{-1}(385.49), 100- grain weight (31.650 g) ,grain yield plant^{-1} (124.6 g), grain yield (8.4311 t ha^{-1}), stover yield (10.396 t ha^{-1}), biological yield (18.827 t ha^{-1}) and harvest Index (44.794 %) but showed lower stover yield plant^{-1} (153.78 g) and V_2 variety took more days to 1st tasseling (85.778 days), days to 1st silking (88.333 days) and days to maturity (145.78 days) while the lowest plant height (209.46 cm), cob length (15.91 cm), cob breadth (15.69 cm), number of rows per cob (12.69), number of grains row^{-1} (27.089), total number of grains cob^{-1} (361.51), 100- grain weight (29.611 g), grain yield plant^{-1} (114.6 g), grain yield (7.7392 t ha^{-1}), stover yield (10.838 t ha^{-1}), biological yield (18.577 t ha^{-1}) and harvest Index (41.678 %)) were obtained from V_2 variety but V_1 showed lower stover yield plant^{-1} (160.44 g) and took less days to 1st tasseling (79.778 days), days to 1st silking (82.44 days), days to maturity (137.89 days). Plant spacing S_3 (70 cm x 25 cm) showed the maximum plant height (222.50 cm), cob length (17.36 cm), cob breadth (16.450 cm), number of rows per cob (12.962), number of grains row^{-1} (29.250), total number of grains cob^{-1} (392.83), 100- grain weight (31.575 g), grain yield plant^{-1} (125.08 g), stover yield plant^{-1} (164.33 g) but produced the minimum grain yield (7.527 t ha^{-1}), stover yield (9.362 t ha^{-1}) and biological yield (16.89 t ha^{-1}) . Plant spacing S_1 (50 cm x 25 cm) showed the lowest plant height (213.92 cm), cob length (15.500 cm), cob breadth (15.617 cm) , number of rows per cob (12.75), number of grains row^{-1} (26.367), total number of grains cob^{-1} (352.20), 100- grain weight (29.750 g), grain yield plant^{-1}(113.50 g), Stover yield plant^{-1} (149.50 g) but achieved the highest grain yield (9.08 t ha^{-1}), stover yield (11.960 t ha^{-1}) and biological yield (21.040 t ha^{-1}). No significant variation occurred in days to 1st tasseling, days to 1st silking, days to maturity and harvest index with different plant spacing treatments. Interaction effect of variety and plant spacing as V_1S_3 (V_1 variety with plant spacing, 70 cm x 25 cm) produced the tallest plant (237.33 cm) but $V_2 S_3$ (V_2 variety with plant spacing, 70 cm x 25 cm) treatment combination took maximum days to 1st tasseling (86.66 days), days to 1st silking (88.667 days),days to maturity (146.33 days). $V_1 S_3$ (V_1 variety with plant spacing, 70 cm x 25 cm) treatment combination was achieved the maximum cob length (17.867 cm), cob breadth (16.833 cm), number of rows per cob (13.277), number of grains row^{-1} (30.433), total number of grains cob^{-1}(406.27), 100- grain weight (32.450 g), grain yield plant^{-1} (129.50 g) but V_2S_3 showed higher stover yield plant^{-1} (168.67 g) and $V_1 S_1$ treatment (V_1 variety with plant spacing, 50 cm x 25 cm) combination produced the highest grain yield (9.560 t ha^{-1}), biological yield (21.293 t ha^{-1}) and harvest Index (44.913 %) but V_2S_3 showed higher stover yield (12.187 t ha^{-1}), The lowest plant height (191.67 cm) was found from $V_2 S_1$ treatment combination and minimum days to 1st tasseling (79.667 days), days to 1st silking (82.333 days) and days to maturity (137.67 days) was recorded from $V_1 S_1$ treatment combination while $V_2 S_1$ treatment combination produced the lowest cob length (14.90 cm), cob breadth (15.233 cm), number of rows per cob (12.433), number of grains row^{-1} (25.667), total number of grains cob^{-1} (339.67), 100- grain weight (28.667 g), grain yield plant^{-1} (107.50 g) but $V_2 S_3$ treatment combination produced less grain yield (6.8952 t ha^{-1}), stover yield (9.581 t ha^{-1}) ,biological yield (16.533 t ha^{-1}) and harvest Index (41.722 %) .

Experiment no. 4

A significant variation was observed among the two white maize varieties to growth, yield and yield attributes such plant height, days to 1st tasseling, days to 1st silking, days to maturity, cob length, cob breadth, number of rows per cob, number of grains row^{-1}, total number of grains cob^{-1}, 100- grain weight, grain yield plant^{-1}, Stover yield plant^{-1}, grain yield, stover yield, biological yield and harvest Index.V_1 variety showed the highest plant height (230.94 cm), cob length (16.751 cm), number of rows per cob (12.901), number of grains row^{-1} (28.472), total number of grains cob^{-1}(369.96), 100- grain weight (26.122 g) , grain yield (6.6617 t ha^{-1}), stover yield (9.1460 t ha^{-1}), biological yield (15.808 t ha^{-1}) and harvest Index (42.196 %). V_2 variety took more days to 1st tasseling (87.778 days), days to 1st silking (89.778 days) and days to maturity (145.56 days) while the lowest plant height (196.08 cm), cob length (15.809 cm), number of rows per cob (12.687), number of grains row^{-1} (26.326), total number of grains cob^{-1} (349.64), 100- grain weight (24.259 g), grain yield (6.1234 t ha^{-1}), stover yield (8.8396 t ha^{-1}), biological yield (14.963 t ha^{-1}) and harvest Index (40.989 %)) were obtained from V_2 variety but V_1 variety took less days to 1st tasseling (79.778 days), days to 1st silking (82.111 days) and days to maturity (138.78days) Plant spacing S_3 (70 cm x 25 cm) showed the maximum plant height (221.33 cm), cob length (16.680 cm), number of rows per cob (12.965), number of grains row^{-1} (29.203), total number of grains cob^{-1} (379.20), 100- grain weight (27.055 g) and harvest index (42.460 %) but S_1 (50 cm x25 cm) achieved the highest grain yield (9.08 t ha^{-1}), stover yield (11.960 t ha^{-1}) and biological yield (21.040 t ha^{-1}). Plant spacing S_1 (50 cm x 25 cm) showed the lowest plant height (206.25 cm), cob length (15.783 cm), number of rows per cob (12.57), number of grains row^{-1} (25.783), total number of grains cob^{-1} (340.69), 100- grain weight (23.437 g), grain yield plant^{-1}(113.50 g) but spacing, S_3 (70 cm x 25 cm) produced the minimum grain yield (5.8145 t ha^{-1}), stover yield (7.876 t ha^{-1}) and biological yield (13.691 t ha^{-1}) No significant variation occurred in days to 1st tasseling, days to 1st silking and days to maturity with different plant spacing treatments. Interaction effect of variety and plant spacing as V_1S_3 (V_1 variety with plant spacing, 70 cm x 25 cm) produced the tallest plant (236.92 cm) but V_2 S_3 (V_2 variety with plant spacing, 70 cm x 25 cm) treatment combination took maximum days to 1st tasseling (88.00 days), days to 1st silking (90.00 days),days to maturity (146.00 days). V_1 S_3 (V_1 variety with plant spacing, 70 cm x 25 cm) treatment combination was achieved the maximum cob length (17.133 cm), number of rows per cob (13.073), number of grains row^{-1} (30.633), total number of grains cob^{-1}(390.22), 100- grain weight (28.00 g) and harvest Index (44.913 %). Again V_1 S_1 treatment (V_1 variety with plant spacing, 50 cm x 25 cm) combination produced the highest grain yield (7.3793 t ha^{-1}), stover yield (10.400 t ha^{-1}) and biological yield (17.779 t ha^{-1}) .The lowest plant height (187.50 cm) was found from V_2 S_1 treatment combination and minimum days to 1st tasseling (79.667 days), days to 1st silking (82.00 days) and days to maturity (138.67 days) was recorded from V_1

S_1 treatment combination while $V_2 S_1$ treatment combination produced the lowest cob length (15.333 cm), number of rows per cob (12.460), number of grains row^{-1} (24.850), total number of grains cob^{-1} (332.65), 100- grain weight (22.667 g), grain yield plant^{-1} (107.50 g) but $V_2 S_3$ treatment combination produced less grain yield (5.565 t ha^{-1}), stover yield (7.714 t ha^{-1}) ,biological yield (13.279 t ha^{-1}) and $V_2 S_1$ interaction showed the lowest harvest Index (40.304 %).

Experiment no. 5

Different plant spacing significantly affected the following growth, yield and yield attributes such as plant height, cob length, cob breadth, number of rows per cob, number of grains row^{-1}, total number of grains cob^{-1}, 100- grain weight, grain yield plant^{-1}, Stover yield plant^{-1}, grain yield per hectare stover yield per hectare and biological yield per hectare. Plant spacing, S_4 (60 cm x 25 cm) showed the highest plant height (242.93 cm), cob length (18.367 cm), cob breadth (18.600cm), number of rows per cob (14.067), number of grains row^{-1} (30.667), total number of grains cob^{-1}(420.49), 100- grain weight (42.667 g), grain yield plant^{-1} (174.67 g), stover yield plant^{-1} (161.67 g) but showed the lowest grain yield per hectare (11.844 t ha^{-1}), stover yield per hectare (110.778 t ha^{-1}) and biological yield per hectare (22.422 t ha^{-1}). Plant spacing S_1 (50 cm x 25 cm) showed the lowest plant height (232.20 cm), cob length (16.433 cm), cob breadth (25.867 cm), number of rows per cob (13.073), number of grains row^{-1} (25.33), total number of grains cob^{-1} (369.79), 100- grain weight (35.667 g), grain yield plant^{-1} (138.00 g), stover yield plant^{-1} (130.33 g) but recorded the highest grain yield (13.800 t ha^{-1}), stover yield (13.033 t ha^{-1}) and biological yield (26.833 t ha^{-1}). No significant variation was observed in days to first tasseling, days to first silking, days to maturity and harvest index with different plant spacing.

Experiment no. 6

A significant number of differences was observed among the plant spacing treatments with the following growth, yield and yield contributing characters such as plant height, cob length, cob breadth, number of rows per cob, number of grains row^{-1}, total number of grains cob^{-1}, 100- grain weight, grain yield plant^{-1}, Stover yield plant^{-1}, grain yield per hectare stover yield per hectare and biological yield per hectare. Plant spacing, S_1 (60 cm x 25 cm) showed the highest plant height (275.67 cm), cob length (16.033 cm), number of rows per cob (13.867), number of grains row^{-1} (26.867), total number of grains cob^{-1}(386.64), 100- grain weight (33.667 g), grain yield plant^{-1} (128.53 g), stover yield plant^{-1} (144.33 g) but showed the lowest grain yield per hectare (11.844 t ha^{-1}), stover yield per hectare (110.778 t ha^{-1}), biological yield per hectare (22.422 t ha^{-1}) and harvest Index (47.309 %).. Plant spacing S_1 (50 cm x 25 cm) showed the lowest plant height (255.00 cm), cob length (14.033 cm), number of rows per cob (12.933), number of grains row^{-1} (23.533), total number of grains cob^{-1} (335.81), 100- grain weight (31.00 g), grain yield plant^{-1} (99.87 g), stover yield plant^{-1} (121.00 g) but recorded the highest grain yield (9.99 t ha^{-1}), stover yield (12.100 t ha^{-1}), biological yield (22.087 t ha^{-1}) and harvest Index (45.209 %). No significant variation was observed in days to first tasseling, days to first silking and days to maturity by the application of different plant spacing treatments.

Experiment no. 7

Different plant spacing significantly affected the following growth, yield and yield attributes such as plant height, cob length, cob breadth, number of rows per cob, number of grains row^{-1}, total number of grains cob^{-1}, 100- grain weight, grain yield plant^{-1}, Stover yield plant^{-1}, grain yield per hectare stover yield per hectare and biological yield per hectare. Plant spacing, S_4 (60 cm x 25 cm) showed the highest plant height (242.93 cm), cob length (18.367 cm), cob breadth (18.600cm), number of rows per cob (14.067), number of grains row^{-1} (30.667), total number of grains cob^{-1}(420.49), 100- grain weight (42.667 g), grain yield plant^{-1} (174.67 g), stover yield plant^{-1} (161.67 g) but showed the lowest grain yield per hectare (11.844 t ha^{-1}), stover yield per hectare (110.778 t ha^{-1}) and biological yield per hectare (22.422 t ha^{-1}). Plant spacing S_1 (50 cm x 25 cm) showed the lowest plant height (232.20 cm), cob length (16.433 cm), cob breadth (25.867 cm), number of rows per cob (13.073), number of grains row^{-1} (25.33), total number of grains cob^{-1} (369.79), 100- grain weight (35.667 g), grain yield plant^{-1} (138.00 g), stover yield plant^{-1} (130.33 g) but recorded the highest grain yield (13.800 t ha^{-1}), stover yield (13.033 t ha^{-1}) and biological yield (26.833 t ha^{-1}). No significant variation was observed in days to first tasseling, days to first silking, days to maturity and harvest index with different plant spacing.

Experiment no. 8

Different irrigation levels showed significant differences to growth, yield and yield attributes such plant height, days to 1st tasseling, days to 1st silking, days to maturity, cob length, cob breadth, number of rows per cob, number of grains row^{-1}, total number of grains cob^{-1}, 100- grain weight, grain yield plant^{-1}, Stover yield plant^{-1}, grain yield, stover yield, biological yield and harvest Index. Irrigation when required (I_{wr}) showed the highest plant height (231.47 cm), days to 1st tasseling (72.583 days), days to 1st silking (74.333 days) and days to maturity (130.17 days), cob length (17.900 cm), number of rows per cob (13.717), number of grains row^{-1} (33.754), total number of grains cob^{-1}(443.65), 100- grain weight (37.917 g) , grain yield per plant (154.56 g), stover yield per plant (175.89 g), grain yield (10.354 t ha^{-1}), stover yield (11.726 t ha^{-1}), biological yield (22.080 t ha^{-1}) and harvest Index (46.882 %). While Irrigation level, I_2 (25 DAS +75 DAS) showed the lowest plant height (176.48C cm), days to 1st tasseling (69.583 days), days to 1st silking (71.417 days) and days to maturity (126.17 days), cob length (13.00 cm), number of rows per cob (12.788), number of grains row^{-1} (25.33), total number of grains cob^{-1} (309.9), 100- grain weight (34.000 g), grain yield per plant (108.76 g), stover yield per plant (127.29 g), grain yield (7.195 t ha^{-1}), stover yield (8.503 t ha^{-1}), biological yield (15.715 t ha^{-1}) and harvest Index (45.817 %). V_1 variety showed maximum plant height (221.33 cm) cob length (16.929 cm), number of rows per cob (13.717), number of grains row^{-1} (30.633), total number of grains cob^{-1} (395.12), 100- grain weight (38.00 g) grain yield per plant (149.20 g), stover yield per plant (168.75 g), grain yield (9.08 t ha^{-1}), stover yield (11.960 t ha^{-1}), biological yield (21.040 t ha^{-1}) and harvest Index (46.842 %) but V_3 variety took more days to 1st tasseling (75.417 days), days to 1st silking (77.500 days) and days to maturity (135.00 days) while. V_4 variety showed the lowest plant height (196.95 cm),days to 1st tasseling (69.083 days), days to 1st silking (70.667 days) and days to maturity (124.17 days), cob length (16.025 cm), number of rows per cob (12.404), number of grains row^{-1} (28.075), total number of grains cob^{-1} (372.29) but minimum 100- grain weight (35.333 g), grain yield per plant (125.13 g), stover yield per plant (146.58 g), grain yield (8.397 t ha^{-1}), stover yield (9.772 t ha^{-1}), biological yield (18.170 t ha^{-1}) and harvest Index (46.116 %) was found from V_2 variety. Interaction effect of irrigation and variety as $I_{WR}V_1$ (Irrigation when required with V_1 variety) produced the highest plant height (245.80 cm), cob length (18.433 cm), number of rows per cob (14.467), number of grains row^{-1} (34.467), total number of grains cob^{-1}(445.81), 100- grain weight (40.66 g) grain yield per plant (167.93 g), stover yield per plant (187.67 g), grain yield (11.196 t ha^{-1}), stover yield (12.511 t ha^{-1}) ,biological yield (23.707 t ha^{-1}) and harvest Index

(47.222 %) but $I_{WR}V_3$ (Irrigation when required with V_3 variety) treatment combination took maximum days to 1st tasseling (76.667 days), days to 1st silking (78.667days),days to maturity (136.33 days). $I_2 V_4$ treatment combination showed the shortest plant (169.00 cm), days to 1st tasseling (67.667 days), days to 1st silking (69.000 days) and days to maturity (121.33 days), cob length (14.10 cm), number of rows per cob (11.95) number of grains row^{-1} (23.86), total number of grains cob^{-1} (293.71) but minimum 100- grain weight (33.333 g), grain yield plant^{-1} (90.91 g), stover yield per plant (110.67 g), grain yield (6.06 t ha^{-1}), stover yield (7.37 t ha^{-1}), biological yield (13.438 t ha^{-1}) and harvest Index (45.071 %) were recorded from V_2 variety.

Experiment no. 9

Different fertilizer levels showed significant differences to growth, yield and yield attributes such plant height, days to 1st tasseling, days to 1st silking, days to maturity, cob length, cob breadth, number of rows per cob, number of grains row^{-1}, total number of grains cob^{-1}, 100- grain weight, grain yield plant^{-1}, Stover yield plant^{-1}, grain yield, stover yield, biological yield and harvest Index. F_3 (25% more of Recommended dose) showed the highest plant height (225.40 cm), cob length (17.880 cm), number of grains row^{-1} (31.655), total number of grains cob^{-1}(426.53), 100- grain weight (42.667 g), grain yield (13.846 t ha^{-1}), stover yield (13.007 t ha^{-1}), biological yield (26.852 t ha^{-1}) and harvest Index (51.573 %) but more days to 1st tasseling (71.067 days), and days to maturity (71.067 days) was observed from F_2 (Half of Recommended fertilizer dose) treatment. While F_2 (Half of Recommended fertilizer dose) showed the lowest plant height (183.67 cm), cob length (14.240 cm), number of grains row^{-1} (24.437), total number of grains cob^{-1} (333.2), 100- grain weight (37.333 g), grain yield per plant (108.76 g), stover yield per plant (127.29 g), grain yield (10.481 t ha^{-1}), stover yield (10.262 t ha^{-1}), biological yield (20.743 t ha^{-1}) and harvest Index (50.497 %) but less days to 1st tasseling (68.000 days) and days to maturity (126.33 days) were found from F_3 (25% more of Recommended fertilizer dose) treatment. V_3 variety showed maximum plant height (224.42 cm), cob length (17.059 cm), number of grains row^{-1} (30.569), total number of grains cob^{-1} (411.90), 100- grain weight (41.667 g), grain yield (13.104 t ha^{-1}), stover yield (12.450 t ha^{-1}), biological yield (25.554 t ha^{-1}) but V_5 variety took more days to 1st tasseling (75.417 days) and days to maturity (135.00 days). Again. V_2 variety showed the lowest plant height (196.95 cm), days to 1^{st} tasseling (69.083 days) and days to maturity (124.17 days), cob length (15.550 cm), number of grains row^{-1} (25.750), total number of grains cob^{-1} (322.78) grain yield (11.233 t ha^{-1}), stover yield (10.668 t ha^{-1}), biological yield (21.901 t ha^{-1}) but minimum 100- grain weight (38.833 g) was found from V_4 variety. No significant variation was observed in harvest index with different varieties. Interaction effect of fertilizer and variety as F_3V_3 (25% more of recommended fertilizer dose with V_3 variety) produced the highest plant height (242.33 cm), cob length (18.767 cm), , number of grains row^{-1} (34.277), total number of grains cob^{-1}(469.47), 100- grain weight (44.667 g), grain yield (14.844 t ha^{-1}), stover yield (13.767 t ha^{-1}) ,biological yield (28.611 t ha^{-1}) and harvest Index (51.852 %) but F_2V_5 (half of recommended fertilizer dose with V_5 variety) took maximum days to 1^{st} tasseling (75.000 days) and days to maturity (137.67 days). F_2V_2 (half of recommended fertilizer dose with V_5 variety) produced the shortest plant (170.67 cm), cob length (13.333 cm), number of grains row^{-1} (22.00), total number of grains cob^{-1} (293.2), grain yield (9.54 t ha^{-1}), stover yield (9.50 t ha^{-1}), biological yield (19.04 t ha^{-1}) and harvest Index (50.056 %) were recorded from V_2 variety but minimum 100- grain weight (36.333 g), was found from F_2V_4 combination and F_3V_2 (25% more of recommended fertilizer dose with V_2 variety) took minimum days to 1^{st} tasseling (64.000 days) and days to maturity (119.33days)

Experiment no. 10

Fertilizer levels revealed that F_2 (25% more of Recommended dose) treatment produced the highest plant height (267.28 cm), stalk diameter (8.0750 cm), days to tasseling(73.667 days), days to silking (75.667 days), days to maturity (132.58 days), leaf area per plant (9801.0 cm^2 at 90 DAS), LAI (6.4308 at 90 DAS),TDM (301.82 g at harvest), cob length (16.575 cm), cob breadth (16.750 cm), number of row per cob (13.677), number of grains row^{-1} (29.633), total number of grains cob^{-1}(402.45), 100- grain weight (39.422 g), grain yield per plant(142.17 g), stover yield per plant (114.12 g), grain yield (11.565 t ha^{-1}), stover yield (9.3114 t ha^{-1}), biological yield (20.876 t ha^{-1}) and the lowest plant height (260.10 cm), stalk diameter (7.4750 cm), days to 1^{st} tasseling(72.333 days), days to 1^{st} silking (74.333 days), days to maturity (131.17 days), leaf area per plant (553.23 cm^2 at 30 DAS), LAI (0.1728 at 30 DAS),TDM (10.659 g at 30 DAS), cob length (15.275 cm), cob breadth (16.092 cm), number of row per cob (13.055), number of grains row^{-1} (26.867), total number of grains cob^{-1}(362.58), 100- grain weight (36.767 g), grain yield per plant(130.88 g), stover yield per plant (105.43 g), grain yield (10.648 t ha^{-1}), stover yield (8.594 t ha^{-1}) and biological yield (19.242 t ha^{-1}) were observed by F_1 (Recommended fertilizer dose). No significant variation found in CGR, RGR, NAR and harvest index with levels of fertilizer application. Different plant spacing, S_4 showed the highest plant height (271.00 cm), stalk diameter (8.100 cm), days to tasseling(73.833 days), days to silking (75.833 days), days to maturity (132.83 days), leaf area per plant (10409 cm^2 at 90 DAS), TDM (316.13 g at harvest), cob length (16.900 cm), cob breadth (16.950 cm), number of row per cob (13.785), number of grains row^{-1} (30.333), total number of grains cob^{-1}(405.41), 100- grain weight (39.892 g), grain yield per plant(150.77 g), stover yield per plant (120.00 g) while highest grain yield was achieved with S_3 (11.565 t ha^{-1}) but highest LAI (6.2841 at 90 DAS), CGR (32.274 g m^{-2} day^{-1} at harvest), stover yield (9.3114 t ha^{-1}) and biological yield (20.876 t ha^{-1}) was observed from S_1 spacing. The lowest plant height (254.73 cm), stalk diameter (7.4000 cm), days to 1st tasseling(72.333 days), days to 1st silking (74.333 days), days to maturity (130.83 days), leaf area per plant (492.30 cm^2 at 30 DAS), LAI (0.1728 at 30 DAS), TDM (10.449 g at 30 DAS), cob length (15.172 cm), cob breadth (15.700 cm), number of row per cob (12.975), number of grains row^{-1} (26.300), total number of grains cob^{-1}(360.97), 100- grain weight (36.153 g), grain yield per plant(114.33 g), stover yield per plant (96.13 g), were observed by S_1 (50 cm x 20 cm) whereas the lowest CGR (1.8425 g m^{-2} day^{-1} at 30 DAS), grain yield (10.051 t ha^{-1}), stover yield (8.000 t ha^{-1}) and biological yield (18.051 t ha^{-1}) were obtained from S_4 treatment. No significant variation found in RGR, NAR and harvest index with different plant spacing. Interaction effect of fertilizer and spacing as F_2 S_4 (25% more of recommended fertilizer dose with spacing, 60 cm x 25 cm) produced the highest plant height (274.53 cm), stalk diameter (8.4000 cm), days to1st tasseling (74.333 days), days to1st silking (76.333 days), days to maturity (133.67 days), leaf area per plant (11033 cm^2 at 90 DAS), TDM (329.53 g at harvest), cob length (17.650 cm), cob breadth (17.433 cm), number of row per cob (14.033), number of grains row^{-1} (32.000), total number of grains cob^{-1}(429.81), 100- grain weight (41.560 g), grain yield per plant(156.67 g), stover yield per plant (124.67 g) while highest grain yield was achieved with F_2S_3 (12.056 t ha^{-1}) but highest LAI (6.8673 at 90 DAS), CGR (34.159 g m^{-2} day^{-1} at harvest), stover yield (10.087 t ha^{-1}) and biological yield (21.953 t ha^{-1}) was observed from F_2 S_1 combinations. 12.056 The lowest plant height(250.6 cm), stalk diameter (7.1000 cm), days to 1st tasseling(71.667 days), days to 1st silking (73.667 days), days to maturity (129.67 days), leaf area per plant (483.66 cm^2 at 30 DAS), TDM (10.022 g at 30 DAS), cob length (14.733 cm), cob breadth (15.533 cm), number of row per cob (12.683), number of grains row^{-1} (25.267), total number of grains cob^{-1}(344.64), 100-grain weight (35.180 g), grain yield per plant (110.00 g), stover yield per plant (91.40 g), were observed by F_1S_1 (50 cm x 20 cm) whereas the lowest LAI (0.1621 at 30 DAS), CGR (1.8189g m^{-2} day^{-1} at 30 DAS), grain yield (9.658 t ha^{-1}), stover yield (7.689 t ha^{-1}) and biological yield (17.347 t ha^{-1}) were obtained from F_1S_4 treatment. No significant variation found in RGR, NAR and harvest index with the combination of fertilizer and plant spacing.

CONCLUSION

Ten field trials were conducted at three different locations; Shere-e-Bangla Agricultural University (SAU) of Dhaka, Dhamrai Upazilla Dhaka and Rangpur Sadar, to optimize planting geometry for the production of white maize in Bangladesh for three consecutive rabi seasons of 2015-16 through 2017-18.

In experiment 1 at SAU, four varieties (Changnuo-1, Q-Xiangnuo-1, Changnuo-6 and Yangnuo-7) were tested under two planting geometries (60cm x 25cm and 70cm x 25cm) in randomized complete block design (RCBD) in the rabi season of 2015-17. Results showed that the Changnuo-6 out yielded than other varieties when sown at 60cm x 25cm spacings (8.765 t ha^{-1}). The minimum seed yield was obtained with Yangnuo-7 planted using spacing of 70cm x 25cm (4.689 t ha^{-1}). Changnuo-6 with plant spacing, 60cm x 25cm also produced the highest stover yield (10.089 t ha^{-1}), biological yield (18.853 t ha^{-1}) and harvest Index (46.487 %).

Second experiment was also set up at SAU in the same season of rabi 2015-16 testing two varieties (PSC-121 and KS-510) under three different planting geometries (50cm x 25cm, 60cm x 25cm and 70cm x 25cm) in RCBD. Results showed that out of two varieties, PSC-121 gave significantly the highest seed yield (9.633 t ha^{-1}) than others when planted at 50cm x 25cm spacing. The variety KS-510 had the lowest seed yield (7.360 t ha^{-1}) at 70cm x 25cm spacing. PSC-121 with 50cm x 25cm spacing also showed highest values in stover yield (12.027 t ha^{-1}), biological yield (21.627 t ha^{-1}) and harvest Index (46.015 %).

In the third rabi season of 2015-16 a separate experiment was conducted at farmer's field of Dhamrai using two varieties (same as SAU) under three different planting geometries (same as SAU). Like at SAU, the PSC-121 gave significantly the highest seed yield (9.080 t ha^{-1}) than others when planted at 50cm x 25cm spacing. The variety KS-510 had the lowest seed yield (7.140 t ha^{-1}) at 70 cm x 25 cm spacing. PSC-121 with 50 cm x 25 cm also had the highest biological yield (21.293 t ha^{-1}) and harvest Index (44.913 %).

In same season of rabi of 2015-16, fourth experiment was conducted at farmer's field of Rangpur Sadar using two varieties (same as SAU and Dhamrai) under three different planting geometries (same as SAU and Dhamrai). Like at SAU and Dhamrai, the PSC-121 gave significantly the highest seed yield (7.373 t ha^{-1}) than others when planted at 50cm x 25cm spacing. The variety KS-510 had the lowest seed yield (5.565 t ha^{-1}) at 70cm x 25cm spacing. PSC-121 with 50cm x 25cm also had the highest stover yield (10.400 t ha^{-1}) and biological yield (17.779 t ha^{-1}).

Fifth experiment was set at SAU in the rabi season of 2016-17 using only one variety (PSC-121) under four different spacings, namely 50cm x 20cm, 50cm x 25cm, 60cm x 20cm and 60cm x 25cm) in RCBD with three replications. The study revealed that identical values were obtained with the three spacings, namely 50cm x 20cm, 50cm x 25cm and 60cm x 20 cm giving significantly higher yields of 13.800, 12.859 and 12.833 t ha^{-1} respectively while the 60cm x 25cm the lowest seed yield (11.644 t ha^{-1}).

Sixth experiment was set at Dhamrai in the same rabi season of 2016-17 (as was done at SAU) using only one variety (PSC-121) under the same planting configuration four treatments as were in SAU, namely 50cm x 20cm, 50cm x 25cm, 60cm x 20cm and 60cm x 25cm) in RCBD with three replications. The study revealed that identical values were obtained with the three spacings, namely 50cm x 20cm, 50cm x 25cm and 60cm x 20 cm giving significantly higher yields of 9.986, 9.637 and 9.550 t ha^{-1}respectively while the 60cm x 25cm the lowest seed yield (8.567 t ha^{-1}). Plant spacing 60 cm x 25 cm showed the highest plant height (275.67 cm), cob length (16.033 cm), number of rows per cob (13.867), number of grains row^{-1} (26.867), total number of grains cob^{-1}(386.64), 100- grain weight (33.667 g) and stover yield $plant^{-1}$ (144.33 g).

Seventh experiment was set at Rangpur Sadar in the same rabi season of 2016-17 (as was done at SAU and Dhamrai) using only one variety (PSC-121) under the same four planting configurations as were in SAU, namely 50cm x 20cm, 50cm x 25cm, 60cm x 20cm and 60cm x 25cm) in RCBD with three replications. The study revealed that identical values were obtained with the three spacings, namely 50cm x 20cm, 50cm x 25cm and 60cm x 20 cm giving significantly higher yields of 13.874, 13.433 and 13.330 t ha^{-1} respectively while the 60cm x 25cm the lowest seed yield (11.633 t ha^{-1}). Plant spacing 60 cm x 25 cm showed the highest plant height (242.93 cm), cob length (18.367 cm), cob breadth (18.600cm), number of rows per cob (14.067), number of grains row^{-1} (30.667), total number of grains cob^{-1}(420.49), 100- grain weight (42.667 g), grain yield $plant^{-1}$ (174.67 g), stover yield $plant^{-1}$ (161.67 g).

Eighth experiment was set at SAU in the rabi season of 2016-17 to evaluate four varieties (PSC-121, Changnuo-1, Yangnjuo-30 and Changnuo-6) under four different irrigation regimes (25+75 DAS, 25+50+75 DAS, 25+50+75+100 DAS and when required based on the wilting appearance of any plant of the plot. The treatments were repeated with three replications. The results showed that the variety PSC-121 showed identical but significantly higher seed yields with 'when required' and four irrigation regimes (11.196 t ha^{-1} and 10.504 t ha^{-1} respectively. Significantly the lowest seed yield was obtained from Changnuo-1 when irrigated two times (25+75 DAS). Irrigation when required with PSC-121 variety produced the highest plant height (245.80 cm), cob length (18.433 cm), number of rows per cob (14.467), number of grains row^{-1} (34.467), total number of grains cob^{-1}(445.81), 100- grain weight (40.66 g) grain yield per plant (167.93 g), stover yield per plant (187.67 g), grain yield (11.196 t ha^{-1}), stover yield (12.511 t ha^{-1}), biological yield (23.707 t ha^{-1}) and harvest Index (47.222 %).

Ninth experiment was set also at SAU in the same rabi season of 2016-17 to evaluate five varieties (Changnuo-1, Q-Xinagnuo-1, PSC-121, Yangnjuo-30 and Changnuo-6) under four different fertilizer regimes (Recommended, half of the recommended, 25% more than recommended and 25% less than the recommended. The trial was set in split plot design placing fertilizer treatments in the main plot and the varieties in the sub plot. The treatments were repeated with three replications. The results showed that the variety PSC-121, Yangnuo-30 and Changnuo-1 gave identical but significantly higher seed yields (14.844, 13.961 and 14.083 t ha^{-1} respectively) with the applied fertilizer dose of 25% more than recommended. Significantly the minimum seed yield was obtained from Q-Xinagnuo-1 (9.540 t ha^{-1}) when grown with the application of half of the recommended dose of fertilizer. PSC-121 WITH 25% more of recommended fertilizer dose produced the highest plant height (242.33 cm), cob length (18.767 cm), , number of grains row^{-1} (34.277), total number of grains cob^{-1}(469.47), 100- grain weight (44.667 g), grain yield (14.844 t ha^{-1}), stover yield (13.767 t ha^{-1}) ,biological yield (28.611 t ha^{-1}) and harvest Index (51.852 %).

Tenth experiment was set also at SAU in third year rabi season of 2017-18 to evaluate four planting geometries (50cm x 20cm, 50cm x 25cm, 60cm x 20cm and 60cm x 25cm) using the variety PSC-121 under two different fertilizer levels (Recommended and 25% more than recommended). The trial was set in split plot design placing fertilizer treatments in the main plot and the planting geometries in the sub plot. The treatments were repeated with three replications. The results showed that the spacings 50cm x 20cm, 50cm x 25cm, 60cm x 20cm gave identical but significantly higher seed yields (11.000, 10.933 and 11.080 t ha^{-1} respectively) with the applied fertilizer dose of 25% more than recommended. Significantly the minimum seed yield was obtained from 60cm x 25cm (8.311 t ha^{-1}) when grown with the application of the recommended dose of fertilizer. The maximum or comparable values in plant height (274.53 cm), days to maturity (133.67), leaf area per plant (11033 cm^2). Leaf area index (over 6), dry matter per plant (over 329 g), crop growth rate (over 28 g m^{-2} day^{-1}), relative growth rate (over 0.0347 g g^{-1} day^{-1}) at 60-90 DAS, net assimilation rate (6.142 g m^{-2} day^{-1}), longest cob (17.65 cm), thickest cob (17.43 cm circumference), number of rows per cob (14.03), number of grains per cob (32), number of grains per cob (429.81), 100-grains weight (41.56 g), stover weight (124.67 g), per plant grain weight (156.67 g), biological yield (187.56 t ha^{-1}) and harvest index (over 55%) were obtained with the interaction treatment 60cm x 20cm and 25% more over the recommended dose of fertilizer.

In experiment 1 at SAU with four varieties (Changnuo-1, Q-Xiangnuo-1, Changnuo-6 and Yangnuo-7) under two planting geometries (60cm x 25cm and 70cm x 25cm) in randomized complete block design (RCBD) in the rabi season of 2015-17. That is, the variety PSC-121 was not included in this trial.

Second experiment included two varieties (PSC-121 and KS-510) under three different planting geometries (50cm x 25cm, 60cm x 25cm and 70cm x 25cm) wherein the variety PSC-121 performed better at 50cm x 25cm spacing, although varieties of the first experiment were not included in this second experiment. So, PSC-121's superiority over other varieties cannot be established from this trial. But out two varieties, PSC-121 showed better performance in the close spacing.

From the results of the experiments two to fourth, it was observed that in these trial among the two varieties the PSC-121 had significantly higher seed yields over that of the KS-510 at the spacing of 50 cm x 25 cm and from this it has been again obvious that the variety PSC-121 was better at 50 cm x 25 cm spacing. However, in these trials neither 50 cm x 20 cm nor 60 cm x 20 cm spacings were not tested. These spacings were tested in experiment five, six, seventh and tenth with the PSC-121 and results showed that three spacings such as 50 cm x 20 cm, 50 cm x 25 cm, 60 cm x 20 cm produced identical seed yield having no significant difference among them in terms of seed yield per hectare. As the closer spacings (50 cm) had higher population density than the wider spacing treatments (60cm), the spacing 60 cm x 20 cm may be the optimum one as it has lower population density (83333 ha^{-1}) and will incur low costs for buying seeds.

However, in experiment 8 and 9, almost all the varieties along with PSC-121 have been tested under varying irrigation and fertilizer regimes, not tested under varying spacings in a single experiment. So, it may be recommended that future trials should be using these varieties together at different planting configurations.

But in the eighth experiment at SAU in the rabi season of 2016-17, four varieties (PSC-121, Changnuo-1, Yangnjuo-30 and Changnuo-6) were tested under four different irrigation regimes (25+75 DAS, 25+50+75 DAS, 25+50+75+100 DAS and when required based on the wilting appearance of any plant of the plot. Results showed that the variety PSC-121 out yielded other varieties when given four or more irrigations in a season. So, from this trial it may again be concluded that the variety PSC-121 may approved to be grown in Bangladesh.

Ninth experiment was with five varieties (Changnuo-1, Q-Xinagnuo-1, PSC-121, Yangnjuo-30 and Changnuo-6) to be tested under four different fertilizer regimes (Recommended, half of the recommended, 25% more than recommended and 25% less than the recommended). In this trial three varieties such as, PSC-121, Yangnjuo-30 and Changnuo-6 showed identical seed yield having no significant differences among them when grown at fertilizer of 25% more over the recommended dose. It has been established here that although in experiment 1 the variety PSC-121 was not included, this variety performed good proving that this variety had potential of producing good yield. However, question may be arisen that here also it may be concluded that the variety PSC-121 was superior using more fertilizers.

From the previous experiments it was decided that the variety PSC-121 showed superiority over the variety KS-510 when grown at spacings of 50 cm x 20 cm to 60 cm x 20 cm. Among these, 60 cm x 20 cm was seemed to be better in respect of low seed cost considerations. So, this spacing was needed to test again under varying irrigation and fertilizer regimes to evaluate the interaction of these two management practices under 60 cm x 20 cm spacing. As in the experiment 1 and two, all the varieties could not been tested altogether, it was also obvious to include the previously good performing varieties altogether (from experiment 1 and 2) to see how they perform compared to the PSC-121 which has been done in experiment 8 and 9. From these two trials it was observed that the variety PSC-121 had the highest seed yields than others. In addition to the results of the experiment 2 it may be confirmed that the variety PSC-121 can be grown in Bangladesh.

In experiment 8 the varieties were tested under varying irrigation where PSC-121 again performed best with four irrigation. In the 9th experiment, varieties under varying regimes of fertilizers were tested where in the variety PSC-121 again showed superiority over others when grown using 25% more fertilizer over the recommended dose. It was then obvious to test this variety under both fertilizer regimes and spacings. So, in the 10th experiment only one variety PSC-121 was tried under varying spacings and fertilizers.

It was observed that most of the per plant parameters were negatively related with the population density regression coefficient values in the range of (-) 0.00005 to (-) 0.687, while the R^2 (R-squired) values in the range of 0.7766 to 0.9990. In contrast the per hectare plant parameters had positive relations showing the regression coefficient values from 0.0005 to 0.002 and R^2 values from 0.8251 to 0.999. A polynomial regression was best fitted with the data of net assimilation rate, and yields per hectare showing a parabola curve. From the polynomial regression, it was found that the possible plant population per hectare would be 90000 per hectare. So, it may be concluded that at all the locations the variety PSC-121 can be grown planting at 60 cm x 20 cm spacing using the fertilizer dose 25% more than the recommended and four irrigations at 25 DAS + 50 DAS + 75 DAS + 100 DAS.

From the above mentioned review of the results from the ten experiments, it may be concluded that at all the locations the variety PSC-121 performed best by planting at 60 cm x 20 cm spacing, using the fertilizer dose 25% more than the recommended dose and applying four irrigations at 25 DAS + 50 DAS + 75 DAS + 100 DAS.

Recommendations

In the experiment 10, the variety PSC – 121 only has been tested under varying spacings and fertilizer doses where in three spacings 50 cm x 20 cm, 50 cm x 25 cm, 60 cm x 20 cm performed better. However, the result could have been different if it included all other varieties along with the PSC-121.

In experiment 8 and 9, almost all the varieties along with PSC-121 have been tested under varying irrigation and fertilizer regimes, not tested under varying spacings in a single experiment. So, it may be recommended that future trials should include all these good performing varieties (PSC-121, Changnuo-1, Changnuo-6 and Yangnuo-30) to be tested together at different planting configurations. Furthermore, these varieties should also be evaluated under the individual performances of plant nutrients such as N, P, K, S, Zn and boron etc.

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APPENDICES

Appendix I: Slide showing the experimental locations (black sign)

Appendix II. Mean square values of ANOVA for phonological and growth parameter of white maize as affected by variety and spacing at SAU during rabi 2015-16

Source of variation	d.f	Days to first tassling	Days to first silking	Days to maturity	Plant height	Number of leaves plant^{-1}
Replication	2	0.54167	2.542	1.292	1.54	0.1667
Variety (A)	3	120.222	123.153	319.22	3566.38	26.375
Spacing (B)	1	0.666	0.375	0.167	187.04	7.0417
Variety (A) x spacing (B)	3	3.478	0.153	0.056	2.49	0.1528
Error	14	0.351	0.399	0.339	5.16	0.2143

df = Degree of freedom

Appendix III. Mean square values of ANOVA for yield components of white maize as affected by variety and spacing at SAU during rabi 2015-16

Source of variation	d.f	Cob length	Cob Breadth	Number of grains rows cob^{-1}	Number of grains row^{-1}	Total number of grains cob^{-1}	100-grain weight
Replication	2	1.5253	0.09413	0.34292	12.106	2229.3	0.292
Variety (A)	3	32.8466	4.90464	0.22778	147.961	33200.3	140.15
Spacing (B)	1	8.1201	4.33075	1.70667	55.510	2927.0	5.042
Variety (A) x spacing (B)	3	0.2011	0.05788	0.09222	0.124	9.4	0.042
Error	14	0.3957	0.15365	0.13149	3.091	535.5	0.339

df = Degree of freedom

Appendix IV. Mean square values of ANOVA for yield and harvest index of white maize as affected by variety and spacing at SAU during rabi 2015-16

Source of variation	d.f	Grain yield plant^{-1}	Stover yield plant^{-1}	Grain yield	Stover yield	Biological yield	Harvest Index
Replication	2	272.92	10978.6	1.0330	1.2485	4.5529	0.21147
Variety (A)	3	3557.06	1808.5	13.6146	13.8834	54.9877	6.16780
Spacing (B)	1	314.65	294.0	2.3635	2.3946	9.5161	0.63857
Variety (A) x spacing (B)	3	1.43	2.3	0.0693	0.0841	0.3011	0.04001
Error	14	16.53	136.6	0.0611	0.0630	0.2432	0.15340

df = Degree of freedom

Appendix V. Mean square values of ANOVA for phonological and growth parameter of white maize as affected by variety and spacing at SAU during rabi 2015-16

Source of variation	d.f	Days to first tassling	Days to first silking	Days to maturity	Plant height
Replication	2	0.167	0.05556	0.22222	85.50
Variety (A)	1	150.222	162.000	162.000	8406.72
Spacing (B)	2	0.167	0.22222	0.22222	262.53
Variety (A) x spacing (B)	2	0.056	3.230	2.646	3.09
Error	10	0.100	0.12222	0.08889	39.84

df = Degree of freedom

Appendix VI. Mean square values of ANOVA for yield components of white maize as affected by variety and spacing at SAU during rabi 2015-16

Source of variation	d.f	Cob length	Number of grains rows cob^{-1}	Number of grains row^{-1}	Total grains cob^{-1}	100- grain weight
Replication	2	0.03047	0.19389	0.6969	110.24	3.7767
Variety (A)	1	9.87161	1.38889	15.3273	1923.16	16.5696
Spacing (B)	2	3.50047	0.25389	14.5705	1611.59	10.8552
Variety (A) x spacing (B)	2	0.60349	0.08722	0.0178	14.03	0.0028
Error	10	0.14562	0.08922	2.7633	296.04	1.9588

df = Degree of freedom

Appendix VII. Mean square values of ANOVA for yield and harvest index of white maize as affected by variety and spacing at SAU during rabi 2015-16

Source of variation	d.f	Grain yield $plant^{-1}$	Stover yield $plant^{-1}$	Grain yield	Stover yield	Biological yield	Harvest Index
Replication	2	85.369	0.667	0.47830	0.00339	0.5154	3.6927
Variety (A)	1	243.469	304.222	1.19904	1.44554	0.0115	34.9975
Spacing (B)	2	428.549	522.167	4.19529	7.78478	23.4095	0.3062
Variety (A) x spacing (B)	2	7.909	2.389	0.09290	0.04897	0.0070	1.0720
Error	10	32.302	46.933	0.15184	0.21648	0.4153	2.1111

df = Degree of freedom

Appendix VIII. Mean square values of ANOVA for phonological and growth parameter of white maize as affected by variety and spacing at Dhamrai during rabi 2015-16

Source of variation	d.f	Days to first tassling	Days to first silking	Days to maturity	Total leaves $plant^{-1}$	Plant height
Replication	2	0.389	0.056	0.667	0.7222	4.67
Variety (A)	1	162.000	156.056	280.056	12.5000	4512.50
Spacing (B)	2	1.389	0.389	0.500	2.0556	321.50
Variety (A) x spacing (B)	2	0.500	0.056	0.056	0.1667	4.50
Error	10	0.456	0.322	0.200	0.3222	44.27

df = Degree of freedom

Appendix IX. Mean square values of ANOVA for yield components of white maize as affected by variety and spacing at Dhamrai during rabi 2015-16

Source of variation	d.f	Cob length	Cob breath	Number of grains rows cob^{-1}	Number of grains row^{-1}	Total grains cob^{-1}	100- grain weight
Replication	2	0.09042	0.20667	0.01361	4.1676	275.71	0.2876
Variety (A)	1	5.50014	2.56889	1.82405	11.5200	2587.20	18.7068
Spacing (B)	2	5.23792	1.06167	0.06807	12.5872	2494.01	4.4693
Variety (A) x spacing (B)	2	0.01514	0.00056	0.00012	0.7117	19.02	0.0193
Error	10	0.19442	0.07533	0.07973	1.3580	125.74	0.4326

df = Degree of freedom

Appendix X. Mean square values of ANOVA for yield and harvest index of white maize as affected by variety and spacing at Dhamrai during rabi 2015-16

Source of variation	d.f	Grain yield $plant^{-1}$	Stover yield $plant^{-1}$	Grain yield	Stover yield	Biological yield	Harvest Index
Replication	2	14.042	136.056	0.07396	0.61964	1.1171	1.2274
Variety (A)	1	450.000	200.000	2.15462	0.87960	0.2809	43.6969
Spacing (B)	2	203.792	330.722	5.61595	9.96510	30.5372	0.0529
Variety (A) x spacing (B)	2	4.542	4.500	0.08507	0.00532	0.0930	0.2442
Error	10	14.825	36.122	0.07294	0.14650	0.2212	1.6235

df = Degree of freedom

Appendix XI. Mean square values of ANOVA for phonological and growth parameter of white maize as affected by variety and spacing at Rangpur during rabi 2015-16

Source of variation	d.f	Days to first tassling	Days to first silking	Days to maturity	Plant height
Replication	2	0.05556	4.05556	1.500	121.52
Variety (A)	1	288.000	264.500	206.722	5468.84
Spacing (B)	2	0.22222	0.22222	0.500	342.65
Variety (A) x spacing (B)	2	1.578	2.272	0.056	16.30
Error	10	0.65556	0.18889	0.367	22.94

df = Degree of freedom

Appendix XII. Mean square values of ANOVA for yield components of white maize as affected by variety and spacing at Rangpur during rabi 2015-16

Source of variation	d.f	Cob length	Grains rows cob^{-1}	Grains row^{-1}	Total grains cob^{-1}	100- grain weight
Replication	2	0.59312	0.03204	0.9901	515.85	1.9374
Variety (A)	1	3.99502	0.20694	20.7368	1858.67	19.6935
Spacing (B)	2	1.24807	0.24657	17.7052	2224.93	15.6241
Variety (A) x spacing (B)	2	0.00682	0.00007	0.5813	20.43	0.1449
Error	10	0.48538	0.04011	3.6215	144.16	1.3785

df = Degree of freedom

Appendix XIII. Mean square values of ANOVA for yield and harvest index of white maize as affected by variety and spacing at Rangpur during rabi 2015-16

Source of variation	d.f	Grain yield plant^{-1}	Stover yield plant^{-1}	Grain yield	Stover yield	Biological yield	Harvest Index
Replication	2	28.973	79.056	0.14672	0.31905	0.7310	1.86037
Variety (A)	1	286.769	93.389	1.30403	0.42262	3.2114	6.55907
Spacing (B)	2	267.371	155.722	2.43036	8.24195	19.6045	3.79407
Variety (A) x spacing (B)	2	0.636	2.056	0.00569	0.00890	0.0247	0.02533
Error	10	14.644	21.589	0.07495	0.11453	0.3161	0.73393

df = Degree of freedom

Appendix XIV. Mean square values of ANOVA for phonological and growth parameter of white maize as affected by spacing at SAU during rabi 2016-17

Source of variation	d.f	Days to first tassling	Days to first silking	Days to maturity	Plant height
Replication	2	1.08333	1.75000	1.58333	2.3633
spacing	3	0.08333	0.08333	0.08333	61.0000
Error	6	0.75000	0.08333	0.25000	22.5367

df = Degree of freedom

Appendix XV. Mean square values of ANOVA for yield components of white maize as affected by spacing at SAU during rabi 2016-17

Source of variation	d.f	Cob length	Cob breath	Grains rows cob^{-1}	Grains row^{-1}	Total grains cob^{-1}	100-grain weight
Replication	2	3.19270	3.37750	0.09326	12.2033	68.59	0.3333
spacing	3	1.99781	3.84222	0.54303	14.9467	1296.08	26.0833
Error	6	0.33181	0.05972	0.08935	1.2700	453.70	1.6667

df = Degree of freedom

Appendix XVI. Mean square values of ANOVA for yield and harvest index of white maize as affected by spacing at SAU during rabi 2016-17

Source of variation	d.f	Grain yield plant^{-1}	Stover yield plant^{-1}	Grain yield	Stover yield	Biological yield	Harvest Index
Replication	2	11.530	33.083	0.12514	0.21990	0.62634	0.29160
spacing	3	681.497	499.333	2.37169	2.56167	9.85219	0.17198
Error	6	48.463	32.417	0.38228	0.20615	0.58689	2.19558

df = Degree of freedom

Appendix XVII. Mean square values of ANOVA for phonological and growth parameter of white maize as affected by spacing at Dhamrai during rabi 2016-17

Source of variation	d.f	Days to first tassling	Days to first silking	Days to maturity	Plant height
Replication	2	0.33333	1.33333	0.58333	13.083
spacing	3	0.08333	0.08333	0.08333	220.889
Error	6	0.33333	0.33333	0.25000	46.972

df = Degree of freedom

Appendix XVIII. Mean square values of ANOVA for yield components of white maize as affected by spacing at Dhamrai during rabi 2016-17

Source of variation	d.f	Cob length	Grains rows cob^{-1}	Grains row^{-1}	Total grains cob^{-1}	100- grain weight
Replication	2	0.03583	0.07000	1.11000	584.81	1.58333
spacing	3	2.10667	0.44778	6.14556	1542.40	3.77778
Error	6	0.15917	0.16778	2.45222	530.16	1.02778

df = Degree of freedom

Appendix XIX. Mean square values of ANOVA for yield and harvest index of white maize as affected by spacing at Dhamrai during rabi 2016-17

Source of variation	d.f	Grain yield $plant^{-1}$	Stover yield $plant^{-1}$	Grain yield	Stover yield	Biological yield	Harvest Index
Replication	2	21.563	1.583	0.16554	0.03013	0.32714	0.63314
spacing	3	439.043	278.972	1.10994	3.08168	7.66531	2.66277
Error	6	24.830	26.806	0.16173	0.15977	0.60115	0.30989

df = Degree of freedom

Appendix XX. Mean square values of ANOVA for phonological and growth parameter of white maize as affected by spacing at Rangpur during rabi 2016-17

Source of variation	d.f	Days to first tassling	Days to first silking	Days to maturity	Plant height
Replication	2	0.58333	0.33333	0.58333	81.083
spacing	3	1.33333	0.08333	0.08333	126.306
Error	6	0.58333	0.33333	0.25000	23.972

df = Degree of freedom

Appendix XXI. Mean square values of ANOVA for yield components of white maize as affected by spacing at Rangpur during rabi 2016-17

Source of variation	d.f	Cob length	Grains rows cob^{-1}	Grains row^{-1}	Total grains cob^{-1}	100- grain weight
Replication	2	0.16083	0.30583	2.1961	592.50	2.08333
spacing	3	2.21889	1.06528	25.7437	4163.73	3.63889
Error	6	0.32972	0.43028	7.9464	194.78	1.30556

df = Degree of freedom

Appendix XXII. Mean square values of ANOVA for yield and harvest index of white maize as affected by spacing at Rangpur during rabi 2016-17

Source of variation	d.f	Grain yield $plant^{-1}$	Stover yield $plant^{-1}$	Grain yield	Stover yield	Biological yield	Harvest Index
Replication	2	124.523	53.083	0.73608	0.34307	1.9542	0.62451
spacing	3	733.622	402.083	2.95497	4.69639	14.8730	1.38036
Error	6	24.319	28.417	0.15666	0.21786	0.2085	1.79844

df = Degree of freedom

Appendix XXIII. Mean square values of ANOVA for phonological and growth parameter of white maize as affected by variety and irrigation at SAU during rabi 2016-17

Source of variation	d.f	Days to first tassling	Days to first silking	Days to maturity	Plant height
Replication	2	0.1875	0.146	0.896	341.91
Irrigation (A)	3	23.5833	21.500	41.243	6378.51
Error (Rep x Fert)	6	0.1042	0.479	0.618	115.99
Variety(B)	3	88.4722	102.444	323.910	3216.32
Irrigation A) X Variety (B)	9	0.4907	0.167	0.058	272.46
Error (rep x fer x spa)	24	0.4028	0.424	0.271	65.97

df = Degree of freedom

Appendix XXIV. Mean square values of ANOVA for yield components of white maize as affected by variety and irrigation at SAU during rabi 2016-17

Source of variation	d.f	Cob length	Grains rows cob^{-1}	Grains row^{-1}	Total grains cob^{-1}	100-grain weight
Replication	2	3.3713	0.02083	2.393	561.6	0.4375
Irrigation (A)	3	36.0636	1.81014	154.318	40657.8	32.9097
Error (Rep x Fert)	6	0.3009	0.43514	2.067	785.7	0.6597
Variety(B)	3	4.4172	4.32069	15.527	1732.8	18.5764
Irrigation A) X Variety (B)	9	0.1839	0.06731	5.054	587.7	1.1319
Error (rep x fer x spa)	24	0.4759	0.41462	3.239	453.7	0.5764

df = Degree of freedom

Appendix XXV. Mean square values of ANOVA for yield and harvest index of white maize as affected by variety and irrigation at SAU during rabi 2016-17

Source of variation	d.f	Grain yield plant^{-1}	Stover yield plant^{-1}	Grain yield	Stover yield	Biological yield	Harvest Index
Replication	2	404.31	357.88	1.3995	1.5206	5.8760	0.22658
Irrigation (A)	3	4796.76	5319.75	22.6735	23.3975	91.6270	2.84231
Error (Rep x Fert)	6	112.45	109.22	0.4981	0.4836	1.9327	0.12051
Variety(B)	3	1538.74	1363.50	6.4379	6.1827	25.0755	1.19546
Irrigation A) X Variety (B)	9	86.19	70.56	0.3203	0.3134	1.2751	0.16190
Error (Rep x Fert x Var)	24	126.77	115.61	0.4722	0.5149	1.9965	0.13812

df = Degree of freedom

Appendix XXVI. Mean square values of ANOVA for phonological and growth parameter of white maize as affected by variety and fertilizer at SAU during rabi 2016-17

Source of variation	d.f	Days to first tassling	Days to maturity	Plant height
Replication	2	1.350	3.950	26.02
Fertilizer (A)	3	28.283	18.861	4884.38
Error (Rep x Fert)	6	0.217	0.261	3.66
Variety(B)	4	139.900	507.392	2340.89
Fertilizerr (A) x variety (B)	12	0.367	0.681	48.34
Error (rep x fer x spa)	32	0.437	0.746	5.44

df = Degree of freedom

Appendix XXVII. Mean square values of ANOVA for yield components of white maize as affected by variety and and fertilizer at SAU during rabi 2016-17

Source of variation	d.f	Cob length	Grains rows cob^{-1}	Grains row^{-1}	Total grains cob^{-1}	100- grain weight
Replication	2	37.3786	0.02083	13.019	87.5	0.0167
Fertilizer (A)	3	0.4661	1.81014	141.800	24196.6	*76.9500*
Error (Rep x Fert)	6	4.0970	0.43514	5.556	1117.1	*0.7500*
Variety(B)	4	0.4690	4.32069	42.397	15440.9	18.8167
Fertilizerr (A) x variety (B)	12	0.3669	0.06731	0.791	469.5	0.4500
Error (rep x fer x spa)	32		0.41462	3.697	355.9	0.9417

df = Degree of freedom

Appendix XXVIII. Mean square values of ANOVA for yield and harvest index of white maize as affected by variety and and fertilizer at SAU during rabi 2016-17

Source of variation	d.f	Grain yield $plant^{-1}$	Stover yield $plant^{-1}$	Grain yield	Stover yield	Biological yield	Harvest Index
Replication	2	211.55	205.37	1.4691	1.4262	4.970	4.13519
Fertilizer(A)	3	4421.29	2915.62	30.7034	20.2474	100.799	3.45568
Error (rep x fer)	6	37.82	32.45	0.2627	0.2254	0.772	1.08488
Variety(B)	4	909.91	817.93	6.3188	5.6800	23.959	0.09694
Fertilizerr (A) x variety (B)	12	20.66	15.69	0.1435	0.1090	0.343	0.74393
Error(rep x fer x spa)	32	58.72	35.10	0.4078	0.2437	1.130	0.71774

df = Degree of freedom

Appendix XXIX. Mean square values of ANOVA for growth parameter of white maize as affected by fertilizer and spacing at SAU during rabi 2017-18

Source of variation	d.f	Leaf area per plant (cm^2) at different			
		30 DAS	60 DAS	90 DAS	At harvest DAS
Replication	2	14965.2	74944	497362	21503
Fertilizer (A)	1	3513.3	1271224	8975030	1989488
Error (rep x fer)	2	7767.8	10835	66670	98924
Spacing (B)	3	27509.3	680619	5448915	1370913
Fertilizer (A) x spacing (B)	3	44.9	6559	9157	8794
Error (rep x fer x spa)	12	4542.9	35851	217867	68733

df = Degree of freedom

Appendix XXX. Mean square values of ANOVA for growth parameter of white maize as affected by fertilizer and spacing at SAU during rabi 2017-18

Source of variation	d.f	Leaf area index (LAI) at			
		30 DAS	60 DAS	90 DAS	At harvest DAS
Replication	2	o.355	0.22861	0.53728	0.01801
Fertilizer (A)	1	o.029	1.05507	5.16488	0.79746
Error (rep x fer)	2	0.457	0.03245	0.08011	0.10743
Spacing (B)	3	4.551	0.10846	0.32347	1.42949
Fertilizer (A) X spacing (B)	3	0.596	0.00539	0.05987	0.01415
Error (rep x fer x spa)	12	0.929	0.06657	0.25801	0.03178

df = Degree of freedom

Appendix XXXI. Mean square values of ANOVA for growth parameter of white maize as affected by fertilizer and spacing at SAU during rabi 2017-18

Source of variation	d.f	Total dry matter per plant (g/m^2) at			
		30 DAS	60 DAS	90 DAS	At harvest
Replication	2	0.18304	190.792	3.965	46.31
Fertilizer (A)	1	7.98801	247.042	828.375	3983.53
Error (rep x fer)	2	0.04035	42.792	44.585	133.78
Spacing (B)	3	0.59299	152.375	988.922	4549.34
Fertilizer (A) X spacing (B)	3	0.06252	0.931	0.295	29.16
Error (rep x fer x spa)	12	0.15151	18.903	69.468	54.90

df = Degree of freedom

Appendix XXXII. Mean square values of ANOVA for growth parameter of white maize as affected by fertilizer and spacing at SAU during rabi 2017-18

Source of variation	d.f	Crop growth rate (CGR) at			
		0-30 DAS	30-60 DAS	60-90 DAS	90 - at harvest (DAS)
Replication	2	0.04027	0.13416	0.9907	6.5364
Fertilizer (A)	1	0.03144	5.99931	24.9460	59.1999
Error (rep x fer)	2	0.01276	1.25964	4.4164	7.8135
Spacing (B)	3	0.41075	4.58500	20.7536	31.0346
Fertilizer (A) X spacing (B)	3	0.00097	0.16145	0.1534	0.5236
Error (rep x fer x spa)	12	0.01275	1.41073	8.6986	5.0913

df = Degree of freedom

Appendix XXXIII. Mean square values of ANOVA for phonological and growth parameter of white maize as affected by fertilizer and spacing at SAU during rabi 2017-18

Source of variation	d.f	Relative growth rate (RGR) at		
Replication	2	30-60 DAS	60-90 DAS	90 - at harvest (DAS)
Fertilizer (A)	1	0.739	0.323	0.334
Error (rep x fer)	2	0.764	0.628	0.301
Spacing (B)	3	0.564	0.030	0.654
Fertilizer (A) X spacing (B)	3	0.304	0.793	0.047
Error (rep x fer x spa)	12	0.465	0.178	0.129

df = Degree of freedom

Appendix XXXIV. Mean square values of ANOVA for phonological and growth parameter of white maize as affected by fertilizer and spacing at SAU during rabi 2017-18

Source of variation	d.f	Net assimilation rate (NAR) at		
		30-60 DAS	60-90 DAS	90 - at harvest DAS
Replication	2	2.34426	0.83463	0.42583
Fertilizer (A)	1	0.82842	0.05493	0.02803
Error (rep x fer)	2	0.38673	0.35726	0.18228
Spacing (B)	3	1.47047	0.20459	0.10438
Fertilizer (A) X spacing (B)	3	0.47430	0.04444	0.02267
Error (rep x fer x spa)	12	1.55144	0.21721	0.11082

df = Degree of freedom

Appendix XXXV. Mean square values of ANOVA for phonological and growth parameter of white maize as affected by fertilizer and spacing at SAU during rabi 2017-18

Source of variation	d.f	Days to first tassling	Days to first silking	Days to maturity	Stem diameter	Plant height
Replication	2	0.2916	1.79167	0.166	0.04875	14.527
Fertilizer (A)	1	0.6666	0.04167	0.666	2.1600	309.602
Error (rep x fer)	2	0.0416	0.04167	0.166	1.250	2.987
Spacing (B)	3	0.1666	0.37500	1.833	0.535	314.051
Fertilizer (A) X spacing (B)	3	3.536	0.04167	0.333	6.144	2.882
Error (rep x fer x spa)	12	0.8333	0.41667	0.1666	0.065	51.754

df = Degree of freedom

Appendix XXXVI. Mean square values of ANOVA for yield components of white maize as affected by fertilizer and spacing at SAU during rabi 2017-18

Source of variation	d.f	Cob length	Cob breath	Grains rows cob^{-1}	Grains row^{-1}	Total grains cob^{-1}	100-grain weight
Replication	2	0.00958	0.42083	0.05230	2.2481	207.97	1.1897
Fertilizer (A)	1	7.96954	3.10320	2.31882	56.3960	7458.20	42.2676
Error (rep x fer)	2	0.16591	0.27583	0.03765	2.2191	645.95	2.0707
Spacing (B)	3	3.26130	2.16565	0.66705	21.2494	1828.87	14.4611
Fertilizer (A) x spacing (B)	3	0.09980	0.06954	0.02456	0.1203	35.41	0.5944
Error (rep x fer x spa)	12	0.13726	0.09005	0.04062	4.3413	272.86	1.2550

df = Degree of freedom

Appendix XXXVII. Mean square values of ANOVA for yield and harvest index of white maize as affected by fertilizer and spacing at SAU during rabi 2017-18

Source of variation	d.f	Grain yield $plant^{-1}$	Stover yield $plant^{-1}$	Grain yield	Stover yield	Biological yield	Harvest Index
Replication	2	209.54	64.08	1.58	0.38	1.97	10.00
Fertilizer (A)	1	763.88	452.40	5.04	3.08	16.02	0.01
Error rep*fer	2	31.21	9.532	0.19	0.07	0.50	0.06
Spacing (B)	3	1472.57	632.65	2.98	2.79	11.05	3.40
Fertilizer (A) x spacing (B)	3	4.77	1.433	0.02	0.03	0.04	0.38
Error (rep x fer x spa)	12	29.26	21.02	0.21	0.15	0.37	2.28

df = Degree of freedom

Plate 1: A view of F_2S_2 treatment at cob emergence stage during rabi 2017-1

(F_2 S_2 = Variety PSC-121 with fertilizer dose 25 % more than recommended dose and planting geometry of 50 cm x 25 cm)

Plate 2: A view of F_2S_3 treatment at cob emergence stage during rabi 2017-18

(F_2 S_3 = Variety PSC-121 with fertilizer dose 25 % more than recommended dose and planting geometry of 60 cm x 20 cm)

Plate 3: A view of $V_3 F_3$ treatment at cob ripening stage during rabi 2016-17
(**$V_3 F_3$** = Variety PSC-121 with fertilizer dose 25 % more than recommended dose)

Plate 4: A view of $V_2 F_2$ treatment at cob ripening stage during rabi 2016-17
(**$V_2 F_2$** = Variety PSC-121 with fertilizer dose 50% less than recommended dose)

Plate 5: A comparison view between F_3V_3 and F_2V_3 treatments of mature cob of white maize during rabi 2016-17

(F_3 V_3 = Variety PSC-121 with fertilizer dose 25% more than recommended dose
F_2V_3 = Variety PSC-121with fertilizer dose 50% less than recommended dose)

Plate 6: A view of ripening cob of white maize (var. PSC-121) at fertilizer level 25% more than recommended dose

Plate 7: A view of V_1I_{wr} treatment at vegetative stage during rabi 2016-17
(**V_1I_{wr}** =Variety PSC-121 with irrigation level 'when required')

Plate 8: A view of V_1I_2 treatment at vegetative stage during rabi 2016-17
(**V_1I_2** =Variety PSC-121 with two irrigation level at 25 DAS and 75 DAS)

Plate 9: A view of V_1T_3 treatment at grain filling stage during rabi 2016-17
(**V_1T_3** =Variety PSC-121 with planting geometry of 60 cm x 20 cm)

Plate 10: A view of V_1T_3 treatment at cob ripening stage during rabi 2016-17
(Variety PSC-121 with planting geometry of 60 cm x 20 cm)